

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain equipment.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 221429

SECTION 221513 - GENERAL-SERVICE COMPRESSED-AIR PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes piping and related specialties for general-service compressed-air systems operating at **200 psig** (1380 kPa) or less.
- B. Related Sections include the following:
 - 1. Section 221519 "General-Service Packaged Air Compressors and Receivers" for general-service air compressors and accessories.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. ABS: Acrylonitrile-butadiene-styrene plastic.
- B. CR: Chlorosulfonated polyethylene synthetic rubber.
- C. EPDM: Ethylene-propylene-diene terpolymer rubber.
- D. HDPE: High-density polyethylene plastic.
- E. NBR: Acrylonitrile-butadiene rubber.
- F. PE: Polyethylene plastic.
- G. PVC: Polyvinyl chloride plastic.
- H. High-Pressure Compressed-Air Piping: System of compressed-air piping and specialties operating at pressures between **150 and 200 psig** (1035 and 1380 kPa).
- I. Low-Pressure Compressed-Air Piping: System of compressed-air piping and specialties operating at pressures of **150 psig** (1035 kPa) or less.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Compressed-air piping and support and installation shall withstand effects of seismic events determined according to [**SEI/ASCE 7, "Minimum Design Loads for Buildings and Other Structures."**] <Insert applicable code requirement.>

1.5 ACTION SUBMITTALS

- A. Product Data: For the following:
1. Plastic pipes, fittings, and valves.
 2. Dielectric fittings.
 3. Flexible pipe connectors.
 4. Safety valves.
 5. Pressure regulators. Include rated capacities and operating characteristics.
 6. Automatic drain valves.
 7. Filters. Include rated capacities and operating characteristics.
 8. Lubricators. Include rated capacities and operating characteristics.
 9. Quick couplings.
 10. Hose assemblies.
 11. Include data substantiating that materials comply with requirements.
- B. Shop Drawings;
1. Indicate piping system schematic and connection requirements.
- C. Coordination Drawings:
1. Provide coordination drawings of piping and equipment, and coordinate locations of all piping and equipment with other trades and/or existing construction.

1.6 INFORMATIONAL SUBMITTALS

- A. [**Brazing**] [**Brazing and welding**] [**Welding**] certificates.
- B. Qualification Data: For Installers.
- C. Field quality-control test reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For general-service compressed-air piping specialties to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual locations of pipe and connections to equipment and components. Modify shop drawings to indicate final locations.

1.8 QUALITY ASSURANCE

A. Installer Qualifications:

1. Extruded-Tee Outlet Procedure: Qualify operators according to training provided by T-DRILL Industries Inc., for making branch outlets.
2. Pressure-Seal Joining Procedure for Copper Tubing: Qualify operators according to training provided by Viega; Plumbing and Heating Systems.
3. Pressure-Seal Joining Procedure for Steel Piping. Qualify operators according to training provided by Victaulic Company.

B. Brazing: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications," or to AWS B2.2, "Standard for Brazing Procedure and Performance Qualification."

C. Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

D. ASME Compliance:

1. Comply with ASME B31.1, "Power Piping," for high-pressure compressed-air piping.
2. Comply with ASME B31.9, "Building Services Piping," for low-pressure compressed-air piping.

1.9 PROJECT CONDITIONS

A. Interruption of Existing Compressed-Air Service: Do not interrupt compressed-air service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary compressed-air service according to requirements indicated:

1. Notify DEN Project Manager no fewer than **[seven (7)]** <Insert number> days in advance of proposed interruption of compressed-air service.
2. Do not proceed with interruption of compressed-air service without DEN Project Manager's written permission.

1.10 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, protect and handle products under provisions of Section 220400 "Basic Plumbing Requirements" and Division 01

B. Protect piping and equipment from weather and construction traffic.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

- A. Schedule 40, Steel Pipe: ASTM A 53/A 53M, Type E or S, Grade B, black or hot-dip zinc coated with ends threaded according to ASME B1.20.1.
1. Steel Nipples: ASTM A 733, made of ASTM A 53/A 53M or ASTM A 106, Schedule 40, galvanized seamless steel pipe. Include ends matching joining method.
 2. Malleable-Iron Fittings: ASME B16.3, Class 150 or 300, threaded.
 3. Malleable-Iron Unions: ASME B16.39, Class 150 or 300, threaded.
 4. Steel Flanges: ASME B16.5, Class 150 or 300, carbon steel, threaded.
 5. Wrought-Steel Butt-Welding Fittings: ASME B16.9, Schedule 40.
 6. Steel Flanges: ASME B16.5, Class 150 or 300, carbon steel.
 7. Grooved-End Fittings and Couplings:
 - a. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1) Anvil International, Inc.
 - 2) Star Pipe Products; Star Fittings Div.
 - 3) Victaulic Company.
 - 4) Ward Manufacturing, Inc.
 - 5) **<Insert manufacturer's name.>**
 - 6) or approved equal.
 - b. Grooved-End Fittings: ASTM A 47/A 47M, malleable-iron castings or ASTM A 536, ductile-iron casting; with grooves according to AWWA C606 and dimensions matching steel pipe.
 - c. Couplings: AWWA C606 or UL 213, for steel-pipe dimensions and rated for **300-psig (2070-kPa)** minimum working pressure. Include ferrous housing sections, gasket suitable for compressed air, and bolts and nuts. Provide EDPM gaskets for oil-free compressed air. Provide NBR gaskets if compressed air contains oil or oil vapor.
- B. Schedule 5, Steel Pipe: ASTM A 135, carbon steel with plain ends and zinc-plated finish.
1. Pressure-Seal Fittings: Listed and labeled by a qualified testing agency and FMG-approved, carbon-steel, pressure-seal housing with O-ring end seals suitable for compressed-air piping and rated for **300-psig (2070-kPa)** minimum

working pressure. Provide EDPM seals for oil-free compressed air. Provide NBR seals if compressed air contains oil or oil vapor.

a. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- 1) Victaulic Company.
- 2) **<Insert manufacturer's name.>**
- 3) or approved equal.

C. Copper Tube: [ASTM B 88, Type K or L (ASTM B 88M, Type A or B)] [and] [ASTM B 88, Type M (ASTM B 88M, Type C)] seamless, drawn-temper, water tube.

1. Wrought-Copper Fittings: ASME B16.22, solder-joint pressure type or MSS SP-73, wrought copper with dimensions for brazed joints.

2. Cast-Copper-Alloy Flanges: ASME B16.24, Class 150 or 300.

3. Copper Unions: ASME B16.22 or MSS SP-123.

4. Press-Type Fittings, NPS 2 (DN 50) and Smaller: Wrought-copper fitting with EPDM O-ring seal in each end.

a. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- 1) Viega; Plumbing and Heating Systems.
- 2) **<Insert manufacturer's name.>**
- 3) or approved equal.

5. Press-Type Fittings, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Bronze fitting with stainless-steel grip ring and EPDM O-ring seal in each end.

a. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- 1) Viega; Plumbing and Heating Systems.
- 2) **<Insert manufacturer's name.>**
- 3) or approved equal.

6. Extruded-Tee Outlets: Procedure for making branch outlets in copper tube according to ASTM F 2014.

a. **Manufacturers: Subject to compliance with requirements, provide procedure according to one of the following:**

- 1) T-DRILL Industries Inc.
- 2) **<Insert manufacturer's name.>**
- 3) or approved equal.

7. Grooved-End Fittings and Couplings:

a. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- 1) Anvil International, Inc.
- 2) Victaulic Company.
- 3) **<Insert manufacturer's name.>**

- 4) or approved equal.
 - b. Grooved-End Fittings: **ASTM B 75** (ASTM B 75M), copper tube or ASTM B 584, bronze castings.
 - c. Couplings: Copper-tube dimensions and design similar to AWWA C606. Include ferrous housing sections, gasket suitable for compressed air, and bolts and nuts. Provide EDPM gasket for oil-free compressed air. Provide NBR gasket if compressed air contains oil or oil vapor.
- D. Transition Couplings for Metal Piping: Metal coupling or other manufactured fitting same size as, with pressure rating at least equal to and ends compatible with, piping to be joined.
- E. PVC Pipe: ASTM D 1785, Schedule 40.
1. PVC Fittings: ASTM D 2466, Schedule 40, socket type.
- F. Blue ABS Piping System: Made of ASTM D 3965, ABS-resin modified to provide shatter-resistant pipe for compressed-air service. Pipe and fittings are light blue and sizes are in millimeters.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. IPEX Inc.
 - b. **<Insert manufacturer's name.>**
 - c. or approved equal.
 2. Transition Fittings, 20 to 63 mm: Composite union with ABS socket end, CR O-ring, and malleable-iron union nut and threaded end; with construction similar to MSS SP-107, transition union.
 3. Transition Fittings, 90 to 110 mm: Flange assembly with ABS flange, CR gasket, and metal flange of material matching piping to be connected.
 4. Valves, 20 to 63 mm: ABS union ball valve with socket ends.
 5. Valves, 90 to 110 mm: ABS butterfly valve with lever handle.
- G. Green ABS Piping System: Made of ASTM D 3965, ABS-resin modified to provide shatter-resistant pipe for compressed-air service. Pipe and fittings are dark green with SDR of 9.0 and same OD as ASTM A 53/A 53M, steel pipe.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. NIBCO INC.
 - b. **<Insert manufacturer's name.>**
 - c. or approved equal.
 2. Transition Fittings, **NPS 1/2 to NPS 2** (DN 15 to DN 50): Composite union with ABS socket end, CR O-ring, ABS union nut, and brass solder-joint end; with construction similar to MSS SP-107, transition union.
 3. Transition Fittings, **NPS 2-1/2 to NPS 4** (DN 65 to DN 100): ABS flange, CR gasket, and metal flange of material matching piping to be connected.

4. Valves, **NPS 1/2 to NPS 2 (DN 15 to DN 50)**: Union ball valve with socket ends.
 5. Valves, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Union ball valve with flanged ends. Include safety exhaust feature in Part 3 "Valve Applications" Article if required.
- H. HDPE Piping System: Made of ASTM D 1248, HDPE resin to provide shatter-resistant pipe for compressed-air service. Pipe and fittings are dark blue with pipe dimensions about the same OD as ASTM D 3035, PE pipe.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Asahi/America.
 - b. **<Insert manufacturer's name.>**
 - c. or approved equal.
 2. Transition Fittings, **NPS 1/2 to NPS 2 (DN 15 to DN 50)**: HDPE adapter with one socket end and one end with threaded brass insert.
 3. Transition Fittings, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: HDPE flange, CR gasket, and metal flange of material matching piping to be connected.
 4. Valves, **NPS 1/2 to NPS 3 (DN 15 to DN 80)**: HDPE union ball valve with socket ends.

2.2 JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: Suitable for compressed-air piping system contents.
1. ASME B16.21, nonmetallic, flat, asbestos free, **1/8-inch (3.2-mm)** maximum thickness unless thickness or specific material is indicated.
 - a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
- B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- C. Plastic Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.
- D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.
- E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated.
- F. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- G. Solvent Cements for Joining Plastic Piping:
1. ABS Piping: ASTM D 2235.
 2. PVC Piping: ASTM D 2564. Include primer complying with ASTM F 656.

2.3 VALVES

- A. Metal Ball, Butterfly, Check, Gate, and Globe Valves: Comply with requirements in Section 220523 "General-Duty Valves for Plumbing Piping."
- B. General: Minimum rated pressure to be 200 PSI WOG at 200 degrees F.
- C. Gate Valves: Bronze body, bronze trim, **[non-rising]** **[rising]** stem, handwheel, inside screw, single wedge or disc, **[solder]** **[or]** **[threaded]** ends.
- D. Ball Valves: **[Bronze]** **[Stainless steel]** **[one]** **[two]** piece body, **[stainless]** **[chrome plated]** steel ball, teflon seats and stuffing box ring, lever handle **[solder]** **[or]** **[threaded]** ends **[with union.]**
- E. Swing Check Valves: Bronze swing disc, **[solder]** **[or]** **[screwed]** ends.
- F. Air Outlets: Quick Connector: **[3/8]** **[1/4]** inch brass, snap on connector with self closing valve.
- G. Pressure Reducing Valve:
 - 1. Pressure Reducing Station: Consisting of automatic reducing valve and bypass, and low pressure side relief valve and gage. Provide oil separator where indicated. Provide inlet and outlet shut-off valves, and globe or plug valve in bypass piping.
 - 2. Valve Capacity: Reduce pressure from 200 psi to 30 psi, adjustable upwards from reduced pressure.

2.4 DIELECTRIC FITTINGS

- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.
- B. Dielectric fittings designed to effectively separate dissimilar metals exposed to water or other electrolytes, conforming to NSF and ASTM F492 standards for continuous use at temperatures up to 225 degrees F and pressures up to 300 psi. Fittings to have electro-zinc-plated steel casings providing for maintained exterior electrical continuity, threaded or flanged ends as applicable, and inert linings.
- C. Dielectric Unions:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Capitol Manufacturing Company.
 - b. Central Plastics Company.
 - c. Hart Industries International, Inc.
 - d. Jomar International Ltd.
 - e. Matco-Norca, Inc.

- f. McDonald, A. Y. Mfg. Co.
- g. Perfection Corporation.
- h. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- i. Wilkins; a Zurn company.
- j. **<Insert manufacturer's name>**.
- k. or approved equal.

2. Description:

- a. Standard: ASSE 1079.
- b. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F (82 deg C)**] [150 psig (1035 kPa)] [250 psig (1725 kPa)].
- c. End Connections: Solder-joint copper alloy and threaded ferrous.

D. Dielectric Flanges:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Capitol Manufacturing Company.
- b. Central Plastics Company.
- c. Matco-Norca, Inc.
- d. Perfection Corporation.
- e. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- f. Wilkins; a Zurn company.
- g. **<Insert manufacturer's name>**.
- h. or approved equal.

2. Description:

- a. Standard: ASSE 1079.
- b. Factory-fabricated, bolted, companion-flange assembly.
- c. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F (82 deg C)**] [150 psig (1035 kPa)] [175 psig (1200 kPa)] [300 psig (2070 kPa)].
- d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

E. Dielectric-Flange Insulating Kits:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Advance Products & Systems, Inc.
- b. Calpico, Inc.
- c. Central Plastics Company.
- d. Perfection Corporation.
- e. Pipeline Seal and Insulator, Inc.
- f. **<Insert manufacturer's name>**.
- g. or approved equal.

2. Description:
 - a. Nonconducting materials for field assembly of companion flanges.
 - b. Pressure Rating: [150 psig (1035 kPa)] <Insert pressure>.
 - c. Gasket: Neoprene or phenolic.
 - d. Bolt Sleeves: Phenolic or polyethylene.
 - e. Washers: Phenolic with steel backing washers.

2.5 FLEXIBLE PIPE CONNECTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Flex-Hose Co., Inc.
2. Flexicraft Industries.
3. Hyspan Precision Products, Inc.
4. Mercer Rubber Co.
5. Metraflex, Inc.
6. Proco Products, Inc.
7. Unaflex, Inc.
8. Universal Metal Hose; a Hyspan Company
9. <Insert manufacturer's name.>
10. or approved equal.

B. Bronze-Hose Flexible Pipe Connectors: Corrugated-bronze tubing with bronze wire-braid covering and ends brazed to inner tubing.

1. Working-Pressure Rating: [200 psig (1380 kPa)] [250 psig (1725 kPa)] minimum.
2. End Connections, NPS 2 (DN 50) and Smaller: Threaded copper pipe or plain-end copper tube.
3. End Connections, NPS 2-1/2 (DN 65) and Larger: Flanged copper alloy.

C. Stainless-Steel-Hose Flexible Pipe Connectors: Corrugated-stainless-steel tubing with stainless-steel wire-braid covering and ends welded to inner tubing.

1. Working-Pressure Rating: [200 psig (1380 kPa)] [250 psig (1725 kPa)] minimum.
2. End Connections, NPS 2 (DN 50) and Smaller: Threaded steel pipe nipple.
3. End Connections, NPS 2-1/2 (DN 65) and Larger: Flanged steel nipple.

2.6 SPECIALTIES

A. Safety Valves: ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," construction; National Board certified, labeled, and factory sealed; constructed of bronze body with poppet-type safety valve for compressed-air service.

1. Pressure Settings: Higher than discharge pressure and same or lower than receiver pressure rating.

- B. Air-Main Pressure Regulators: Bronze body, direct acting, spring-loaded manual pressure-setting adjustment, and rated for [250-psig (1725-kPa)] <Insert pressure> inlet pressure, unless otherwise indicated.
1. Type: Pilot operated.
- C. Air-Line Pressure Regulators: [Diaphragm] [Diaphragm or pilot] [Pilot] operated, bronze body, direct acting, spring-loaded manual pressure-setting adjustment, and rated for [200-psig (1380-kPa)] <Insert pressure> minimum inlet pressure, unless otherwise indicated.
- D. Air-Line Pressure Regulators: Diaphragm operated, aluminum alloy or plastic body, direct acting, spring-loaded manual pressure-setting adjustment, and rated for [200-psig (1380-kPa)] <Insert pressure> minimum inlet pressure, unless otherwise indicated.
- E. Automatic Drain Valves: Stainless-steel body and internal parts, rated for [200-psig (1380-kPa)] <Insert pressure> minimum working pressure, capable of automatic discharge of collected condensate. [**Include mounting bracket if wall mounting is indicated.**]
- F. Coalescing Filters: Coalescing type with activated carbon capable of removing water and oil aerosols; with color-change dye to indicate when carbon is saturated and warning light to indicate when selected maximum pressure drop has been exceeded. [**Include mounting bracket if wall mounting is indicated.**]
- G. Mechanical Filters: Two-stage, mechanical-separation-type, air-line filters. Equip with deflector plates, resin-impregnated-ribbon-type filters with edge filtration, and drain cock. [**Include mounting bracket if wall mounting is indicated.**]
- H. Air-Line Lubricators: With drip chamber and sight dome for observing oil drop entering air stream; with oil-feed adjustment screw and quick-release collar for easy bowl removal. [**Include mounting bracket if wall mounting is indicated.**]
1. Provide with automatic feed device for supplying oil to lubricator.

2.7 QUICK COUPLINGS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. Aeroquip Corporation; Eaton Corp.
 2. Bowes Manufacturing Inc.
 3. Foster Manufacturing, Inc.
 4. Milton Industries, Inc.
 5. Parker Hannifin Corp.; Fluid Connectors Group; Quick Coupling Div.
 6. Rectus Corp.
 7. Schrader-Bridgeport; Amflo Div. Schrader-Bridgeport/Standard Thomson.
 8. Snap-Tite, Inc.; Quick Disconnect & Valve Division.

9. TOMCO Products Inc.
 10. Tuthill Corporation; Hansen Coupling Div.
 11. **<Insert manufacturer's name.>**
 12. or approved equal.
- B. General Requirements for Quick Couplings: Assembly with locking-mechanism feature for quick connection and disconnection of compressed-air hose.
- C. Automatic-Shutoff Quick Couplings: Straight-through brass body with O-ring or gasket seal and stainless-steel or nickel-plated-steel operating parts.
1. Socket End: With one-way valve and threaded inlet for connection to piping or threaded hose fitting.
 2. Plug End: **[Flow-sensor-bleeder, check-valve] [Straight-through]** type with barbed outlet for attaching hose.
- D. Valveless Quick Couplings: Straight-through brass body with stainless-steel or nickel-plated-steel operating parts.
1. Socket End: With O-ring or gasket seal, without valve, and with barbed inlet for attaching hose.
 2. Plug End: With barbed outlet for attaching hose.

2.8 HOSE ASSEMBLIES

- A. Description: Compatible hose, clamps, couplings, and splicers suitable for compressed-air service, of nominal diameter indicated, and rated for **[300-psig (2070-kPa)]** **<Insert pressure>** minimum working pressure, unless otherwise indicated.
1. Hose: Reinforced **[single] [single- or double] [double]**-wire-braid, CR-covered hose for compressed-air service.
 2. Hose Clamps: Stainless-steel clamps or bands.
 3. Hose Couplings: Two-piece, straight-through, threaded brass or stainless-steel O-ring or gasket-seal swivel coupling with barbed ends for connecting two sections of hose.
 4. Hose Splicers: One-piece, straight-through brass or stainless-steel fitting with barbed ends for connecting two sections of hose.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

- A. Compressed-Air Piping between Air Compressors and Receivers: Use **[one of]** the following piping materials for each size range:
1. **[NPS 2 (DN 50)]** **<Insert pipe size>** and Smaller: Schedule 40, **[black] [galvanized]**-steel pipe; threaded, malleable-iron fittings; and threaded joints.

2. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 5, galvanized-steel pipe; pressure-seal fittings; and pressure-sealed joints.
 3. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints.
 4. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed joints.
 5. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Schedule 40, [black] [galvanized]-steel pipe; threaded, malleable-iron fittings; and threaded joints.
 6. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Schedule 40, [black] [galvanized]-steel pipe; grooved-end fittings; couplings; and grooved joints.
 7. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints.
 8. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed joints.
 9. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; grooved-end copper fittings; couplings; and grooved joints.
 10. [NPS 5 (DN 125)] <Insert pipe size> and Larger: Schedule 40, [black] [galvanized]-steel pipe; threaded, malleable-iron fittings; and threaded joints.
 11. [NPS 5 (DN 125)] <Insert pipe size> and Larger: Schedule 40, [black] [galvanized]-steel pipe; grooved-end fittings; couplings; and grooved joints.
 12. [NPS 5 (DN 125)] <Insert pipe size> and Larger: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints.
 13. [NPS 5 (DN 125)] <Insert pipe size> and Larger: Grooved-end, Type K or L (ASTM B 88M Type A or B), copper tube; grooved-end copper fittings; couplings; and grooved joints.
- B. Low-Pressure Compressed-Air Distribution Piping: Use [one of] the following piping materials for each size range:
1. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 40, [black] [galvanized]-steel pipe; threaded, malleable-iron fittings; and threaded joints.
 2. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 5, galvanized-steel pipe; pressure-seal fittings; and pressure-sealed joints.
 3. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed [or soldered] joints.
 4. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Type K or L (Type A or B), copper tube; press-type fittings; and pressure-sealed joints.
 5. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: 63-mm and smaller, blue ABS pipe and fittings; transition fittings; valves; and solvent-cemented joints.
 6. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Green ABS pipe and fittings, transition fittings, and valves; and solvent-cemented joints.
 7. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: HDPE pipe, fittings, and valves; and heat-fusion joints.
 8. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Schedule 40, [black] [galvanized]-steel pipe; threaded, malleable-iron fittings; and threaded joints.

9. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Schedule 40, **[black] [galvanized]**-steel pipe; grooved-end fittings; couplings; and grooved joints.
 10. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed[**or soldered**] joints.
 11. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; grooved-end copper fittings; couplings; and grooved joints.
 12. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; press-type fittings; and pressure-sealed joints.
 13. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: 90- and 110-mm, blue ABS pipe and fittings; transition fittings; and solvent-cemented joints. Include butterfly valves and flanged joints.
 14. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: NPS 3 and NPS 4 (DN 80 and DN 100), green ABS pipe and fittings; transition fittings; and solvent-cemented joints. Include ball valves and flanged joints.
 15. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: NPS 3 and NPS 4 (DN 80 and DN 100), HDPE pipe and fittings; valves; and heat-fusion joints.
 16. [NPS 5 and NPS 6 (DN 125 and DN 150)] <Insert pipe size range>: Schedule 40, **[black] [galvanized]**-steel pipe; threaded, malleable-iron fittings; and threaded joints.
 17. [NPS 5 (DN 125)] <Insert pipe size> and Larger: Schedule 40, **[black] [galvanized]**-steel pipe; grooved-end fittings; couplings; and grooved joints.
 18. [NPS 5 to NPS 8 (DN 125 to DN 200)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; grooved-end copper fittings; couplings; and grooved joints.
- C. High-Pressure Compressed-Air Distribution Piping: Use[**one of**] the following piping materials for each size range:
1. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 40, **[black] [galvanized]**-steel pipe; threaded, malleable-iron fittings; and threaded joints.
 2. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 5, galvanized-steel pipe; pressure-seal fittings; and pressure-sealed joints.
 3. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints.
 4. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed[**or soldered**] joints.
 5. [NPS 2-1/2 to NPS 6 (DN 65 to DN 150)] <Insert pipe size range>: Schedule 40, **[black] [galvanized]**-steel pipe; threaded, malleable-iron fittings; and threaded joints.
 6. [NPS 2-1/2 to NPS 6 (DN 65 to DN 150)] <Insert pipe size range>: Schedule 40, **[black] [galvanized]**-steel pipe; grooved-end fittings; couplings; and grooved joints.
 7. [NPS 2-1/2 to NPS 6 (DN 65 to DN 150)] <Insert pipe size range>: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints.
 8. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed[**or soldered**] joints.

9. [NPS 2-1/2 to NPS 6 (DN 65 to DN 150)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; wrought-copper fittings; and brazed joints.
10. [NPS 2-1/2 to NPS 6 (DN 65 to DN 150)] <Insert pipe size range>: Type K or L (Type A or B), copper tube; grooved-end copper fittings; couplings; and grooved joints.
11. [NPS 8 (DN 200)] <Insert pipe size> and Larger: Schedule 40, [black] [galvanized]-steel pipe; grooved-end fittings; couplings; and grooved joints.
12. [NPS 8 (DN 200)] <Insert pipe size> and Larger: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints.
13. [NPS 8 (DN 200)] <Insert pipe size>: Type K or L (Type A or B), copper tube; grooved-end copper fittings; couplings; and grooved joints.

D. Drain Piping: Use[**one of**] the following piping materials:

1. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Type M (Type C) copper tube; wrought-copper fittings; and brazed or soldered joints.
2. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: PVC pipe and fittings; and solvent-cemented joints.

3.2 VALVE APPLICATIONS

A. General-Duty Valves: Comply with requirements in Section 220523 "General-Duty Valves for Plumbing Piping" for metal general-duty valves. Use metal valves, unless otherwise indicated.

1. Metal General-Duty Valves: Use valve types specified in "Valve Applications" Article in Section 220523 "General-Duty Valves for Plumbing Piping" according to the following:
 - a. Low-Pressure Compressed Air: Valve types specified for low-pressure compressed air.
 - b. High-Pressure Compressed Air: Valve types specified for medium-pressure compressed air.
 - c. Equipment Isolation NPS 2 (DN 50) and Smaller: Safety-exhaust, copper-alloy ball valve with exhaust vent and pressure rating at least as great as piping system operating pressure.
 - d. Grooved-end valves may be used with grooved-end piping and grooved joints.
2. Plastic General-Duty Valves: Provide valves, made by piping manufacturer, that are compatible with piping. Do not use plastic valves between air compressors and receivers.
 - a. Blue ABS Piping System: Ball and butterfly valves.
 - b. Green ABS Piping System: Ball valves.
 - c. HDPE Piping System: Ball valves.

3.3 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of compressed-air piping. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, air-compressor sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Install piping concealed from view and protected from physical contact by building occupants, unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited, unless otherwise indicated.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal and to coordinate with other services occupying that space.
- E. Install piping adjacent to equipment and machines to allow service and maintenance.
- F. Install air and drain piping with 1 percent slope downward in direction of flow.
- G. Install nipples, flanges, unions, transition and special fittings, and valves with pressure ratings same as or higher than system pressure rating, unless otherwise indicated.
- H. Equipment and Specialty Flanged Connections:
 - 1. Use steel companion flange with gasket for connection to steel pipe.
 - 2. Use cast-copper-alloy companion flange with gasket and brazed[**or soldered**] joint for connection to copper tube. Do not use soldered joints for connection to air compressors or to equipment or machines producing shock or vibration.
- I. Flanged joints may be used instead of specified joint for any piping or tubing system.
- J. Extended-tee outlets with brazed branch connection may be used for copper tubing, within extruded-tee connection diameter to run tube diameter ratio for tube type, according to Extruded Tee Connections Sizes and Wall Thickness for Copper Tube (Inches) Table in ASTM F 2014.
- K. Install eccentric reducers where compressed-air piping is reduced in direction of flow, with bottoms of both pipes and reducer fitting flush.
- L. Install branch connections to compressed-air mains from top of main. Provide drain leg and drain trap at end of each main and branch and at low points.
- M. Install thermometer and pressure gage on discharge piping from each air compressor and on each receiver. Comply with requirements in Section 220519 "Meters and Gages for Plumbing Piping."
- N. Install piping to permit valve servicing.

- O. Install piping free of sags and bends.
- P. Install fittings for changes in direction and branch connections.
- Q. Install seismic restraints on piping. Seismic-restraint devices are specified in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment."
- R. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 220517 "Sleeves and Sleeve Seals for Plumbing Piping."
- S. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 220517 "Sleeves and Sleeve Seals for Plumbing Piping."
- T. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 220518 "Escutcheons for Plumbing Piping."
- U. Make air cock and drain connection on horizontal casing.
- V. Connect condensate drains to nearest floor drain.
- W. Install valved bypass around air dryer. Factory insulate inlet and outlet connections.
- X. Install valved drip connections at low points of piping system.
- Y. Install take offs to outlets from top of main, with shut off valve after take off. Slope take off piping to outlets.
- Z. Install compressed air couplings, female quick connectors, and pressure gages where outlets are indicated.
- AA. Install tees instead of elbows at changes in direction of piping. Fit open end of each tee with plug.
- BB. Identify piping system and components. Refer to Section 220553 "Identification for Plumbing Piping and Equipment".

3.4 JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. Welded Joints for Steel Piping: Join according to AWS D10.12/D10.12M.
- E. Brazed Joints for Copper Tubing: Join according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter.
- F. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Join according to ASTM B 828 or CDA's "Copper Tube Handbook."
- G. Extruded-Tee Outlets for Copper Tubing: Form branches according to ASTM F 2014, with tools recommended by procedure manufacturer, and using operators qualified according to Part 1 "Quality Assurance" Article.
- H. Flanged Joints: Use asbestos-free, nonmetallic gasket suitable for compressed air. Join flanges with gasket and bolts according to ASME B31.9 for bolting procedure.
- I. Grooved Joints: Assemble couplings with housing, gasket, lubricant, and bolts. Join according to AWWA C606 for grooved joints. Do not apply lubricant to prelubricated gaskets.
- J. Heat-Fusion Joints for PE Piping: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657 for socket-fusion joints.
- K. Pressure-Sealed Joints: Join with tools recommended by fitting manufacturer, using operators qualified according to Part 1 "Quality Assurance" Article.
- L. Solvent-Cemented Joints for ABS Piping: Clean and dry joining surfaces. Join according to the following:
1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
 2. Join according to ASME B31.9 for solvent-cemented joints and to ASTM D 2235 Appendix.
- M. Solvent-Cemented Joints for PVC Piping: Clean and dry joining surfaces. Join according to the following:
1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
 2. Apply primer and join according to ASME B31.9 for solvent-cemented joints and to ASTM D 2672.
- N. Dissimilar Metal Piping Material Joints: Use dielectric fittings.

3.5 VALVE INSTALLATION

- A. General-Duty Valves: Comply with requirements in Section 220523 "General-Duty Valves for Plumbing Piping."
- B. Install shutoff valves and unions or flanged joints at compressed-air piping to air compressors.
- C. Install shutoff valve at inlet to each automatic drain valve, filter, lubricator, and pressure regulator.
- D. Install check valves to maintain correct direction of compressed-air flow to and from compressed-air piping specialties and equipment.
- E. Install line size gate valve and check valve on compressor discharge.

3.6 DIELECTRIC FITTING INSTALLATION

- A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.
- B. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Use dielectric unions.
- C. [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Use dielectric flanges.
- D. [NPS 5 (DN 125)] <Insert pipe size>and Larger: Use dielectric flange kits.

3.7 FLEXIBLE PIPE CONNECTOR INSTALLATION

- A. Install flexible pipe connectors in discharge piping[**and in inlet air piping from remote air-inlet filter**] of each air compressor.
- B. Install bronze-hose flexible pipe connectors in copper compressed-air tubing.
- C. Install stainless-steel-hose flexible pipe connectors in steel compressed-air piping.

3.8 SPECIALTY INSTALLATION

- A. Install safety valves on receivers in quantity and size to relieve at least the capacity of connected air compressors.
- B. Install air-main pressure regulators in compressed-air piping at or near air compressors.
- C. Install air-line pressure regulators in branch piping to equipment[**and tools**].
- D. Install automatic drain valves on aftercoolers, receivers, and dryers. Discharge condensate onto nearest floor drain.

- E. Install coalescing filters in compressed-air piping at or near air compressors and upstream from mechanical filters. [**Mount on wall at locations indicated.**]
- F. Install mechanical filters in compressed-air piping at or near air compressors and downstream from coalescing filters. [**Mount on wall at locations indicated.**]
- G. Install air-line lubricators in branch piping to machine tools. [**Mount on wall at locations indicated.**]
- H. Install quick couplings at piping terminals for hose connections.
- I. Install hose assemblies at hose connections.

3.9 CONNECTIONS

- A. Install unions, in piping **NPS 2 (DN 50)** and smaller, adjacent to each valve and at final connection to each piece of equipment and machine.
- B. Install flanges, in piping **NPS 2-1/2 (DN 65)** and larger, adjacent to flanged valves and at final connection to each piece of equipment and machine.

3.10 HANGER AND SUPPORT INSTALLATION

- A. Comply with requirements in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment" for seismic-restraint devices.
- B. Comply with requirements in Section 220529 "Hangers and Supports for Plumbing Piping and Equipment" for pipe hanger and support devices.
- C. Vertical Piping: MSS Type 8 or 42, clamps.
- D. Individual, Straight, Horizontal Piping Runs:
 - 1. **100 Feet (30 m)** or Less: MSS Type 1, adjustable, steel clevis hangers.
 - 2. Longer Than **100 Feet (30 m)**: MSS Type 43, adjustable roller hangers.
- E. Multiple, Straight, Horizontal Piping Runs **100 Feet (30 m)** or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
- F. Base of Vertical Piping: MSS Type 52, spring hangers.
- G. Support horizontal piping within [**12 inches (300 mm)**] **<Insert dimension>** of each fitting and coupling.
- H. Rod diameter may be reduced 1 size for double-rod hangers, with **3/8-inch (10-mm)** minimum rods.
- I. Install hangers for Schedule 40, steel piping with the following maximum horizontal spacing and minimum rod diameters:

1. NPS 1/4 to NPS 1/2 (DN 8 to DN 15): 96 inches (2400 mm) with 3/8-inch (10-mm) rod.
 2. NPS 3/4 to NPS 1-1/4 (DN 20 to DN 32): 84 inches (2100 mm) with 3/8-inch (10-mm) rod.
 3. NPS 1-1/2 (DN 40): 12 feet (3.7 m) with 3/8-inch (10-mm) rod.
 4. NPS 2 (DN 50): 13 feet (4 m) with 3/8-inch (10-mm) rod.
 5. NPS 2-1/2 (DN 65): 14 feet (4.3 m) with 1/2-inch (13-mm) rod.
 6. NPS 3 (DN 80): 15 feet (4.6 m) with 1/2-inch (13-mm) rod.
 7. NPS 3-1/2 (DN 90): 16 feet (4.9 m) with 1/2-inch (13-mm) rod.
 8. NPS 4 (DN 100): 17 feet (5.2 m) with 5/8-inch (16-mm) rod.
 9. NPS 5 (DN 125): 19 feet (5.8 m) with 5/8-inch (16-mm) rod.
 10. NPS 6 (DN 150): 21 feet (6.4 m) with 3/4-inch (19-mm) rod.
 11. NPS 8 (DN 200): 24 feet (7.3 m) with 3/4-inch (19-mm) rod.
 12. NPS 10 (DN 250): 26 feet (7.9 m) with 7/8-inch (22-mm) rod.
 13. NPS 12 (DN 300): 30 feet (9.1 m) with 7/8-inch (22-mm) rod.
- J. Install supports for vertical, Schedule 40, steel piping every 15 feet (4.6 m).
- K. Install hangers for Schedule 5, steel piping with the following maximum horizontal spacing and minimum rod diameters:
1. NPS 1/2 (DN 15): 72 inches (1800 mm) with 3/8-inch (10-mm) rod.
 2. NPS 3/4 (DN 20): 84 inches (2100 mm) with 3/8-inch (10-mm) rod.
 3. NPS 1 (DN 25): 96 inches (2400 mm) with 3/8-inch (10-mm) rod.
 4. NPS 1-1/4 (DN 32): 108 inches (2700 mm) with 3/8-inch (10-mm) rod.
 5. NPS 1-1/2 (DN 40): 10 feet (3 m) with 3/8-inch (10-mm) rod.
 6. NPS 2 (DN 50): 11 feet (3.4 m) with 3/8-inch (10-mm) rod.
- L. Install supports for vertical, Schedule 5, steel piping every 10 feet (3 m).
- M. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:
1. NPS 1/4 (DN 8): 60 inches (1500 mm) with 3/8-inch (10-mm) rod.
 2. NPS 3/8 and NPS 1/2 (DN 10 and DN 15): 72 inches (1800 mm) with 3/8-inch (10-mm) rod.
 3. NPS 3/4 (DN 20): 84 inches (2100 mm) with 3/8-inch (10-mm) rod.
 4. NPS 1 (DN 25): 96 inches (2400 mm) with 3/8-inch (10-mm) rod.
 5. NPS 1-1/4 (DN 32): 108 inches (2700 mm) with 3/8-inch (10-mm) rod.
 6. NPS 1-1/2 (DN 40): 10 feet (3 m) with 3/8-inch (10-mm) rod.
 7. NPS 2 (DN 50): 11 feet (3.4 m) with 3/8-inch (10-mm) rod.
 8. NPS 2-1/2 (DN 65): 13 feet (4 m) with 1/2-inch (13-mm) rod.
 9. NPS 3 (DN 80): 14 feet (4.3 m) with 1/2-inch (13-mm) rod.
 10. NPS 3-1/2 (DN 90): 15 feet (4.6 m) with 1/2-inch (13-mm) rod.
 11. NPS 4 (DN 100): 16 feet (4.9 m) with 1/2-inch (13-mm) rod.
 12. NPS 5 (DN 125): 18 feet (5.5 m) with 1/2-inch (13-mm) rod.
 13. NPS 6 (DN 150): 20 feet (6 m) with 5/8-inch (16-mm) rod.
 14. NPS 8 (DN 200): 23 feet (7 m) with 3/4-inch (19-mm) rod.
- N. Install supports for vertical copper tubing every 10 feet (3 m).

- O. Install vinyl-coated hangers for ABS piping with the following maximum horizontal spacing and minimum rod diameters:
1. All Sizes: Install continuous support for piping with compressed air at normal operating temperature above [100 deg F (38 deg C)] **<Insert temperature>**.
 2. NPS 3/8 and NPS 1/2 (DN 10 and DN 15): 30 inches (760 mm) with 3/8-inch (10-mm) rod.
 3. NPS 3/4 (DN 20): 38 inches (975 mm) with 3/8-inch (10-mm) rod.
 4. NPS 1 (DN 25): 40 inches (1015 mm) with 3/8-inch (10-mm) rod.
 5. NPS 1-1/4 (DN 32): 45 inches (1140 mm) with 3/8-inch (10-mm) rod.
 6. NPS 1-1/2 (DN 40): 52 inches (1330 mm) with 3/8-inch (10-mm) rod.
 7. NPS 2 (DN 50): 58 inches (1470 mm) with 3/8-inch (10-mm) rod.
 8. NPS 3 (DN 80): 68 inches (1730 mm) with 1/2-inch (13-mm) rod.
 9. NPS 4 (DN 100): 76 inches (1900 mm) with 1/2-inch (13-mm) rod.
- P. Install supports for vertical ABS piping every 48 inches (1220 mm).
- Q. Install vinyl-coated hangers for HDPE piping with the following maximum horizontal spacing and minimum rod diameters:
1. All Sizes: Install continuous support for piping with compressed air at normal operating temperature above [100 deg F (38 deg C)] **<Insert temperature>**.
 2. NPS 1/2 (DN 15): 30 inches (760 mm) with 3/8-inch (10-mm) rod.
 3. NPS 3/4 (DN 20): 35 inches (890 mm) with 3/8-inch (10-mm) rod.
 4. NPS 1 (DN 25): 40 inches (1015 mm) with 3/8-inch (10-mm) rod.
 5. NPS 1-1/4 (DN 32): 43 inches (1090 mm) with 3/8-inch (10-mm) rod.
 6. NPS 1-1/2 (DN 40): 49 inches (1245 mm) with 3/8-inch (10-mm) rod.
 7. NPS 2 (DN 50): 55 inches (1400 mm) with 3/8-inch (10-mm) rod.
 8. NPS 3 and NPS 4 (DN 80 and DN 100): 96 inches (2440 mm) with 1/2-inch (13-mm) rod.
- R. Install supports for vertical HDPE piping every 48 inches (1220 mm).

3.11 LABELING AND IDENTIFICATION

- A. Install identifying labels and devices for general-service compressed-air piping, valves, and specialties. Comply with requirements in Section 220553 "Identification for Plumbing Piping and Equipment."

3.12 FIELD QUALITY CONTROL

- A. Perform field tests and inspections.
- B. Tests and Inspections:
1. Piping Leak Tests for Metal Compressed-Air Piping: Test new and modified parts of existing piping. Cap and fill general-service compressed-air piping with oil-free dry air or gaseous nitrogen to pressure of 50 psig (345 kPa) above system

- operating pressure, but not less than [150 psig (1035 kPa)] **<Insert pressure>**. Isolate test source and let stand for four hours to equalize temperature. Refill system, if required, to test pressure; hold for two hours with no drop in pressure.
2. Piping Leak Tests for ABS Compressed-Air Piping: Test new and modified parts of existing piping. Cap and fill general-service compressed-air piping with oil-free dry air or gaseous nitrogen, at temperature of 110 deg F (43 deg C) or less, to pressure of [40 psig (275 kPa)] **<Insert pressure>** above system operating pressure, but not less than [80 psig (550 kPa)] [100 psig (690 kPa)] **<Insert pressure>** or more than 120 psig (825 kPa). Isolate test source and let stand for four hours to equalize temperature. Refill system, if required, to test pressure; hold for two hours with no drop in pressure.
 3. Piping Leak Tests for HDPE Compressed-Air Piping: Test new and modified parts of existing piping. Cap and fill general-service compressed-air piping with oil-free dry air or gaseous nitrogen, at temperature of 100 deg F (38 deg C) or less, to pressure of [40 psig (275 kPa)] **<Insert pressure>** above system operating pressure, but not less than [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] **<Insert pressure>** or more than 180 psig (1240 kPa). Isolate test source and let stand for four hours to equalize temperature. Refill system, if required, to test pressure; hold for two hours with no drop in pressure.
 4. Repair leaks and retest until no leaks exist.
 5. Inspect [filters] [lubricators] [and] [pressure regulators] for proper operation.
- C. Repair or replace compressed air piping as required to eliminate leaks, and retest to demonstrate compliance.
 - D. Cap (seal) ends of piping when not connected to mechanical equipment.
 - E. Prepare test reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 221513

SECTION 221519 - GENERAL-SERVICE PACKAGED AIR COMPRESSORS AND RECEIVERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Lubricated, reciprocating air compressors.
 - 2. Oil-free, reciprocating air compressors.
 - 3. Oilless, reciprocating air compressors.
 - 4. Oil-free, rotary-screw air compressors.
 - 5. Oil-flooded, rotary-screw air compressors.
 - 6. Oil-free, rotary, sliding-vane air compressors.
 - 7. Oil-sealed, rotary, sliding-vane air compressors.
 - 8. Inlet-air filters.
 - 9. Air-cooled, compressed-air aftercoolers.
 - 10. Water-cooled, compressed-air aftercoolers.
 - 11. Refrigerant compressed-air dryers.
 - 12. Desiccant compressed-air dryers.
 - 13. Computer interface cabinet.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Actual Air: Air delivered from air compressors. Flow rate is delivered compressed air measured in **acfm** (actual L/s).
- B. Standard Air: Free air at **68 deg F** (20 deg C) and **1 atmosphere** (29.92 in. Hg) before compression or expansion and measured in **scfm** (standard L/s).

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.

1. Provide manufacturers catalog literature with capacity, weight, and connection requirements.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
3. Include data substantiating that materials comply with requirements.

B. Shop Drawings:

1. Include diagrams for power, signal, and control wiring. Indicate electrical characteristics and connection requirements.

C. Delegated-Design Submittal: For compressed-air equipment mounting.

1. Detail fabrication and assembly of supports.
2. Include design calculations for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For compressed-air equipment, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Provide certificate of compliance from [**authority having jurisdiction**] <Insert **authority**> indicating approval of air receiver.
3. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
4. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For compressed-air equipment to include in emergency, operation, and maintenance manuals.

B. Test Reports: Submit inspector's certificate for air receiver for inclusion in Operating and Maintenance Manuals.

C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

D. Record actual locations of equipment and components. Modify shop drawings to indicate final locations.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Air-Compressor, Inlet-Air-Filter Elements: Equal to **<Insert number>** percent of amount installed, but no fewer than **<Insert number>** units.
 - 2. Belts: **[One] [Two] <Insert number>** for each belt-driven compressor.
 - 3. Provide **[two (2)] <Insert amount>** quart containers of compressor oil.

1.8 FIELD CONDITIONS

- A. Interruption of Existing Compressed-Air Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary service according to requirements indicated:
 - 1. Notify DEN Project Manager no fewer than **[seven (7)] <Insert number>** days in advance of proposed interruption of compressed-air service.
 - 2. Do not proceed with interruption of compressed-air service without DEN Project Manager's written permission.

1.9 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products under provisions of Section 220400 "Basic Plumbing Requirements" and Division 01
- B. Accept air compressors, refrigerated air dryer on site in factory fabricated containers with shipping skids and plastic pipe end protectors in place. Inspect for damage.
- C. Protect piping and equipment from weather and construction traffic.

1.11 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 220400 "Basic Plumbing Requirements".
- B. Provide minimum five (5) year warranty for air compressors.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419

"Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label receivers to comply with ASME Boiler and Pressure Vessel Code.

2.2 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design compressed-air equipment mounting.
- B. Seismic Performance: Compressed-air equipment shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **[and the unit will be fully operational after the seismic event].**"

2.3 GENERAL REQUIREMENTS FOR PACKAGED AIR COMPRESSORS AND RECEIVERS

- A. General Description: Factory-assembled, -wired, -piped, and -tested; electric-motor-driven; air-cooled; continuous-duty air compressors and receivers that deliver air of quality equal to intake air.
- B. Control Panels: Automatic control station with load control and protection functions. Comply with NEMA ICS 2 and UL 508.
 - 1. Enclosure: NEMA ICS 6, Type 12 control panel unless otherwise indicated.
 - 2. Motor Controllers: Full-voltage, combination magnetic type with undervoltage release feature and motor-circuit-protector-type disconnecting means and short-circuit protective device.
 - 3. Control Voltage: 120-V ac or less, using integral control power transformer.
 - 4. Motor Overload Protection: Overload relay in each phase.
 - 5. Starting Devices: Hand-off-automatic selector switch in cover of control panel, plus pilot device for automatic control.
 - 6. Automatic control switches to **[alternate lead-lag compressors for duplex] [sequence lead-lag compressors for multiplex]** air compressors.

7. Instrumentation: Include discharge-air pressure gage, air-filter maintenance indicator, hour meter, compressor discharge-air and coolant temperature gages, and control transformer.
8. Alarm Signal Device: For connection to alarm system to indicate when backup air compressor is operating.

C. Receivers: Steel tank constructed according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

1. Pressure Rating: At least as high as highest discharge pressure of connected compressors, and bearing appropriate code symbols.
2. Interior Finish: Corrosion-resistant coating.
3. Accessories: Include safety valve, pressure gage, drain, and pressure-reducing valve.

D. Mounting Frame: Fabricate mounting and attachment to pressure vessel with reinforcement strong enough to resist packaged equipment movement during a seismic event when base is anchored to building structure.

2.4 LUBRICATED, RECIPROCATING AIR COMPRESSORS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Atlas Copco.](#)
2. [CompAir, Ltd.](#)
3. [Curtis-Toledo.](#)
4. [Gardner Denver, Inc.](#)
5. [General Air Products, Inc.](#)
6. [Ingersoll-Rand; Air Solutions Group.](#)
7. [Kaeser Compressors, Inc.](#)
8. [Powerex, Inc.](#)
9. [Quincy Compressor; an EnPro Industries company.](#)
10. [Saylor-Beall Manufacturing Company.](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

B. Compressor(s): Lubricated, reciprocating-piston type with lubricated compression chamber and crankcase.

1. Submerged gear-type oil pump.
2. Oil filter.
3. Combined high discharge-air temperature and low lubrication-oil pressure switch.
4. Belt guard totally enclosing pulleys and belts.

C. Capacities and Characteristics:

1. Air Compressor(s): **[One] [Two] [Three] <Insert number>; [single] [single or two] [two] stage.**

- a. Intercooler between stages of two-stage units.
2. Standard-Air Capacity of Each Air Compressor: **<Insert scfm (standard L/s)>** free air.
3. Actual-Air Capacity of Each Air Compressor: **<Insert acfm (actual L/s)>** delivered.
4. Discharge-Air Pressure: [100 psig (690 kPa)] [125 psig (860 kPa)] [175 psig (1200 kPa)] **<Insert value>**.
5. Intake-Air Temperature: **<Insert deg F (deg C)>**.
6. Discharge-Air Temperature: **<Insert deg F (deg C)>**.
7. Mounting: [Freestanding] [Tank mounted].
8. Motor (Each Air Compressor):
 - a. Horsepower: **<Insert value>**.
 - b. Speed: [1750] [3400] **<Insert value>** rpm.
9. Electrical Characteristics:
 - a. Volts: [120] [208] [240] **<Insert value>**.
 - b. Phase(s): [Single] [Three].
 - c. Hertz: [60] **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
10. Receiver: ASME construction steel tank.
 - a. Arrangement: [Horizontal] [Vertical].
 - b. Capacity: **<Insert gal. (L)>**.
 - c. Interior Finish: [Epoxy] [Epoxy or galvanized] [Galvanized] **<Insert coating>** coating.
 - d. Pressure Rating: [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] [200 psig (1380 kPa)] [250 psig (1725 kPa)] **<Insert value>** minimum.
 - e. Pressure Regulator Setting: **<Insert psig (kPa)>**.
 - f. Pressure Relief Valve Setting: **<Insert psig (kPa)>**.
 - g. Drain: [Automatic] [Manual] valve.

2.5 OIL-FREE, RECIPROCATING AIR COMPRESSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Gast Manufacturing Inc.](#)
2. [Ingersoll-Rand.](#)
3. [Quincy Compressor.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

- B. Compressor(s): Oil-free, reciprocating-piston type with nonlubricated compression chamber, lubricated crankcase, and of construction that prohibits oil from entering compression chamber.
1. Submerged gear-type oil pump.
 2. Oil filter.
 3. Combined high discharge-air temperature and low lubrication-oil pressure switch.
 4. Belt guard totally enclosing pulleys and belts.
- C. Capacities and Characteristics:
1. Air Compressor(s): **[One] [Two] [Three]** <Insert number>; single stage.
 2. Standard-Air Capacity of Each Air Compressor: <Insert scfm (standard L/s)> free air.
 3. Actual-Air Capacity of Each Air Compressor: <Insert acfm (actual L/s)> delivered.
 4. Discharge-Air Pressure: **[100 psig (690 kPa)] [125 psig (860 kPa)] [175 psig (1200 kPa)]** <Insert value>.
 5. Intake-Air Temperature: <Insert deg F (deg C)>.
 6. Discharge-Air Temperature: <Insert deg F (deg C)>.
 7. Mounting: **[Freestanding] [Tank mounted]**.
 8. Motor (Each Air Compressor):
 - a. Horsepower: <Insert value>.
 - b. Speed: **[1750] [3400]** <Insert value> rpm.
 9. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase(s): **[Single] [Three]**.
 - c. Hertz: **[60]** <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
 10. Receiver: ASME construction steel tank.
 - a. Arrangement: **[Horizontal] [Vertical]**.
 - b. Capacity: <Insert gal. (L)>.
 - c. Interior Finish: **[Epoxy] [Epoxy or galvanized] [Galvanized]** <Insert coating> coating.
 - d. Pressure Rating: **[100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] [200 psig (1380 kPa)] [250 psig (1725 kPa)]** <Insert value> minimum.
 - e. Pressure Regulator Setting: <Insert psig (kPa)>.
 - f. Pressure Relief Valve Setting: <Insert psig (kPa)>.
 - g. Drain: **[Automatic] [Manual]** valve.

2.6 OILLESS, RECIPROCATING AIR COMPRESSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [FS-Curtis Air Compressors.](#)
2. [Gast Manufacturing Inc.](#)
3. [General Air Products.](#)
4. [Ingersoll-Rand Company; Compressed Air Solutions.](#)
5. [JUN-AIR USA Inc.](#)
6. [Kaeser Compressors, Inc.](#)
7. [Ohio Medical Corporation; Squire-Cogswell brand.](#)
8. [Powerex, Inc.](#)
9. [Quincy Compressor.](#)
10. **<Insert manufacturer's name>.**
11. or approved equal.

B. Compressor(s): Oilless (nonlubricated), reciprocating-piston type, with sealed oil-free bearings, that deliver air of quality equal to intake air.

1. High discharge-air temperature switch.
2. Belt guard totally enclosing pulleys and belts.

C. Capacities and Characteristics:

1. Air Compressor(s): **[One] [Two] [Three] <Insert number>; [single] [single or two] [two] stage.**
 - a. Intercooler between stages of two-stage units.
2. Standard-Air Capacity of Each Air Compressor: **<Insert scfm (standard L/s)>** free air.
3. Actual-Air Capacity of Each Air Compressor: **<Insert acfm (actual L/s)>** delivered.
4. Discharge-Air Pressure: **[100 psig (690 kPa)] [125 psig (860 kPa)] [175 psig (1200 kPa)] <Insert value>.**
5. Intake-Air Temperature: **<Insert deg F (deg C)>.**
6. Discharge-Air Temperature: **<Insert deg F (deg C)>.**
7. Mounting: **[Freestanding] [Tank mounted].**
8. Motor (Each Air Compressor):
 - a. Horsepower: **<Insert value>.**
 - b. Speed: **[1750] [3400] <Insert value>** rpm.
9. Electrical Characteristics:
 - a. Volts: **<Insert value>.**
 - b. Phase(s): **[Single] [Three].**
 - c. Hertz: **[60] <Insert value>.**
 - d. Full-Load Amperes: **<Insert value>.**
 - e. Minimum Circuit Ampacity: **<Insert value>.**

- f. Maximum Overcurrent Protection: **<Insert amperage>**.
10. Receiver: ASME construction steel tank.
- a. Arrangement: **[Horizontal] [Vertical]**.
 - b. Capacity: **<Insert gal. (L)>**.
 - c. Interior Finish: **[Epoxy] [Epoxy or galvanized] [Galvanized] <Insert coating>** coating.
 - d. Pressure Rating: **[100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] [200 psig (1380 kPa)] [250 psig (1725 kPa)] <Insert value>** minimum.
 - e. Pressure Regulator Setting: **<Insert psig (kPa)>**.
 - f. Pressure Relief Valve Setting: **<Insert psig (kPa)>**.
 - g. Drain: **[Automatic] [Manual]** valve.

2.7 OIL-FREE, ROTARY-SCREW AIR COMPRESSORS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Atlas Copco](#).
2. [CompAir, Ltd.](#)
3. [Gardner Denver, Inc.](#)
4. [Ingersoll-Rand; Air Solutions Group](#).
5. **<Insert manufacturer's name>**.
6. or approved equal.

B. Compressor(s): Oil-free, rotary-screw type with nonlubricated helical screws and lubricated gear box, and of construction that prohibits oil from entering compression chamber.

1. Coupling: Nonlubricated, flexible type.
2. Cooling/Lubrication System: Unit-mounted, air-cooled exchanger package prepiped to unit; with air pressure circulation system with coolant stop valve, full-flow coolant filter, and thermal bypass valve.
3. Air Filter: Dry type, with maintenance indicator and cleanable, replaceable filter element.
4. Air/Coolant Receiver and Separation System: **150-psig- (1035-kPa-)** rated steel tank with ASME safety valve, coolant-level gage, multistage air-coolant separator element, minimum pressure valve, blowdown valve, discharge check valve, coolant stop valve, full-flow coolant filter, and thermal bypass valve.
5. Capacity Control: Capacity modulation between zero and 100 percent air delivery, with operating pressures between **50 and 100 psig (345 and 690 kPa)**. Include necessary control to hold constant pressure. When air demand is zero, unload compressor by using pressure switch and blowdown valve.

C. Capacities and Characteristics:

1. Air Compressor(s): **[One] [Two] <Insert number>**; single stage.

2. Standard-Air Capacity of Each Air Compressor: <Insert scfm (standard L/s)> free air.
3. Actual-Air Capacity of Each Air Compressor: <Insert acfm (actual L/s)> delivered.
4. Discharge-Air Pressure: [100 psig (690 kPa)] [125 psig (860 kPa)] [175 psig (1200 kPa)] <Insert value>.
5. Intake-Air Temperature: <Insert deg F (deg C)>.
6. Discharge-Air Temperature: <Insert deg F (deg C)>.
7. Motor (Each Air Compressor):
 - a. Horsepower: <Insert value>.
 - b. Speed: [1750] [3400] <Insert value> rpm.
8. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase(s): [Single] [Three].
 - c. Hertz: [60] <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
9. Receiver: ASME construction steel tank.
 - a. Arrangement: [Horizontal] [Vertical].
 - b. Capacity: <Insert gal. (L)>.
 - c. Interior Finish: [Epoxy] [Epoxy or galvanized] [Galvanized] <Insert coating> coating.
 - d. Pressure Rating: [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] [200 psig (1380 kPa)] <Insert value> minimum.
 - e. Pressure Regulator Setting: <Insert psig (kPa)>.
 - f. Pressure Relief Valve Setting: <Insert psig (kPa)>.
 - g. Drain: [Automatic] [Manual] valve.
10. Enclosure: Steel with sound-attenuating material lining.

2.8 OIL-FLOODED, ROTARY-SCREW AIR COMPRESSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Atlas Copco.](#)
2. [CompAir, Ltd.](#)
3. [Gardner Denver, Inc.](#)
4. [Ingersoll-Rand; Air Solutions Group.](#)
5. [Kaeser Compressors, Inc.](#)
6. [Quincy Compressor; an EnPro Industries company.](#)
7. [Sullair Corporation.](#)
8. <Insert manufacturer's name>.
9. or approved equal.

- B. Compressor(s): Oil-flooded, rotary-screw type with lubricated helical screws and lubricated gear box.
1. Coupling: Nonlubricated, flexible type.
 2. Cooling/Lubrication System: Unit-mounted, air-cooled exchanger package prepiped to unit; with air pressure circulation system with coolant stop valve, full-flow coolant filter, and thermal bypass valve.
 3. Air Filter: Dry type, with maintenance indicator and cleanable, replaceable filter element.
 4. Air/Coolant Receiver and Separation System: **150-psig- (1035-kPa-)** rated steel tank with ASME safety valve, coolant-level gage, multistage air-coolant separator element, minimum pressure valve, blowdown valve, discharge check valve, coolant stop valve, full-flow coolant filter, and thermal bypass valve.
 5. Capacity Control: Capacity modulation between zero and 100 percent air delivery, with operating pressures between **50 and 100 psig (345 and 690 kPa)**. Include necessary control to hold constant pressure. When air demand is zero, unload compressor by using pressure switch and blowdown valve.
- C. Capacities and Characteristics:
1. Air Compressor(s): **[One] [Two] <Insert number>; [single] [single or two] [two]** stage.
 2. Standard-Air Capacity of Each Air Compressor: **<Insert scfm (standard L/s)>** free air.
 3. Actual-Air Capacity of Each Air Compressor: **<Insert acfm (actual L/s)>** delivered.
 4. Discharge-Air Pressure: **[100 psig (690 kPa)] [125 psig (860 kPa)] [175 psig (1200 kPa)] [200 psig (1380 kPa)] <Insert value>**.
 5. Intake-Air Temperature: **<Insert deg F (deg C)>**.
 6. Discharge-Air Temperature: **<Insert deg F (deg C)>**.
 7. Motor (Each Air Compressor):
 - a. Horsepower: **<Insert value>**.
 - b. Speed: **[1750] [3400] <Insert value>** rpm.
 8. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase(s): **[Single] [Three]**.
 - c. Hertz: **[60] <Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
 9. Receiver: ASME construction steel tank.
 - a. Arrangement: **[Horizontal] [Vertical]**.
 - b. Capacity: **<Insert gal. (L)>**.
 - c. Interior Finish: **[Epoxy] [Epoxy or galvanized] [Galvanized] <Insert coating>** coating.

- d. Pressure Rating: [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] [200 psig (1380 kPa)] [250 psig (1725 kPa)] <Insert value> minimum.
 - e. Pressure Regulator Setting: <Insert psig (kPa)>.
 - f. Pressure Relief Valve Setting: <Insert psig (kPa)>.
 - g. Drain: [Automatic] [Manual] valve.
10. Enclosure: Steel with sound-attenuating material lining.

2.9 OIL-FREE, ROTARY, SLIDING-VANE AIR COMPRESSORS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Becker Pumps Corp.](#)
2. [Gast Manufacturing Inc.](#)
3. <Insert manufacturer's name>.
4. or approved equal.

B. Compressor(s): Oil-free, nonpulsating, rotary, sliding-vane type with nonlubricated sliding vanes.

1. Cleanable inlet screens.
2. Outlet silencers on discharge connections.

C. Capacities and Characteristics:

1. Air Compressor(s): [One] [Two] <Insert number>; single stage.
2. Standard-Air Capacity of Each Air Compressor: <Insert scfm (standard L/s)> free air.
3. Actual-Air Capacity of Each Air Compressor: <Insert acfm (actual L/s)> delivered.
4. Discharge-Air Pressure: [15 psig (103 kPa)] [20 psig (138 kPa)] [25 psig (173 kPa)] <Insert value>.
5. Intake-Air Temperature: <Insert deg F (deg C)>.
6. Discharge-Air Temperature: <Insert deg F (deg C)>.
7. Mounting: [Freestanding] [Tank mounted].
8. Motor (Each Air Compressor):
 - a. Horsepower: <Insert value>.
 - b. Speed: [1750] [3400] <Insert value> rpm.

9. Electrical Characteristics:

- a. Volts: <Insert value>.
- b. Phase(s): [Single] [Three].
- c. Hertz: [60] <Insert value>.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

10. Receiver: ASME construction steel tank.
 - a. Arrangement: **[Horizontal]** **[Vertical]**.
 - b. Capacity: **<Insert gal. (L)>**.
 - c. Interior Finish: **[Epoxy]** **[Epoxy or galvanized]** **[Galvanized]** **<Insert coating>** coating.
 - d. Pressure Rating: **[100 psig (690 kPa)]** **<Insert value>** minimum.
 - e. Pressure Regulator Setting: **<Insert psig (kPa)>**.
 - f. Pressure Relief Valve Setting: **<Insert psig (kPa)>**.
 - g. Drain: **[Automatic]** **[Manual]** valve.

2.10 OIL-SEALED, ROTARY, SLIDING-VANE AIR COMPRESSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Becker Pumps Corp.](#)
2. [Davey Compressor Company.](#)
3. [Gast Manufacturing Inc.](#)
4. [CompAir.](#)
5. **<Insert manufacturer's name>**.
6. or approved equal.

B. Compressor(s): Nonpulsating, rotary, sliding-vane type with oil-sealed sliding vanes.

1. Cleanable inlet screens.
2. Outlet silencers and oil-mist separators on discharge connections.

C. Capacities and Characteristics:

1. Air Compressor(s): **[One]** **[Two]** **<Insert number>**; single stage.
2. Standard-Air Capacity of Each Air Compressor: **<Insert scfm (standard L/s)>** free air.
3. Actual-Air Capacity of Each Air Compressor: **<Insert acfm (actual L/s)>** delivered.
4. Discharge-Air Pressure: **[20 psig (138 kPa)]** **[25 psig (173 kPa)]** **[30 psig (207 kPa)]** **[100 psig (690 kPa)]** **[125 psig (860 kPa)]** **<Insert value>**.
5. Intake-Air Temperature: **<Insert deg F (deg C)>**.
6. Discharge-Air Temperature: **<Insert deg F (deg C)>**.
7. Mounting: **[Freestanding]** **[Tank mounted]**.
8. Motor (Each Air Compressor):
 - a. Horsepower: **<Insert value>**.
 - b. Speed: **[1750]** **[3400]** **<Insert value>** rpm.
9. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase(s): **[Single]** **[Three]**.
 - c. Hertz: **[60]** **<Insert value>**.

- d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
10. Receiver: ASME construction steel tank.
- a. Arrangement: [Horizontal] [Vertical].
 - b. Capacity: <Insert gal. (L)>.
 - c. Interior Finish: [Epoxy] [Epoxy or galvanized] [Galvanized] <Insert coating> coating.
 - d. Pressure Rating: [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] <Insert value> minimum.
 - e. Pressure Regulator Setting: <Insert psig (kPa)>.
 - f. Pressure Relief Valve Setting: <Insert psig (kPa)>.
 - g. Drain: [Automatic] [Manual] valve.

2.11 INLET-AIR FILTERS

- A. Description: Combination inlet-air filter-silencer, suitable for remote installation, for each air compressor.
1. Construction: Weatherproof housing for replaceable, dry-type filter element, with silencer tubes or other method of sound reduction.
 2. Capacity: Match capacity of air compressor, with filter having collection efficiency of 99 percent retention of particles larger than 10 micrometers.
- B. Description: Combination inlet-air filter-silencer, suitable for remote installation, for multiple air compressors.
1. Construction: Weatherproof housing for replaceable, dry-type filter element, with silencer tubes or other method of sound reduction.
 2. Capacity: Match total capacity of connected air compressors, with filter having collection efficiency of 99 percent retention of particles larger than 10 micrometers.

2.12 AIR-COOLED, COMPRESSED-AIR AFTERCOOLERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. [Air/Tak, Inc.](#)
 2. [FS-Curtis Air Compressors.](#)
 3. [Gardner Denver, Inc.](#)
 4. [Ingersoll-Rand Company](#); Compressed Air Solutions.
 5. [McIntire Company](#); Arrow Dryers.
 6. [Pneumatech.](#)
 7. [Saylor-Beall Manufacturing Company.](#)
 8. [SPX Hankison.](#)

9. [Van Air Systems.](#)
10. [ZEKS Compressed Air Solutions.](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

B. Description: Electric-motor-driven, fan-operation, finned-tube unit; rated at [250 psig (1725 kPa)] **<Insert value>** and leak tested at 350-psig (2415-kPa) minimum air pressure; in capacities indicated. Size units to cool compressed air in compressor-rated capacities to [10 deg F (6 deg C)] **<Insert temperature>** above summertime maximum ambient temperature. Include moisture separator and automatic drain.

C. Capacities and Characteristics:

1. Standard-Air Capacity of Each Aftercooler: **<Insert scfm (standard L/s)>** free air.
2. Pressure: **<Insert psig (kPa)>**.
3. Entering, Compressed-Air Temperature: **<Insert deg F (deg C)>**.
4. Leaving, Compressed-Air Temperature: **<Insert deg F (deg C)>**.
5. Ambient-Air Temperature: **<Insert deg F (deg C)>**.
6. Maximum Compressed-Air-Pressure Drop: **<Insert psig (kPa)>**.
7. Motor Horsepower: **<Insert value>**.
8. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase(s): **[Single] [Three]**.
 - c. Hertz: **[60] <Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.13 Water-Cooled, Compressed-Air Aftercoolers

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Air/Tak, Inc.](#)
2. [FS-Curtis Air Compressors.](#)
3. [Gardner Denver, Inc.](#)
4. [Ingersoll-Rand Company; Compressed Air Solutions.](#)
5. [McIntire Company](#); Arrow Dryers.
6. [Pneumatech.](#)
7. [Saylor-Beall Manufacturing Company.](#)
8. [SPX Hankison.](#)
9. [Van Air Systems.](#)
10. [ZEKS Compressed Air Solutions.](#)
11. **<Insert manufacturer's name>**.
12. or approved equal.

- B. Description: Shell-and-tube unit, rated at [250 psig (1725 kPa)] <Insert value> and leak tested at 350-psig (2415-kPa) minimum air pressure, in capacities indicated. Include moisture separator and automatic drain.
- C. Capacities and Characteristics:
1. Standard-Air Capacity of Each Aftercooler: <Insert scfm (standard L/s)> free air.
 2. Pressure: <Insert psig (kPa)>.
 3. Entering-Water Temperature: <Insert deg F (deg C)>.
 4. Water Flow: <Insert gpm (L/s)>.
 5. Entering, Compressed-Air Temperature: <Insert deg F (deg C)>.
 6. Leaving, Compressed-Air Temperature: <Insert deg F (deg C)>.

2.14 REFRIGERANT COMPRESSED-AIR DRYERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Air/Tak, Inc.](#)
2. [Atlas Copco Compressors LLC.](#)
3. [Donaldson Company, Inc.](#); Compressed Air & Gas.
4. [FS-Curtis Air Compressors.](#)
5. [Ingersoll-Rand Company](#); Compressed Air Solutions.
6. [Kaeser Compressors, Inc.](#)
7. [McIntire Company](#); Arrow Dryers.
8. [Numatics, Incorporated.](#)
9. [Pioneer Air Systems, Inc.](#)
10. [Pneumatech Inc.](#)
11. [SPX Air Treatment.](#)
12. [Van Air Systems, Inc.](#)
13. [Wilkerson Operations; Pneumatic Division.](#)
14. [Zeks Compressed Air Solutions.](#)
15. <Insert manufacturer's name>.
16. or approved equal.

- B. Description: Noncycling, air-cooled, electric-motor-driven unit with steel enclosure and capability to deliver 35 deg F (2 deg C), 100-psig (690-kPa) air at dew point. Include automatic ejection of condensate from airstream, step-down transformers, disconnect switches, inlet and outlet pressure gages, thermometers, automatic controls, and filters.

- C. Capacities and Characteristics:

1. Standard-Air Capacity of Each Compressed-Air Dryer: <Insert scfm (standard L/s)> free air.
2. Pressure: <Insert psig (kPa)>.
3. Entering-Air Temperature: <Insert deg F (deg C)>.
4. Leaving-Air Temperature: <Insert deg F (deg C)>.
5. Leaving-Air Dew Point Temperature: <Insert deg F (deg C)>.

6. Ambient-Air Temperature: <Insert deg F (deg C)>.
7. Maximum Air-Pressure Drop: <Insert psig (kPa)>.
8. Inlet Filter: [5] <Insert number> micrometers.
9. Outlet Filter: [1] <Insert number> micrometer(s).
10. Motor Horsepower: <Insert value>.
11. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase(s): [Single] [Three].
 - c. Hertz: [60] <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.15 DESICCANT COMPRESSED-AIR DRYERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Air/Tak, Inc.](#)
2. [Donaldson Company, Inc.; Compressed Air & Gas.](#)
3. [Ingersoll-Rand Company; Compressed Air Solutions.](#)
4. [Kaeser Compressors, Inc.](#)
5. [Numatics, Incorporated.](#)
6. [Pioneer Air Systems, Inc.](#)
7. [Pneumatech.](#)
8. [SPX Deltech.](#)
9. [SPX Hankison.](#)
10. [Van Air Systems.](#)
11. [Wilkerson Corp.](#)
12. [ZEKS Compressed Air Solutions.](#)
13. <Insert manufacturer's name>.
14. or approved equal.

B. **General:** Factory assembled dual chamber designs with each chamber filled with equal quantities of adsorbing desiccant. Regeneration flow shall be counter current to the direction of the inlet gas flow. Desiccant vessels shall be designed in accordance with the ASME pressure vessel code and shall be stamped as such. Provide package with blower purge heater.

C. **Assembly:** Each desiccant chamber shall be fitted with fill and drain ports equal to, or greater in diameter than the main flow pipe size, to facilitate filling and drawing of desiccant without the need to disassemble manifold piping. Each chamber shall be provided with a removable stainless steel perforated sheet inlet diffuser screen and desiccant bed support screen, and fitted with a relief valve. Chambers are not to be supported by interconnecting piping in any way. Install heater and blower in accordance with ASME, ASTM, and NEC Specifications.

D. **Controls:** Dryer shall be furnished with a repressurization circuit to allow the

regeneration chamber to reach line pressure prior to switch over. The controller shall be responsible for initiation and monitoring of the dryer operation. Standard instrumentation shall include a locally mounted purge flow indicator, chamber pressure gauges, visual type color change outlet moisture indicator, inlet and outlet pressure gauges, and discharge dewpoint indicating transmitter. Provide dryer with a NEMA 1 panel with motor starters, fusible disconnects, alternator, and transformer for a single point electrical connection.

- E. Description: Twin-tower unit with purge system, mufflers, and capability to deliver [plus 10 deg F (minus 12 deg C), 100-psig (690-kPa)] <Insert values> air at dew point. Include dew point controlled purge, step-down transformers, disconnect switches, inlet and outlet pressure gages, thermometers, automatic controls, and filters.

F. Capacities and Characteristics:

1. Standard-Air Capacity of Each Compressed-Air Dryer: <Insert scfm (standard L/s)> free air.
2. Pressure: <Insert psig (kPa)>.
3. Entering-Air Temperature: <Insert deg F (deg C)>.
4. Leaving-Air Temperature: <Insert deg F (deg C)>.
5. Leaving-Air Dew Point Temperature: <Insert deg F (deg C)>.
6. Ambient-Air Temperature: <Insert deg F (deg C)>.
7. Maximum Air-Pressure Drop: <Insert psig (kPa)>.
8. Inlet Filter: [5] <Insert number> micrometers.
9. Outlet Filter: [1] <Insert number> micrometer(s).
10. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase(s): [Single] [Three].
 - c. Hertz: [60] <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.16 COMPUTER INTERFACE CABINET

A. Description:

1. Wall mounting.
2. Welded steel with white enamel finish.
3. Gasketed door.
4. Grounding device.
5. Factory-installed, signal circuit boards.
6. Power transformer.
7. Circuit breaker.
8. Wiring terminal board.
9. Internal wiring capable of interfacing [20] <Insert number> alarm signals.

2.17 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 220513 "Common Motor Requirements for Plumbing Equipment."
1. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load does not require motor to operate in service factor range above 1.0.
- B. <Insert unique motor characteristics>.

PART 3 - EXECUTION

3.1 EQUIPMENT INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Equipment Mounting:
1. Install air compressors[**and aftercoolers**] [**and air dryers**] [, **aftercoolers, and air dryers**] on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Install [**water-cooled, compressed-air aftercoolers**] [**and**] [**desiccant compressed-air dryers**] on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 3. Install compressor unit on vibration isolators. Level and bolt in place.
 4. Comply with requirements for vibration isolation and seismic control devices specified in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment"
 5. Comply with requirements for vibration isolation devices specified in Section 220548.13 "Vibration Controls for Plumbing Piping and Equipment."
- C. Install compressed-air equipment anchored to substrate.
- D. Arrange equipment so controls and devices are accessible for servicing.
- E. Maintain manufacturer's recommended clearances for service and maintenance.
- F. Install the following devices on compressed-air equipment:

1. Thermometer, Pressure Gage, and Safety Valve: Install on each compressed-air receiver.
 2. Pressure Regulators: Install downstream from air compressors[**and dryers**].
 3. Automatic Drain Valves: Install on aftercoolers, receivers, and dryers. Discharge condensate over nearest floor drain.
- G. Make air cock and drain connection on horizontal casing.
- H. Install line size gate valve and check valve on compressor discharge.
- I. Install replaceable cartridge type filter silencer of adequate capacity for each compressor.
- J. Place shut off valve on water inlet to aftercooler. Pipe drain to floor drain.
- K. Connect condensate drains to nearest floor drain.
- L. Piping: See Section 221513 "General-Service Compressed-Air Piping" for piping requirements.
1. Install valved bypass around air dryer. Factory insulate inlet and outlet connections.
 2. Install valved drip connections at low points of piping system.
 3. Install take offs to outlets from top of main, with shut off valve after take off. Slope take off piping to outlets.
 4. Install tees instead of elbows at changes in direction of piping. Fit open end of each tee with plug.
- M. Install compressed air couplings, female quick connectors, and pressure gages where outlets are indicated.
- N. Identify piping system and components. Refer to Section 220553 "Identification for Plumbing Piping and Equipment".

3.2 CONNECTIONS

- A. Comply with requirements for piping specified in Section 221513 "General-Service Compressed-Air Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to machine, allow space for service and maintenance.

3.3 IDENTIFICATION

- A. Identify general-service air compressors and components. Comply with requirements for identification specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.4 STARTUP SERVICE

- A. Field inspection and testing shall be performed under provisions of Division 01.
- B. Compressed Air Piping Leak Test: Prior to initial operation, clean and test compressed air piping in accordance with ANSI B31.1.
- C. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Check for lubricating oil in lubricated-type equipment.
 - 3. Check belt drives for proper tension.
 - 4. Verify that air-compressor inlet filters and piping are clear.
 - 5. Check for equipment vibration-control supports and flexible pipe connectors, and verify that equipment is properly attached to substrate.
 - 6. Check safety valves for correct settings. Ensure that settings are higher than air-compressor discharge pressure, but not higher than rating of system components.
 - 7. Check for proper seismic restraints.
 - 8. Drain receiver tanks.
 - 9. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 10. Test and adjust controls and safeties.
- D. Repair or replace compressed air piping as required to eliminate leaks, and retest to demonstrate compliance.
- E. Cap (seal) ends of piping when not connected to mechanical equipment.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air compressors[**and aftercoolers**][**and air dryers**] [, **aftercoolers, and air dryers**].
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 221519

SECTION 223100 - DOMESTIC WATER SOFTENERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Commercial water softeners.
 - 2. Chemicals.
 - 3. Water-testing sets.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Water softeners shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for water softeners.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Wiring Diagrams: For power, signal, and control wiring.
 - 4. Include data substantiating that materials comply with requirements.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For water softeners, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control reports.
- C. Field quality-control reports.
- D. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For water softeners to include in emergency, operation, and maintenance manuals.
 - 1. Include operation, maintenance, and inspection data, replacement part numbers and availability, and service depot location and telephone number.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Salt for Brine Tanks: Furnish in same form as and at least **[four]** **<Insert number>** times original load, but not less than **[200 lb (90.7 kg)] [1000 lb (453.6 kg)] <Insert weight>**. Deliver on pallets according to the following:
 - a. Food-Grade Pellet Salt: In **[40- or 50-lb (18.1- or 22.7-kg)] [80-lb (36.3-kg)] <Insert weight>** packages.
 - b. Plain Pellet Salt: In **[40- or 50-lb (18.1- or 22.7-kg)] [80-lb (36.3-kg)] <Insert weight>** packages.
 - c. Crystallized Solar Salt: In **[40- or 50-lb (18.1- or 22.7-kg)] [80-lb (36.3-kg)] <Insert weight>** packages.
 - d. Plain, Brine Block Salt: In **[50-lb (22.7-kg)] <Insert weight>** blocks.
 - 2. Store salt on raised platform where directed by Owner. Do not store in contact with concrete floor.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended application.
- B. ASME Compliance for Steel Tanks: Fabricate and label mineral tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, where indicated.
- C. ASME Compliance for FRP Tanks: Fabricate and label mineral tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, where indicated.
- D. UL Compliance: Fabricate and label water softeners to comply with UL 979, "Water Treatment Appliances."

1.9 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products under provisions of Section 22400 "Basic Plumbing Requirements" and Division 01
- B. Provide temporary inlet and outlet caps. Maintain caps in place until installation.

1.11 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water softeners that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures of mineral and brine tanks.
 - b. Faulty operation of controls.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal use.
 - d. Attrition loss of resin exceeding 3 percent per year.
 - e. Mineral washed out of system during service run or backwashing period.
 - f. Effluent turbidity greater and color darker than incoming water.
 - g. Fouling of underdrain system, gravel, and resin with turbidity or by dirt, rust, or scale from water softener or soft water, while operating according to manufacturer's written operating instructions.
 - 2. Residential Water Softeners, Warranty Period: From date of Substantial Completion.
 - a. Tanks: Minimum [**five (5)**] <Insert number> years.

- b. Control Valve: Minimum **[one (1)] <Insert number>** year(s).
- 3. Commercial Water Softeners, Warranty Period: From date of Substantial Completion.
 - a. Mineral Tanks: Minimum **[five (5)] [ten (10)] <Insert number>** years.
 - b. Brine Tanks: Minimum **[ten (10)] <Insert number>** years.
 - c. Control Valve: Minimum **[One (1)] <Insert number>** year(s).

1.12 MAINTENANCE SERVICE

- A. Initial Maintenance Service: Beginning at Substantial Completion, provide **[three] [six] [nine] [12]** months' full maintenance by skilled employees of water softener Installer. Include **[monthly] [quarterly]** preventive maintenance, repair, or replacement of worn or defective components, cleaning, and adjusting as required for proper water softener operation at rated capacity. Provide parts and supplies the same as those used in the manufacture and installation of original equipment.
- B. Continuing Maintenance Proposal: From Installer to Owner, in the form of a standard yearly (or other period) maintenance agreement, starting on date initial maintenance service is concluded. State services, obligations, conditions, and terms for agreement period and for future renewal options.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 COMMERCIAL WATER SOFTENERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. [Aquion Water Treatment Products.](#)
 - 2. [Culligan International Company.](#)
 - 3. [CUNO Incorporated.](#)
 - 4. [Diamond Water Conditioning; a Griesbach company.](#)
 - 5. [Diamond Water Systems, Inc.](#)
 - 6. [Ecodyne Water Treatment, Inc.](#)
 - 7. [Hungerford & Terry, Inc.](#)
 - 8. [Integration Separation Solutions, LLC.](#)
 - 9. [Kinetico Incorporated.](#)
 - 10. [Marlo Incorporated.](#)
 - 11. [Parker Boiler.](#)

12. [Springsoft International, Inc.](#)
13. [Water King.](#)
14. [WaterSoft; a division of Amtrol, Inc.](#)
15. **<Insert manufacturer's name>.**
16. or approved equal.

B. Description: Factory-assembled, pressure-type water softener.

1. Standard: Comply with NSF 61, "Drinking Water System Components - Health Effects."
2. Configuration: **[Single unit with one mineral tank] [Twin unit with two mineral tanks] [Triple unit with three mineral tanks] <Insert configuration>** and one brine tank.
3. Mounting: On skids.
4. Wetted Components: Suitable for water temperatures from **[40 to at least 100 deg F (5 to at least 38 deg C)] [40 to at least 120 deg F (5 to at least 49 deg C)] [40 to at least 150 deg F (5 to at least 66 deg C)] <Insert temperature>.**
5. Mineral Tanks: FRP, pressure-vessel quality.
 - a. Construction: **[Non-ASME code.] [Fabricated and stamped to comply with ASME Boiler and Pressure Vessel Code: Section X, "Fiber-Reinforced Plastic Pressure Vessels."]**
 - b. Pressure Rating: **[100 psig (690 kPa)] [125 psig (860 kPa)] <Insert pressure>** minimum.
 - c. Freeboard: 50 percent minimum for backwash expansion above normal resin bed level.
 - d. Support Legs or Skirt: Constructed of structural steel, welded to tank **before testing and labeling**.
 - e. Upper Distribution System: Single, point type, fabricated from galvanized-steel pipe and fittings.
 - f. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from nonmetallic pipe and fittings with individual, fine-slotted, nonclogging plastic strainers, and arranged for even flow distribution through resin bed.
 - g. Liner: PE, ABS, or other material suitable for potable water.
6. Mineral Tanks: **[Steel] [Stainless steel]**, electric welded; pressure-vessel quality.
 - a. Seismic Requirements: Fabricate supports and attachments to tank with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure.
 - b. Construction: **[Non-ASME code.] [Fabricated and stamped to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.]**
 - c. Pressure Rating: **[100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] <Insert pressure>** minimum.
 - d. Freeboard: 50 percent minimum for backwash expansion above normal resin bed level.

- e. Handholes: 4 inches (102 mm) round or 4 by 6 inches (102 by 152 mm) elliptical, in top head and lower sidewall of tanks [30 inches (762 mm)] <Insert tank size> and smaller in diameter.
 - f. Manhole: 11 by 15 inches (280 by 380 mm) in top head of tanks larger than [30 inches (762 mm)] <Insert tank size> in diameter.
 - g. Support Legs or Skirt: Constructed of structural steel, welded to tank[**before testing and labeling**].
 - h. Finish: Hot-dip galvanized on exterior and interior of tank after fabrication unless tank is stainless steel.
 - i. Finish: Exterior of tank spray-painted with rust-resistant prime coat, 2- to 3-mil (0.051- to 0.076-mm) dry film thickness. Interior sandblasted and lined with epoxy-polyamide coating, 8- to 10-mil (0.203- to 0.254-mm) dry film thickness.
 - j. Upper Distribution System: Single, point type, fabricated from galvanized-steel pipe and fittings.
 - k. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from PVC pipe and fittings with individual, fine-slotted, nonclogging PE strainers, and arranged for even flow distribution through resin bed.
 - l. Liner: PE, ABS, or other material suitable for potable water.
7. Controls: Automatic; factory wired and factory mounted on unit.
- a. Adjustable duration of various regeneration steps.
 - b. Push-button start and complete manual operation.
 - c. Electric time clock and switch for automatic operation except for manual return to service.
 - d. Sequence of Operation: Multiport pilot-control valve automatically pressure-actuates main operating valve through steps of regeneration.
 - e. Pointer on pilot-control valve shall indicate cycle of operation.
 - f. Includes means of manual operation of pilot-control valve if power fails.
8. Controls: Fully automatic; factory wired and factory mounted on unit.
- a. Adjustable duration of various regeneration steps.
 - b. Push-button start and complete manual operation.
 - c. Electric time clock and switch for fully automatic operation, adjustable to initiate regeneration at any hour of day and any day of week or at fixed intervals.
 - d. Sequence of Operation: Multiport pilot-control valve automatically pressure-actuates main operating valve through steps of regeneration and return to service.
 - e. Pointer on pilot-control valve shall indicate cycle of operation.
 - f. Includes means of manual operation of pilot-control valve if power fails.
9. Main Operating Valves: Industrial, automatic, multiport, diaphragm type with the following features:
- a. Slow opening and closing, nonslam operation.
 - b. Diaphragm guiding on full perimeter from fully open to fully closed.

- c. Isolated, dissimilar metals within valve.
 - d. Self-adjusting, internal, automatic brine injector that draws brine and rinses at constant rate independent of pressure.
 - e. Valve for single mineral-tank unit with internal automatic bypass of raw water during regeneration.
 - f. Sampling cocks for soft water.
 - g. Special tools are not required for service.
10. Flow Control: Automatic, to control backwash and flush rates over wide variations in operating pressure; does not require field adjustments.
 - a. Meter Control: Each mineral tank is equipped with signal-register-head water meter that produces electrical signal indicating need for regeneration on reaching hand-set total in **gallons (liters)**. Signal will continue until reset.
 - b. Demand-Initiated Control: Single mineral tank is equipped with automatic-reset-head water meter that electrically activates cycle controller to initiate regeneration at preset total in **gallons (liters)**. Head automatically resets to preset total in **gallons (liters)** for next service run.
 - c. Demand-Initiated Control: Each mineral tank of twin mineral-tank unit is equipped with automatic-reset-head water meter that electrically activates cycle controllers to initiate regeneration at preset total in **gallons (liters)**. Head automatically resets to preset total in **gallons (liters)** for next service run. Electrical lockout prevents simultaneous regeneration of both tanks.
 - d. Demand-Initiated Control: Each twin mineral-tank unit is equipped with automatic-reset-head water meter, in common outlet header, that electrically activates cycle controller to automatically regenerate one mineral tank at preset total in **gallons (liters)** and divert flow to other tank. Automatically repeats with other tank. Electrical lockout prevents simultaneous regeneration of both tanks.
 - e. Demand-Initiated Control: Each mineral tank of multiple mineral-tank unit is equipped with automatic-reset-head water meter that electrically activates cycle controllers to automatically regenerate at preset total in **gallons (liters)**. Head automatically resets to preset total in **gallons (liters)** for next service run. Electrical lockout prevents simultaneous regeneration of more than one tank.
 - f. Demand-Initiated Control: Each multiple mineral-tank unit is equipped with automatic-reset-head water meter, in common outlet header, that electrically activates cycle controller to automatically regenerate one mineral tank at preset total in **gallons (liters)** and divert flow to other tanks. Automatically repeats with other tanks. Electrical lockout prevents simultaneous regeneration of more than one tank.
11. Brine Tank: Combination measuring and wet-salt storing system.
 - a. Tank and Cover Material: Fiberglass, **3/16 inch (4.8 mm)** thick; or molded PE, **3/8 inch (9.5 mm)** thick.
 - b. Brine Valve: Float operated and plastic fitted for automatic control of brine withdrawal and freshwater refill.
 - c. Size: Large enough for at least four regenerations at full salting.

12. Factory-Installed Accessories:

- a. Piping, valves, tubing, and drains.
- b. Sampling cocks.
- c. Main-operating-valve position indicators.
- d. Water meters.

C. Capacities and Characteristics:

1. Water Analysis:

- a. Hardness: <Insert grains/gal. or ppm (mg/L)>.
- b. Iron: <Insert ppm (mg/L)>.
- c. Dissolved Solids: <Insert ppm (mg/L)>.
- d. Concentration: <Insert pH>.
- e. Inlet Water Pressure: <Insert psig (kPa)>.
- f. Water Temperature: <Insert deg F (deg C)>.

2. Continuous Service Flow Rate: <Insert number> gpm at 15-psig (<Insert number> L/s at 104-kPa) pressure drop.
3. Peak Service Flow Rate: <Insert number> gpm at 25-psig (<Insert number> L/s at 173-kPa) pressure drop.
4. Water Meter Size: <Insert NPS (DN)>.
5. Manifold Pipe Size: <Insert NPS (DN)>.
6. Backwash-to-Drain Pipe Size: <Insert NPS (DN)>.
7. Water Consumption: <Insert gal./day (cu. m/day)>.
8. Water Demand: <Insert hours/day>.
9. Number of Mineral Tanks: [One] [Two] [Three] <Insert number>.
10. Mineral Quantity, Each Tank: <Insert cu. ft. (cu. m)>.
11. Mineral Exchange Capacity: <Insert grains/cu. ft. per lb (kg/cu. m per kg) of salt>.
12. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phases: <Insert value>.
 - c. Hertz: <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
13. Salt Capacity: <Insert lb (kg)>.
14. Minimum Number of Regenerations per Refill: <Insert number>.
15. Floor Area Required: <Insert sq. ft. (sq. m)>.
16. Height Required: <Insert inches (mm)>.

2.2 CHEMICALS

- A. Mineral: High-capacity, sulfonated-polystyrene, ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock.

1. Exchange Capacity: [30,000 grains/cu. ft. (69 kg/cu. m)] <Insert capacity> of calcium carbonate of resin when regenerated with 15 lb (6.8 kg) of salt.
- B. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are unacceptable.
 1. Form: Processed, [food-grade salt pellets] [plain salt pellets] [crystallized solar salt collected from shallow ponds and milled into irregular particles] [plain, brine block salt].

2.3 WATER-TESTING SETS

- A. Description: Manufacturer's standard water-hardness testing apparatus and chemicals with testing procedure instructions. Include metal container suitable for wall mounting.

2.4 SOURCE QUALITY CONTROL

- A. Hydrostatically test mineral tanks before shipment to a minimum of one and one-half times the pressure rating.
- B. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 WATER SOFTENER INSTALLATION

- A. Equipment Mounting:
 1. Install **commercial** water softeners on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment"
 3. Comply with requirements for vibration isolation devices specified in Section 220548.13 "Vibration Controls for Plumbing Piping and Equipment."
- B. Install seismic restraints for tanks and floor-mounting accessories and anchor to building structure.
- C. Install brine lines and fittings furnished by equipment manufacturer but not specified to be factory installed.
- D. Prepare mineral-tank distribution system and underbed for minerals and place specified mineral into mineral tanks.

- E. Install water-testing sets mounted on wall, unless otherwise indicated, and near water softeners.

3.2 CONNECTIONS

- A. Comply with requirements for piping specified in Section 221116 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where piping is installed adjacent to equipment, allow space for service and maintenance of equipment.
- C. Install shutoff valves on raw-water inlet and soft-water outlet piping of each mineral tank[, **and on inlet and outlet headers**].
 - 1. Metal general-duty valves are specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 - 2. Plastic valves are specified in Section 221116 "Domestic Water Piping."
 - 3. Exception: Water softeners with factory-installed shutoff valves at locations indicated.
- D. Install pressure gages on raw-water inlet and soft-water outlet piping of each mineral tank. Pressure gages are specified in Section 220519 "Meters and Gages for Plumbing Piping."
 - 1. Exception: Water softeners with factory-installed pressure gages at locations indicated.
 - 2. Exception: Household water softeners.
 - 3. Exception: Water softeners in hot-water service.
- E. Install valved bypass in water piping around water softeners.
 - 1. Metal general-duty valves are specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 - 2. Plastic valves are specified in Section 221116 "Domestic Water Piping."
 - 3. Water piping is specified in Section 221116 "Domestic Water Piping."
 - 4. Exception: Household water softeners.
 - 5. Exception: Water softeners in hot-water service.
- F. Install drains as indirect wastes to spill into open drains or over floor drains.

3.3 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.4 FIELD QUALITY CONTROL

- A. Tests and Inspections:

1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 2. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation.
 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Water softeners will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
- B. Add water to brine tanks and fill with the following form of salt:
1. Commercial Water Softeners: Processed, **[plain salt pellets] [crystallized solar salt collected from shallow ponds and milled into irregular particles] [plain, brine block salt] <Insert salt form>**.
- C. Sample water softener effluent after startup and at three consecutive seven-day intervals (total of four samples), and prepare certified test reports for required water performance characteristics. Comply with the following:
1. ASTM D 859, "Test Method for Silica in Water."
 2. ASTM D 1067, "Test Methods for Acidity or Alkalinity of Water."
 3. ASTM D 1068, "Test Methods for Iron in Water."
 4. ASTM D 1126, "Test Method for Hardness in Water."
 5. ASTM D 1129, "Terminology Relating to Water."
 6. ASTM D 3370, "Practices for Sampling Water from Closed Conduits."

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain services.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **223100**

SECTION 223200 - DOMESTIC WATER FILTRATION EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Bag-type filters.
2. Freestanding cartridge filters.
3. Off-floor cartridge filters.
4. Carbon filters.
5. Circulating sand filters.
6. Multimedia sand filters.
7. Greensand filters.
8. Separators.

- B. Related Sections:

1. Section 221119 "Domestic Water Piping Specialties" for plumbing piping strainers.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: **[Bag-type filters,] [freestanding cartridge filters,] [carbon filters,] [circulating sand filters,] [multimedia sand filters,] [greensand filters,] [and] [separators]** shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.

1. The term "withstand" means that "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **and the unit will be fully operational after the seismic event**."

1.4 ACTION SUBMITTALS

- A. **Product Data:** For each type of product indicated. **[Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for filters and separators.] [Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.]**
1. Include data substantiating that materials comply with requirements.
- B. **Shop Drawings:** For water filtration equipment. Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. **Wiring Diagrams:** For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. **Seismic Qualification Certificates:** For **[bag-type filters,] [freestanding cartridge filters,] [carbon filters,] [circulating sand filters,] [multimedia sand filters,] [greensand filters,] [separators,]** accessories, and components, from manufacturer.
1. **Basis for Certification:** Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. **Dimensioned Outline Drawings of Equipment Unit:** Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. **Certificates of Shop Inspections and Data Reports:** For products required to have ASME label, signed by product manufacturer.
- C. Welding certificates.
- D. Source quality-control reports.
- E. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. **Operation and Maintenance Data:** For water filtration equipment to include in emergency, operation, and maintenance manuals.
1. Include operation, maintenance, and inspection data, replacement part numbers and availability, and service depot location and telephone number.
- B. **As-Built Plans:** Submit complete as-built plans of all Work, including interface with

other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MATERIALS MAINTENANCE SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Bag-Type Filter Bags: Bags for bag-type filters equal to [200] [400] <Insert number> percent of amount installed for each size and media indicated.
 2. Cartridge-Filter Elements: Elements for cartridge filters equal to [200] [400] <Insert number> percent of amount installed for each size and media indicated.

1.8 QUALITY ASSURANCE

- A. Source Limitations: Obtain each type of water filtration equipment through one source from a single manufacturer.
- B. Welding Qualifications: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with NSF 61, "Drinking Water System Components - Health Effects," for all components that will be in contact with potable water.

1.9 PROJECT CONDITIONS

- A. Feedwater Analysis:
1. Alkalinity: <Insert ppm (mg/L)>.
 2. Arsenic: <Insert ppm (mg/L)>.
 3. Calcium: <Insert ppm (mg/L)>.
 4. Chlorine: <Insert ppm (mg/L)>.
 5. Color: <Insert nephelometric turbidity units>.
 6. Hydrogen-Ion Concentration: <Insert pH>.
 7. Hardness: <Insert ppm (mg/L)>.
 8. Hydrogen Sulfide: <Insert ppm (mg/L)>.
 9. Iron: <Insert ppm (mg/L)>.
 10. Lead: <Insert ppm (mg/L)>.
 11. Magnesium: <Insert ppm (mg/L)>.
 12. Manganese: <Insert ppm (mg/L)>.
 13. Potassium: <Insert ppm (mg/L)>.
 14. Sand: <Insert ppm (mg/L)>.
 15. Silt: <Insert ppm (mg/L)>.
 16. Sodium: <Insert ppm (mg/L)>.

17. Total Dissolved Solids: <Insert ppm (mg/L)>.
18. Turbidity: <Insert ppm (mg/L)>.
19. <Insert characteristic>: <Insert value>.

B. Feedwater Properties:

1. Inlet Water Pressure: <Insert psig (kPa)>.
2. Water Temperature: <Insert deg F (deg C)>.

1.10 COORDINATION

- A. Coordinate size and location of concrete bases with actual equipment provided.

1.11 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products under provisions of Section 220400 "Basic Plumbing Requirements" and Division 01
- B. Provide temporary inlet and outlet caps. Maintain caps in place until installation.

1.12 WARRANTY

- A. Provide minimum five (5) <Insert number> year warranty for domestic water filtration equipment.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 BAG-TYPE FILTERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. Cycron Corporation.
 2. Eden Equipment Company.
 3. Filter Specialists, Inc.
 4. Filtration Systems; Mechanical Mfg. Corporation.
 5. Hayward Industrial Products, Inc.
 6. Krystal Klear Filtration.
 7. Parker Hannifin Corp.; Process Filtration Division.

8. PEP Filters, Inc.
 9. Rosedale Products, Inc.
 10. RPA Process Technologies.
 11. Shelco Filters.
 12. Siemens AG Water Technologies.
 13. **<Insert manufacturer's name>**.
 14. or approved equal.
- B. Description: Simplex, floor-mounted housing with [**single-bag filter**] [**multiple-bag filter**] for removing suspended particles from water.
1. Housing: Corrosion resistant; designed to separate feedwater from filtrate and to direct feedwater through bag-type water filter(s); with bag support and base, feet, or skirt.
 - a. Material: [**Carbon steel with NSF 61 lining material**] [**Plastic**] [**Stainless steel**].
 - b. Seals: [**NBR**] **<Insert material>**.
 - c. Bag Support: Top lock ring and perforated [**stainless-steel**] **<Insert material>** basket.
 - d. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - e. Steel Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if housing is stainless steel.
 - f. Plastic Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: **150-psig (1035-kPa)** plastic flanges.
 2. Bag: Replaceable; of shape to fit housing.
- C. Capacity and Characteristics:
1. Filtrate Design Concentrations:
 - a. Alkalinity: **<Insert ppm (mg/L)>**.
 - b. Chlorine: **<Insert ppm (mg/L)>**.
 - c. Color: **<Insert nephelometric turbidity units>**.
 - d. Hydrogen Sulfide: **<Insert ppm (mg/L)>**.
 - e. Iron: **<Insert ppm (mg/L)>**.
 - f. Manganese: **<Insert ppm (mg/L)>**.
 - g. Sand: **<Insert ppm (mg/L)>**.
 - h. Silt: **<Insert ppm (mg/L)>**.
 - i. Turbidity: **<Insert ppm (mg/L)>**.
 - j. **<Insert characteristic>**: **<Insert value>**.
 2. Filter Design:
 - a. Continuous Flow: **<Insert gpm (L/s)>**.
 - b. Peak Flow: **<Insert gpm (L/s)>**.

- c. Filtration Efficiency: **[98]** <Insert number> percent retention of suspended particles **[10]** **[20]** <Insert size> micrometers and larger from feedwater of listed filtrate design concentrations.
 - d. Pressure Drop: Not to exceed **[2 psig (14 kPa)]** <Insert value> at filter design flow rate when clean **[and <Insert value> when dirty]**.
3. Housing:
- a. Pressure Rating: <Insert psig (kPa)>.
 - b. Diameter: <Insert inches (mm)>.
 - c. Height or Length: <Insert inches (mm)>.
 - d. Inlet and Outlet Size: <Insert NPS (DN)>.
 - e. Drain Size: **[Not applicable]** <Insert NPS (DN)>.
4. Bag:
- a. Nominal Diameter: <Insert inches (mm)>.
 - b. Nominal Length: <Insert inches (mm)>.
 - c. Media: **[Cotton]** **[Polyester]** **[PP]** <Insert material>; **[felt, filament, or mesh]** **[felt]** **[filament]** **[mesh]** construction.

2.2 CARTRIDGE FILTERS

A. Freestanding Cartridge Filters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Campbell Manufacturing, Inc.
 - b. Cycron Corporation.
 - c. Diamond Water Conditioning; a Griesbach company.
 - d. Eden Equipment Company.
 - e. Filter Specialists, Inc.
 - f. Filterspun.
 - g. Filtrine Manufacturing Co.
 - h. General Electric Company; GE Water & Process Technologies.
 - i. Graver Technologies.
 - j. Harmsco, Inc.
 - k. Hydro Systems International.
 - l. ITT Water Equipment Technologies.
 - m. Keystone Filter Division; Met-Pro Corporation.
 - n. Krystal Klear Filtration.
 - o. Parker Hannifin Corp.; Process Filtration Division.
 - p. PEP Filters, Inc.
 - q. Rosedale Products, Inc.
 - r. Serfilco, Ltd.
 - s. Shelco Filters.
 - t. Siemens AG Water Technologies.
 - u. Watts Regulator Company; a division of Watts Water Technologies, Inc.

- v. **<Insert manufacturer's name>**.
 - w. or approved equal.
2. Description: Simplex, floor-mounted housing with replaceable element(s) for removing suspended particles from water.
- a. Housing: Corrosion resistant; designed to separate feedwater from filtrate and to direct feedwater through water filter element(s); with element support(s) and base, feet, or skirt.
 - 1) Fabricate supports and base, feet, or skirt and attachment to housing with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.
 - 2) Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - 3) Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if housing is stainless steel.
 - 4) Plastic Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: **150-psig (1035-kPa)** plastic flanges.
 - b. Element(s): Replaceable; of shape to fit housing.
3. Capacity and Characteristics:
- a. Filtrate Design Concentrations:
 - 1) Alkalinity: **<Insert ppm (mg/L)>**.
 - 2) Chlorine: **<Insert ppm (mg/L)>**.
 - 3) Color: **<Insert nephelometric turbidity units>**.
 - 4) Hydrogen Sulfide: **<Insert ppm (mg/L)>**.
 - 5) Iron: **<Insert ppm (mg/L)>**.
 - 6) Manganese: **<Insert ppm (mg/L)>**.
 - 7) Sand: **<Insert ppm (mg/L)>**.
 - 8) Silt: **<Insert ppm (mg/L)>**.
 - 9) Turbidity: **<Insert ppm (mg/L)>**.
 - 10) **<Insert characteristic>**: **<Insert value>**.
 - b. Filter Design:
 - 1) Continuous Flow: **<Insert gpm (L/s)>**.
 - 2) Peak Flow: **<Insert gpm (L/s)>**.
 - 3) Filtration Efficiency: **[98] <Insert number>** percent retention of suspended particles **[1] [10] [20] <Insert size>** micrometers and larger from feedwater of listed filtrate design concentrations.
 - 4) Pressure Drop: Not to exceed **[2 psig (14 kPa)] <Insert value>** at filter design flow rate when clean **[and <Insert value> when dirty]**.
 - c. Housing:

- 1) Material: [**Plastic**] [**Stainless steel**] <Insert material>.
- 2) Pressure Rating: <Insert psig (kPa)>.
- 3) Seals: [**NBR**] <Insert material>.
- 4) Diameter: <Insert inches (mm)>.
- 5) Height or Length: <Insert inches (mm)>.
- 6) Inlet and Outlet Size: <Insert NPS (DN)>.
- 7) Drain Size: [**Not applicable**] <Insert NPS (DN)>.

d. Elements:

- 1) Number Required: [**One**] [**Two**] <Insert number>.
- 2) Nominal Diameter: <Insert inches (mm)>.
- 3) Nominal Length: <Insert inches (mm)>.
- 4) Media: [**Activated charcoal**] [or] [**ground charcoal**].
- 5) Media: [**Pleated polyester**] [or] [**pleated PP**].
- 6) Media: [**Wound polyester**] [or] [**wound PP**].
- 7) Media: <Insert material>.

B. Off-Floor Cartridge Filters:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. AMTROL, Inc.; WaterSoft Products.
- b. Campbell Manufacturing, Inc.
- c. Culligan International Company.
- d. Eagle Spring Filtration, Inc.
- e. Eden Equipment Company.
- f. Everpure, LLC.
- g. Fairey Industrial Ceramics.
- h. Filpro Corporation.
- i. Filterspun.
- j. Filtrine Manufacturing Co.
- k. Flint & Walling, Inc.
- l. General Electric Company; GE Water & Process Technologies.
- m. Graver Technologies.
- n. Harmsco, Inc.
- o. Hydro Systems International.
- p. Hydrotech, Inc.; a division of WaterGroup.
- q. ITT Water Equipment Technologies.
- r. Keystone Filter Division; Met-Pro Corporation.
- s. Matterhorn Filter Corp.
- t. Ompure Filter Company.
- u. Parker Hannifin Corp.; Process Filtration Division.
- v. Pentair Filtration, Inc.
- w. Shelco Filters.
- x. Siemens AG Water Technologies.
- y. Topway Global, Inc.
- z. Watts Premier Inc.
- aa. Watts Regulator Company; a division of Watts Water Technologies, Inc.

- bb. Watts Water Technologies, Inc.; Alamo Water.
 - cc. **<Insert manufacturer's name>**.
 - dd. or approved equal.
2. Description: Simplex, **[in-line]** **[wall-mounted]** housing with replaceable element for removing suspended particles from water.
- a. Housing: Corrosion resistant; designed to separate feedwater from filtrate and to direct feedwater through water filter element; with element support.
 - 1) Pipe Connections: Threaded according to ASME B1.20.1.
 - 2) Support: Wall bracket.
 - b. Element: Replaceable; of shape to fit housing.
3. Capacity and Characteristics:
- a. Filtrate Design Concentrations:
 - 1) Alkalinity: **<Insert ppm (mg/L)>**.
 - 2) Chlorine: **<Insert ppm (mg/L)>**.
 - 3) Color: **<Insert nephelometric turbidity units>**.
 - 4) Hydrogen Sulfide: **<Insert ppm (mg/L)>**.
 - 5) Iron: **<Insert ppm (mg/L)>**.
 - 6) Manganese: **<Insert ppm (mg/L)>**.
 - 7) Sand: **<Insert ppm (mg/L)>**.
 - 8) Silt: **<Insert ppm (mg/L)>**.
 - 9) Turbidity: **<Insert ppm (mg/L)>**.
 - 10) **<Insert characteristic>**: **<Insert value>**.
 - b. Filter Design:
 - 1) Continuous Flow: **<Insert gpm (L/s)>**.
 - 2) Peak Flow: **<Insert gpm (L/s)>**.
 - 3) Filtration Efficiency: **[98]** **<Insert number>** percent retention of suspended particles **[1]** **[10]** **[20]** **<Insert size>** micrometers and larger from feedwater of listed filtrate design concentrations.
 - 4) Pressure Drop: Not to exceed **[2 psig (14 kPa)]** **<Insert value>** at filter design flow rate when clean **[and <Insert value> when dirty]**.
 - c. Housing:
 - 1) Material: **[PE or PP]** **[Plastic]** **[Stainless steel]** **<Insert material>**.
 - 2) Pressure Rating: **<Insert psig (kPa)>**.
 - 3) Seals: **[NBR]** **<Insert material>**.
 - 4) Diameter: **<Insert inches (mm)>**.
 - 5) Height or Length: **<Insert inches (mm)>**.
 - 6) Inlet and Outlet Size: **<Insert NPS (DN)>**.
 - 7) Drain Size: **[Not applicable]** **<Insert NPS (DN)>**.

d. Element:

- 1) Nominal Diameter: <Insert inches (mm)>.
- 2) Nominal Length: <Insert inches (mm)>.
- 3) Media: [Activated charcoal] [or] [ground charcoal].
- 4) Media: [Pleated polyester] [or] [pleated PP].
- 5) Media: [Wound polyester] [or] [wound PP].
- 6) Media: <Insert material>.

2.3 CARBON FILTERS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. AMTROL, Inc.; WaterSoft Products.
2. Aquion Water Treatment Products; RainSoft Division.
3. CSI Controls.
4. Culligan International Company.
5. CUNO Incorporated.
6. Diamond Water Conditioning; a Griesbach company.
7. EcoWater Systems LLC.
8. Integrated Separation Solutions, LLC.
9. Marlo Incorporated.
10. PEP Filters, Inc.
11. Separmatic Fluid Systems.
12. Siemens AG Water Technologies.
13. Springsoft Intl, Inc.
14. Water & Power Technologies Incorporated; a Tyco International Ltd. company.
15. Water-Right, Inc.
16. Watts Water Technologies, Inc.; Alamo Water.
17. <Insert manufacturer's name>.
18. or approved equal.

B. **Description: Simplex carbon filter, with media tank, media, and automatic backwash for [removing chlorine from] [and] [improving color, odor, and taste of] <Insert application> water.**

1. Media Tank: Corrosion resistant with distribution system and media.
 - a. Construction:
 - 1) Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
 - 2) Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section X, if indicated.
 - 3) Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.

- 4) Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - 5) Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if tank is stainless steel.
 - 6) FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; [**Designation E, 125-psig (0.862-MPa)**] [**or**] [**Designation F, 150-psig (1.034-MPa)**] pressure category flanges of grade same as tank material according to ASTM D 5421.
 - 7) Support: Base, feet, or skirt.
2. Controls: Automatic for control of backwash; factory wired for single, external electrical connection.
 - a. Panel: NEMA 250, Type [4] **<Insert type>** enclosure.
 - b. Backwash Initiation Device: [**Differential pressure gages**] [**Electric time clock**] [**Water meter**].
- C. Capacity and Characteristics:
1. Filtrate Design Concentrations:
 - a. Alkalinity: **<Insert ppm (mg/L)>**.
 - b. Chlorine: **<Insert ppm (mg/L)>**.
 - c. Color: **<Insert nephelometric turbidity units>**.
 - d. Hydrogen-Ion Concentration: **<Insert pH>**.
 - e. Hydrogen Sulfide: **<Insert ppm (mg/L)>**.
 - f. Iron: **<Insert ppm (mg/L)>**.
 - g. Manganese: **<Insert ppm (mg/L)>**.
 - h. Total Dissolved Solids: **<Insert ppm (mg/L)>**.
 - i. Turbidity: **<Insert ppm (mg/L)>**.
 - j. **<Insert characteristic>**: **<Insert value>**.
 2. Filter Design:
 - a. Continuous Flow: **<Insert gpm (L/s)>**.
 - b. Flow Rate: **<Insert gpm/sq. ft. (L/s per sq. m)>** of media cross-sectional area.
 - c. Peak Flow: **<Insert gpm (L/s)>**.
 - d. Filtration Efficiency: [98] **<Insert number>** percent retention of suspended particles [20] [40] **<Insert size>** micrometers and larger from feedwater of listed filtrate design concentrations.
 - e. Pressure Drop: Not to exceed [2 psig (14 kPa)] **<Insert value>** at filter design flow rate when clean[**and <Insert value> when dirty**].
 - f. Backwash Flow: **<Insert gpm (L/s)>**.
 3. Filter Backwash Interval: **<Insert psig (kPa)>** pressure drop measured by differential pressure gages.
 4. Filter Backwash Interval: **<Insert number>** days measured by time clock.

5. Filter Backwash Interval: **<Insert gal. (cu. m)>** measured by water meter.
6. Media Tank:
 - a. Material: **[Carbon steel with NSF 61 lining material] [FRP] [Stainless steel]**.
 - b. Pressure Rating: **<Insert psig (kPa)>**.
 - c. Media: **[Activated charcoal] [Ground charcoal] <Insert material>**.
 - d. Media Quantity: **<Insert cu. ft. (cu. m)>**.
 - e. Diameter: **<Insert inches (mm)>**.
 - f. Height: **<Insert inches (mm)>**.
 - g. Inlet and Outlet Size: **<Insert NPS (DN)>**.
7. Unit Electrical Characteristics:
 - a. Volts: **[120] [240] [277] [480] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: **[60] <Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 SAND FILTERS

A. Circulating Sand Filters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Diamond Water Systems, Inc.
 - b. Everfilt.
 - c. Griswold Controls.
 - d. LAKOS; Claude Laval Corporation.
 - e. Miami Filter, Inc.
 - f. PEP Filters, Inc.
 - g. Puroflux Corporation.
 - h. United Industries, Inc.
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Description: Factory-fabricated and -tested, simplex, sand-filter system of filter tank, media, strainer, circulating pump, piping, and controls for removing sediment particles from water.
 - a. Filter Tank: Corrosion resistant with distribution system and media.
 - 1) Construction:
 - a) Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

- b) Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section X, if indicated.
 - c) Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.
- 2) Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - 3) Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - 4) FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; Designation [**E, 125-psig (0.862-MPa)**] [**or**] [**F, 150-psig (1.034-MPa)**] pressure category flanges of grade same as tank material according to ASTM D 5421.
- b. Strainer: Basket type.
- 1) Pipe Connections:
 - a) Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - b) Connections **NPS 2-1/2 (DN 65)** and Larger: Cast-iron, Class 125 flanges according to ASME B16.1.
- c. Piping: [**Galvanized steel pipe, galvanized cast-iron fittings**] [**Stainless-steel pipe, stainless-steel fittings**], and flanged, grooved, or threaded joints.
- d. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
- e. Safety Valves: Automatic and manual pressure relief.
- f. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
- 1) Pump Construction: Bronze fitted.
 - a) Casing: Radially split, cast iron.
 - b) Pressure Rating: [**125 psig (860 kPa)**] [**150 psig (1035 kPa)**] minimum.
 - c) Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 - d) Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
 - e) Seal: Mechanical.
 - 2) Motor: General requirements for motors are specified in Section 220513 "Common Motor Requirements for Plumbing Equipment."
- g. Controls: Automatic for control of circulating pump and tank backwash; factory wired for single, external electrical connection.

- 1) Panel: NEMA 250, Type [4] <Insert type> enclosure with time clock and pressure gages.
 - 2) Pump: Automatic and manual.
 - 3) Backwash: Automatic; with [time-clock] [differential-pressure-switch] initiation device.
 - 4) Backwash Valve: Tank mounted.
- h. Support: Skid mounting.
3. Capacity and Characteristics:
- a. Filtrate Design Concentrations:
 - 1) Sand: <Insert ppm (mg/L)>.
 - 2) Silt: <Insert ppm (mg/L)>.
 - 3) <Insert characteristic>: <Insert value>.
 - b. Filter Design:
 - 1) Continuous Flow: <Insert gpm (L/s)> at [5-psig (34.5-kPa)] <Insert value> pressure drop.
 - 2) Flow Rate: <Insert gpm/sq. ft. (L/s per sq. m)> of media cross-sectional area.
 - 3) Peak Flow: <Insert gpm (L/s)>.
 - 4) Filtration Efficiency: [98] <Insert number> percent removal of [1.8] <Insert number> minimum specific-gravity suspended particles [5] [10] [20] [45] <Insert size> micrometers and larger from feedwater of listed filtrate design concentrations.
 - c. Filter Tank: With internal distribution piping.
 - 1) Material: [Carbon steel with NSF 61 lining material] [FRP] <Insert material>.
 - 2) Pressure Rating: <Insert psig (kPa)>.
 - 3) Diameter: <Insert inches (mm)>.
 - 4) Height: <Insert inches (mm)>.
 - 5) Inlet and Outlet Size: <Insert NPS (DN)>.
 - 6) Purge Size: <Insert NPS (DN)>.
 - d. Filter Media: [Graded silica sand] <Insert media>.
 - e. Filter Backwash Interval: <Insert psig (kPa)> pressure drop measured by differential pressure gages.
 - f. Filter Backwash Interval: <Insert number> days measured by time clock.
 - g. Circulating Pump:
 - 1) Capacity: <Insert gpm (L/s)>.
 - 2) Total Dynamic Head: <Insert feet (kPa)>.
 - 3) Speed: <Insert rpm>.
 - 4) Inlet Size: <Insert NPS (DN)>.
 - 5) Outlet Size: <Insert NPS (DN)>.

- h. Pump Motor Size and Electrical Characteristics:
 - 1) Horsepower: **<Insert value>**.
 - 2) Volts: **[120] [208] [240] [277] [480] <Insert value>**.
 - 3) Phase: **[Single] [Three]**.
 - 4) Hertz: **[60] <Insert value>**.
- i. Unit Electrical Characteristics:
 - 1) Full-Load Amperes: **<Insert value>**.
 - 2) Minimum Circuit Ampacity: **<Insert value>**.
 - 3) Maximum Overcurrent Protection: **<Insert amperage>**.

B. Multimedia Sand Filters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. AMTROL, Inc.; WaterSoft Products.
- b. Aquion Water Treatment Products; RainSoft Division.
- c. Aries; a division of ResinTech, Inc.
- d. Columbia Water; a division of R & M Manufacturing, Inc.
- e. CSI Controls.
- f. Culligan International Company.
- g. CUNO Incorporated.
- h. Diamond Water Conditioning; a Griesbach company.
- i. Diamond Water Systems, Inc.
- j. Everfilt.
- k. Filtronics, Inc.
- l. Hungerford & Terry, Inc.
- m. Industrial Filter & Pump Mfg. Co.
- n. Integrated Separation Solutions, LLC.
- o. LAKOS; Claude Laval Corporation.
- p. Marlo Incorporated.
- q. Mer-Made Filter, Inc.
- r. Miami Filter, Inc.
- s. PEP Filters, Inc.
- t. Puroflux Corporation.
- u. Separmatic Fluid Systems.
- v. Smith & Loveless.
- w. Springsoft Intl, Inc.
- x. Water & Power Technologies Incorporated.; a Tyco International Ltd. company.
- y. Water King.
- z. Watts Water Technologies, Inc.; Alamo Water.
- aa. **<Insert manufacturer's name>**.
- bb. or approved equal.

2. Description: Factory-fabricated and -tested, [**simplex**] [**duplex**] [**triplex**], multimedia, sand-filter system of filter tank(s), media, piping, and controls for removing sediment particles from water.
 - a. Tank Construction:
 - 1) Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
 - 2) Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section X, if indicated.
 - 3) Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.
 - b. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - c. Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - d. FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; Designation [**E, 125-psig (0.862-MPa)**] [**or**] [**F, 150-psig (1.034-MPa)**] pressure category flanges of grade same as tank material according to ASTM D 5421.
 - e. Service Valve(s): Diaphragm type [**hydraulically**] [**pneumatically**] operated.
 - f. Piping: [**Galvanized steel pipe, galvanized cast-iron fittings**] [**Stainless-steel pipe, stainless-steel fittings**], and flanged, grooved, or threaded joints.
 - g. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
 - h. Piping: Schedule 80 ABS or PVC pipe and fittings with solvent-cemented joints.
 - i. Safety Valves: Automatic air vent.
 - j. Controls for Simplex Tank System: Automatic, electric time clock for control of filter system flow and backwash cycles; factory-wired for single, external electrical connection.
 - k. Controls for [**Duplex**] [**Triplex**] Tank System: Automatic, electric time clock for control of filter system flow and backwash cycles; factory-wired for single, external electrical connection. System operation shall be continuous with bypass piping and not more than one tank in backwash cycle at same time.
 - l. Support: Skid mounting.
3. Capacity and Characteristics:
 - a. Filtrate Design Concentrations:
 - 1) Chlorine: <Insert ppm (mg/L)>.
 - 2) Color: <Insert nephelometric turbidity units>.
 - 3) Iron: <Insert ppm (mg/L)>.

- 4) Manganese: <Insert ppm (mg/L)>.
- 5) Total Dissolved Solids: <Insert ppm (mg/L)>.
- 6) Turbidity: <Insert ppm (mg/L)>.
- 7) <Insert characteristic>: <Insert value>.

b. Filter Design:

- 1) Continuous Flow: <Insert gpm (L/s)> at <Insert psig (kPa)> pressure drop.
- 2) Peak Flow: <Insert gpm (L/s)> at <Insert psig (kPa)> pressure drop.
- 3) Filtration Efficiency: [98] <Insert number> percent removal of suspended particles [10] [20] [40] <Insert size> micrometers and larger from feedwater of listed filtrate design concentrations.
- 4) Backwash Flow: <Insert gpm (L/s)> at <Insert psig (kPa)> pressure drop.

c. Media Tank: Single with controls.

d. Media Tanks: [Two] [Three] with manifolded inlet, outlet, and drain piping and controls.

e. Each Media Tank:

- 1) Material: [Carbon steel with NSF 61 lining material] [FRP] <Insert material>.
- 2) Pressure Rating: <Insert psig (kPa)> minimum.
- 3) Distribution System: Factory-installed plastic.
- 4) Temperature Rating: <Insert deg F (deg C)> minimum.
- 5) Diameter: <Insert inches (mm)>.
- 6) Height: <Insert inches (mm)>.
- 7) Service Valve Size: <Insert NPS (DN)>.
- 8) Inlet and Outlet Size: <Insert NPS (DN)>.
- 9) Drain Size: <Insert NPS (DN)>.

f. Filter Media: [Graded silica sand] <Insert media>.

C. Greensand Filters:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. AMTROL, Inc.; WaterSoft Products.
- b. Aquion Water Treatment Products; RainSoft Division.
- c. Aries; a division of ResinTech, Inc.
- d. CSI Controls.
- e. Culligan International Company.
- f. CUNO Incorporated.
- g. Diamond Water Conditioning; a Griesbach company.
- h. Filtronics, Inc.
- i. Hungerford & Terry, Inc.
- j. Integrated Separation Solutions, LLC.
- k. Marlo Incorporated.

- I. PEP Filters, Inc.
 - m. Separmatic Fluid Systems.
 - n. Watts Water Technologies, Inc.; Alamo Water.
 - o. **<Insert manufacturer's name>**.
 - p. or approved equal.
2. Description: Greensand-filter system of piping, and controls for removing [iron] [iron and manganese] [manganese] from water.
 - a. Tank Construction:
 - 1) Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
 - 2) Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code, Section X, if indicated.
 - 3) Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.
 - b. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - c. Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - d. FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; Designation [**E, 125-psig (0.862-MPa)**] [**or**] [**F, 150-psig (1.034-MPa)**] pressure category flanges of grade same as tank material according to ASTM D 5421.
 - e. Service Valve(s): Diaphragm type [**hydraulically**] [**pneumatically**] operated.
 - f. Piping: [**Galvanized steel pipe, galvanized cast-iron fittings**] [**Stainless-steel pipe, stainless-steel fittings**], and flanged, grooved, or threaded joints.
 - g. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
 - h. Piping: Schedule 80 ABS or PVC pipe and fittings with solvent-cemented joints.
 - i. Safety Valves: Automatic air vent.
 - j. Controls for Simplex Tank System: Automatic, electric time clock for control of filter system flow and backwash cycles; factory wired for single, external electrical connection.
 - k. Controls for [**Duplex**] [**Triplex**] Tank System: Automatic, electric time clock for control of filter system flow and backwash cycles; factory wired for single, external electrical connection. System operation shall be continuous with bypass piping and not more than one tank in backwash cycle at same time.
 - l. Support: Skid mounting.
3. Capacity and Characteristics:

- a. Filtrate Design Concentrations:
 - 1) Iron: <Insert ppm (mg/L)>.
 - 2) Manganese: <Insert ppm (mg/L)>.
 - 3) <Insert characteristic>: <Insert value>.
- b. Filter Design:
 - 1) Continuous Flow: <Insert gpm (L/s)> at <Insert psig (kPa)> pressure drop.
 - 2) Peak Flow: <Insert gpm (L/s)> at <Insert psig (kPa)> pressure drop.
 - 3) Filtration Efficiency: [98] <Insert number> percent removal of suspended particles [10] [20] [40] <Insert size> micrometers and larger from feedwater of listed filtrate design concentrations.
 - 4) Backwash Flow: <Insert gpm (L/s)> at <Insert psig (kPa)> pressure drop.
- c. Media Tank: Single with controls.
- d. Media Tanks: [Two] [Three] with manifolded inlet, outlet, and drain piping and controls.
- e. Each Media Tank:
 - 1) Material: [Carbon steel with NSF 61 lining material] [FRP] <Insert material>.
 - 2) Pressure Rating: <Insert psig (kPa)> minimum.
 - 3) Distribution System: Factory-installed plastic.
 - 4) Temperature Rating: <Insert deg F (deg C)> minimum.
 - 5) Diameter: <Insert inches (mm)>.
 - 6) Height: <Insert inches (mm)>.
 - 7) Service Valve Size: <Insert NPS (DN)>.
 - 8) Inlet and Outlet Size: <Insert NPS (DN)>.
 - 9) Drain Size: <Insert NPS (DN)>.
- f. Filter Media: [Graded silica sand] <Insert media>.

2.5 SEPARATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Culligan International Company.
2. Griswold Controls.
3. LAKOS; Claude Laval Corporation.
4. PEP Filters, Inc.
5. Puroflux Corporation.
6. Rosedale Products, Inc.
7. Watts Water Technologies, Inc.; Alamo Water.
8. <Insert manufacturer's name>.
9. or approved equal.

- B. Description: Simplex separator housing with baffles and chambers for removing sediment particles from water by centrifugal action and gravity.
- C. Description: Factory-fabricated and -tested, simplex separator system of housing with baffles and chambers, strainer, circulating pump, piping, and controls for removing sediment particles from water by centrifugal action and gravity.
- D. Housing: With manufacturer's proprietary system of baffles and chambers.
1. Construction:
 - a. Fabricate and label steel separator housing to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
 - b. Fabricate supports and base and attachment to separator housing with reinforcement strong enough to resist separator movement during a seismic event when separator base is anchored to building structure.
 2. Inlet: Designed with tangential entry to produce centrifugal flow of feedwater.
 3. Vortex Chamber: Designed for downward vortex flow and gravity separation of particles.
 4. Collection Chamber: Designed to hold separated particles.
 5. Outlet: Near top of unit.
 6. Purge: At bottom of collection chamber.
 7. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 8. Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: ASME B16.1; steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if tank is stainless steel.
- E. Strainer: Basket type.
1. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 2. Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Cast-iron, Class 125 flanges according to ASME B16.1.
- F. Piping: [**Galvanized steel pipe, galvanized cast-iron fittings**] [**Stainless-steel pipe, stainless-steel fittings**], and flanged, grooved, or threaded joints.
- G. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
- H. Safety Valves: Automatic and manual pressure relief.
- I. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
1. Pump Construction: Bronze fitted.
 - a. Casing: Radially split, cast iron.
 - b. Pressure Rating: [**125 psig (860 kPa)**] [**150 psig (1035 kPa)**] minimum.

- c. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 - d. Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
 - e. Seal: Mechanical.
2. Motor: General requirements for motors are specified in Section 220513 "Common Motor Requirements for Plumbing Equipment."
- J. Controls: Automatic for control of circulating pump and separator purge; factory wired for single, external electrical connection.
 1. Panel: NEMA 250, Type [4] <Insert type> enclosure.
 2. Pump: Automatic and manual.
 3. Separator Purge: Automatic and manual.
- K. Support: Skid mounting.
- L. Capacity and Characteristics:
 1. Filtrate Design Concentrations:
 - a. Sand: <Insert ppm (mg/L)>.
 - b. Silt: <Insert ppm (mg/L)>.
 - c. <Insert characteristic>: <Insert value>.
 2. Separator Design:
 - a. Continuous Flow: <Insert gpm (L/s)> at [5-psig (34.5-kPa)] <Insert value> pressure drop.
 - b. Peak Flow: <Insert gpm (L/s)>.
 - c. Separator Efficiency: [98] <Insert number> percent removal of listed [1.8] <Insert number> minimum specific-gravity suspended particles [5] [10] [20] [45] <Insert size> micrometers and larger from feedwater of listed filtrate design concentrations.
 3. Housing:
 - a. Material: [Carbon] [Stainless] steel.
 - b. Pressure Rating: <Insert psig (kPa)>.
 - c. Diameter: <Insert inches (mm)>.
 - d. Height: <Insert inches (mm)>.
 - e. Inlet and Outlet Size: <Insert NPS (DN)>.
 - f. Purge Size: <Insert NPS (DN)>.
 4. Circulating Pump:
 - a. Capacity: <Insert gpm (L/s)>.
 - b. Total Dynamic Head: <Insert feet (kPa)>.
 - c. Speed: <Insert rpm>.
 - d. Inlet Size: <Insert NPS (DN)>.

- e. Outlet Size: <Insert NPS (DN)>.
5. Pump Motor Size and Electrical Characteristics:
- a. Horsepower: <Insert value>.
 - b. Volts: [120] [208] [240] [277] [480] <Insert value>.
 - c. Phase: [Single] [Three].
 - d. Hertz: [60] <Insert value>.
6. Unit Electrical Characteristics:
- a. Full-Load Amperes: <Insert value>.
 - b. Minimum Circuit Ampacity: <Insert value>.
 - c. Maximum Overcurrent Protection: <Insert amperage>.
- 2.6 SOURCE QUALITY CONTROL
- A. Before shipping, hydrostatically test [carbon filters,] [circulating sand filters,] [multimedia sand filters,] [greensand filters,] [and] [separators] to minimum of one and one-half times pressure rating.
 - B. Prepare test reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of [filters] [and] [separators].
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before equipment installation.
- C. Examine walls and floors for suitable conditions where [filters] [and] [separators] will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EQUIPMENT MOUNTING

- A. Equipment Mounting: Install [filters, except wall-mounted cartridge filters,] [and] [separators] on concrete bases. Comply with requirements for concrete bases specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of concrete base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

3.3 BAG-TYPE FILTER INSTALLATION

- A. Equipment Mounting: Install filters on concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
- B. Install bag-type filters level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.
- C. Install filter media bags.
- D. Install seismic restraints for bag-type filter housings and anchor to building structure.

3.4 CARTRIDGE-FILTER INSTALLATION

- A. Install cartridge filters level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.
- B. Equipment Mounting: Install freestanding cartridge filters on concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 1. Exception: Omit concrete bases if installation directly on floor is indicated.
- C. Attach wall brackets for off-floor, wall-mounted, cartridge filter to vertical surface. Attach housing(s), and base if any, to wall bracket.
- D. Install housings for off-floor, in-line, cartridge filters in piping.
- E. Install filter elements in cartridges.
- F. Install seismic restraints for freestanding cartridge-filter housings and anchor to building structure.

3.5 CARBON-FILTER INSTALLATION

- A. Install carbon filters on concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
- B. Prepare carbon-filter tank distribution system and underbed, if any, for filter media and place specified media into tanks.
- C. Install seismic restraints for carbon-filter housings and anchor to building structure.

3.6 SAND-FILTER INSTALLATION

- A. Install sand-filter tanks on concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
- B. Prepare sand-filter tank distribution system and underbed for filter media and place specified sand and other media into tanks.
- C. Install seismic restraints for sand-filter tanks and accessories and anchor to building structure.

3.7 SEPARATOR INSTALLATION

- A. Install separators on concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
- B. Install seismic restraints for separators and accessories and anchor to building structure.

3.8 CONNECTIONS

- A. Comply with requirements for piping specified in Section 221116 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to equipment to allow service and maintenance.
- C. Make piping connections between water filtration equipment and dissimilar-metal water piping with dielectric fittings. Comply with requirements for dielectric fittings specified in Section 221116 "Domestic Water Piping."
- D. Install shutoff valves on feedwater-inlet and filtrate-outlet piping of each water filtration equipment [**filter**] [**and**] [**separator**] [**and on inlet and outlet headers**].
 - 1. Comply with requirements for metal general-duty valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."

2. Comply with requirements for plastic valves specified in Section 221116 "Domestic Water Piping."
 3. Exception: Water filtration equipment with factory-installed shutoff valves at locations indicated.
- E. Install pressure gages on feedwater-inlet and filtrate-outlet piping of each water filtration equipment **[filter]** **[and]** **[separator]**. Comply with requirements for pressure gages specified in Section 220519 "Meters and Gages for Plumbing Piping."
1. Exception: Water filtration equipment with factory-installed pressure gages at locations indicated.
 2. Exception: Cartridge water filters.
- F. Install valved bypass water piping around each water filtration equipment **[filter]** **[and]** **[separator]**.
1. Comply with requirements for metal general-duty valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 2. Comply with requirements for plastic valves specified in Section 221116 "Domestic Water Piping."
 3. Comply with requirements for water piping specified in Section 221116 "Domestic Water Piping."
 4. Exception: Bag-type water filtration equipment.
 5. Exception: Cartridge water filtration equipment.
- G. Install drains as indirect wastes to spill into open drains or over floor drains.

3.9 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.10 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 2. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation.
 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Domestic water filtration equipment will be considered defective if it does not pass tests and inspections.

- D. Prepare test and inspection reports.

3.11 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service for **[circulating sand filters,] [multimedia sand filters,] [greensand filters,] [and] [separators]**.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. **<Insert startup steps if any>**.

- B. Sample **[filter] [and] [separator]** filtrate after startup and at three consecutive seven-day intervals (total of four samples), and prepare certified test reports for required water performance characteristics.

3.12 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain **[circulating sand filters,] [multimedia sand filters,] [greensand filters,] [and] [separators]**.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 223200

SECTION 223300 - ELECTRIC, DOMESTIC-WATER HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
1. Commercial, electric, domestic-water booster heaters.
 2. Commercial, electric, storage, domestic-water heaters.
 3. Commercial, light-duty, storage, electric, domestic-water heaters.
 4. Flow-control, electric, tankless, domestic-water heaters.
 5. Thermostat-control, electric, tankless, domestic-water heaters.
 6. Domestic-water heater accessories.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Commercial domestic-water heaters shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and size of domestic-water heater indicated.[**Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.**]
1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1, Section 7, "Service Water Heating."

C. Shop Drawings:

1. Wiring Diagrams: For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For commercial domestic-water heaters, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

B. Product Certificates: For each type of **[commercial]** **[residential]** **[and]** **[tankless]**, electric, domestic-water heater, from manufacturer.

C. Domestic-Water Heater Labeling: Certified and labeled by testing agency acceptable to authorities having jurisdiction.

D. Source quality-control reports.

E. Field quality-control reports.

F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For electric, domestic-water heaters to include in emergency, operation, and maintenance manuals.

1. Include operation, maintenance, and inspection data, replacement part numbers and availability, and service depot location and telephone number.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
- C. ASME Compliance: Where ASME-code construction is indicated, fabricate and label commercial, domestic-water heater storage tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- D. NSF Compliance: Fabricate and label equipment components that will be in contact with potable water to comply with NSF 61, "Drinking Water System Components - Health Effects."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products under provisions of Section 220400 "Basic Plumbing Requirements" and Division 01
- B. Provide temporary inlet and outlet caps. Maintain caps in place until installation.

1.10 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of electric, domestic-water heaters that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

- a. Structural failures including storage tank and supports.
- b. Faulty operation of controls.
- c. Deterioration of metals, metal finishes, and other materials beyond normal use.

2. Warranty Periods: From date of Substantial Completion.

- a. Commercial, Electric, Domestic-Water Booster Heaters:
 - 1) Controls and Other Components: Minimum **[three (3)] [five (5)]** **<Insert number>** years.
- b. Commercial, Electric, Storage, Domestic-Water Heaters:

- 1) Storage Tank: Minimum[**three (3)**] [**five (5)**] <Insert number> years.
- 2) Controls and Other Components: Minimum[**three (3)**] [**five (5)**] <Insert number> years.

c. Commercial, Light-Duty, Storage, Electric, Domestic-Water Heaters:

- 1) Storage Tank: [**Three**] [**Five**] <Insert number> years.
- 2) Controls and Other Components: [**Two**] [**Three**] <Insert number> years.

d. Electric, Tankless, Domestic-Water Heaters: Minimum[**one (1)**] [**two (2)**] [**five (5)**] <Insert number> year(s).

e. Compression Tanks: Minimum[**five (5)**] <Insert number> years.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 COMMERCIAL, ELECTRIC, DOMESTIC-WATER HEATERS

A. Commercial, Electric, Domestic-Water Booster Heaters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Bradford White Corporation.
- b. Coates Heater Company, Inc.
- c. Electric Heater Company (The).
- d. Hatco Corporation.
- e. HESco Industries, Inc.
- f. Lochinvar Corporation.
- g. Rheem Manufacturing Company.
- h. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
- i. <Insert manufacturer's name>.
- j. or approved equal.

2. Standard: UL 1453.

3. Tank Construction: [**Corrosion-resistant metal**] [**or**] [**steel**].

- a. Tappings: ASME B1.20.1 pipe thread.
- b. Pressure Rating: **150 psig** (1035 kPa).
- c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending lining material into tappings.

4. Factory-Installed Tank Appurtenances:

- a. Anode Rod: Replaceable magnesium.
- b. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
- c. Insulation: Comply with ASHRAE/IESNA 90.1.
- d. Jacket: Rectangular shaped, with stainless-steel front panel, unless otherwise indicated.
- e. Heating Elements: Electric, screw-in or bolt-on immersion type arranged in multiples of three.
 - 1) Option: Booster heaters with total of 9 kW or less may have two or three elements.
- f. Temperature Control: Adjustable thermostat, to setting of at least 180 deg F (82 deg C).
- g. Safety Controls: High-temperature-limit and low-water cutoff devices or systems.
- h. Relief Valve: ASME rated and stamped for combination temperature-and-pressure relief valve. Include relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select relief valve with sensing element that extends into storage tank.
- i. Gages: Combination temperature-and-pressure type or separate thermometer and pressure gage.

5. Special Requirements: NSF 5 construction with **[brackets for undercounter]** **[legs for floor]** installation.

B. Commercial, Electric, Storage, Domestic-Water Heaters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Water Heaters.
- b. Bradford White Corporation.
- c. Cemline Corporation.
- d. Electric Heater Company (The).
- e. GSW Water Heating.
- f. HESco Industries, Inc.
- g. Lochinvar Corporation.
- h. Precision Boilers, Inc.
- i. PVI Industries, LLC.
- j. RECO USA.
- k. Rheem Manufacturing Company.
- l. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
- m. State Industries.
- n. Vaughn Manufacturing Corporation.
- o. **<Insert manufacturer's name>**.
- p. or approved equal.

2. Standard: UL 1453.
 3. Storage-Tank Construction: **[Non-]ASME-code**, steel **[horizontal] [vertical]** arrangement.
 - a. Tappings: Factory fabricated of materials compatible with tank and piping connections. Attach tappings to tank before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.
 - b. Pressure Rating: **[150 psig (1035 kPa)] <Insert value>**.
 - c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending lining material into tappings.
 4. Factory-Installed Storage-Tank Appurtenances:
 - a. Anode Rod: Replaceable magnesium.
 - b. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
 - c. Insulation: Comply with ASHRAE/IESNA 90.1.
 - d. Jacket: Steel with enameled finish.
 - e. Heating Elements: Electric, screw-in or bolt-on immersion type arranged in multiples of three.
 - f. Temperature Control: Adjustable thermostat.
 - g. Safety Controls: High-temperature-limit and low-water cutoff devices or systems.
 - h. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
 5. Special Requirements: NSF 5 construction.
- C. Commercial, Light-Duty, Storage, Electric, Domestic-Water Heaters:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Water Heaters.
 - b. Bradford White Corporation.
 - c. Electric Heater Company (The).
 - d. GSW Water Heating.
 - e. Heat Transfer Products, Inc.
 - f. Lochinvar Corporation.
 - g. Rheem Manufacturing Company.
 - h. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - i. State Industries.

- j. **<Insert manufacturer's name>**.
 - k. or approved equal.
 2. Standard: UL 174.
 3. Storage-Tank Construction: Steel, vertical arrangement.
 - a. Tappings: ASME B1.20.1 pipe thread.
 - b. Pressure Rating: **150 psig** (1035 kPa).
 - c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending lining material into tappings.
 4. Factory-Installed Storage-Tank Appurtenances:
 - a. Anode Rod: Replaceable magnesium.
 - b. Dip Tube: Required unless cold-water inlet is near bottom of tank.
 - c. Drain Valve: ASSE 1005.
 - d. Insulation: Comply with ASHRAE/IESNA 90.1[**or ASHRAE 90.2**].
 - e. Jacket: Steel with enameled finish.
 - f. Heat-Trap Fittings: Inlet type in cold-water inlet and outlet type in hot-water outlet.
 - g. Heating Elements: Two; electric, screw-in immersion type; wired for simultaneous operation unless otherwise indicated. Limited to 12 kW total.
 - h. Temperature Control: Adjustable thermostat.
 - i. Safety Control: High-temperature-limit cutoff device or system.
 - j. Relief Valve: ASME rated and stamped for combination temperature-and-pressure relief valves. Include relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select relief valve with sensing element that extends into storage tank.
 5. Special Requirements: NSF 5 construction with legs for off-floor installation.
- D. Capacity and Characteristics:
 1. Capacity: **<Insert gal. (L)>**.
 2. Recovery: **<Insert gph (L/s)>** at [40 deg F (22 deg C)] [50 deg F (28 deg C)] [100 deg F (56 deg C)] **<Insert temperature>** temperature rise.
 3. Temperature Setting: [125 deg F (52 deg C)] [140 deg F (60 deg C)] [180 deg F (82 deg C)] **<Insert temperature>**.
 4. Power Demand: **<Insert kilowatts>**.
 5. Heating Elements:
 - a. Number of Elements: [Two] [Three] [Six] [Nine] **<Insert number>**.
 - b. Kilowatts Each Element: **<Insert kilowatts>**.
 - c. Number of Stages: [One] [Two] [Three] [Four] **<Insert number>**.
 6. Electrical Characteristics:
 - a. Volts: [120] [240] [277] [480] **<Insert value>**.
 - b. Phases: [Single] [Three].

- c. Hertz: 60.
- d. Full-Load Amperes: **<Insert value>**.
- e. Minimum Circuit Ampacity: **<Insert value>**.
- f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.2 ELECTRIC, TANKLESS, DOMESTIC-WATER HEATERS

A. Flow-Control, Electric, Tankless, Domestic-Water Heaters:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Bosch Water Heating.
- b. Chronomite Laboratories, Inc.
- c. Eemax, Inc.
- d. Stiebel Eltron, Inc.
- e. **<Insert manufacturer's name>**.
- f. or approved equal.

2. Standard: UL 499 for electric, tankless, (domestic-water heater) heating appliance.

3. Construction: Copper piping or tubing complying with NSF 61 barrier materials for potable water, without storage capacity.

- a. Connections: ASME B1.20.1 pipe thread.
- b. Pressure Rating: [150 psig (1035 kPa)] **<Insert value>**.
- c. Heating Element: Resistance heating system.
- d. Temperature Control: Flow-control fitting.
- e. Safety Control: High-temperature-limit cutoff device or system.
- f. Jacket: Aluminum or steel with enameled finish or plastic.

4. Support: Bracket for wall mounting.

5. Capacity and Characteristics:

- a. Flow Rate: **<Insert gpm (L/s)>**.
- b. Maximum Temperature Setting: **<Insert temperature>**.
- c. Power Demand: **<Insert kilowatts>**.
- d. Electrical Characteristics:
 - 1) Volts: [120] [240] [277] [480] **<Insert value>**.
 - 2) Phases: [Single] [Three].
 - 3) Hertz: 60.
 - 4) Full-Load Amperes: **<Insert value>**.
 - 5) Minimum Circuit Ampacity: **<Insert value>**.
 - 6) Maximum Overcurrent Protection: **<Insert amperage>**.

B. Thermostat-Control, Electric, Tankless, Domestic-Water Heaters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Bosch Water Heating.
 - b. Chronomite Laboratories, Inc.
 - c. E-Tankless Water Heaters Corp.
 - d. Keltech, Inc.
 - e. Niagara Industries, Inc.
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
2. Standard: UL 499 for electric, tankless, (domestic-water heater) heating appliance.
3. Construction: Copper piping or tubing complying with NSF 61 barrier materials for potable water, without storage capacity.
 - a. Connections: ASME B1.20.1 pipe thread.
 - b. Pressure Rating: [150 psig (1035 kPa)] **<Insert value>**.
 - c. Heating Element: Resistance heating system.
 - d. Temperature Control: Thermostat.
 - e. Safety Control: High-temperature-limit cutoff device or system.
 - f. Jacket: Aluminum or steel with enameled finish or plastic.
4. Support: Bracket for wall mounting.
5. Capacity and Characteristics:
 - a. Flow Rate: **<Insert gpm (L/s)>** at [100 deg F (56 deg C)] **<Insert temperature>** temperature rise.
 - b. Temperature Setting: [125 deg F (52 deg C)] [140 deg F (60 deg C)] **<Insert temperature>**.
 - c. Power Demand: **<Insert kilowatts>**.
 - d. Electrical Characteristics:
 - 1) Volts: [120] [240] [277] [480] **<Insert value>**.
 - 2) Phases: [Single] [Three].
 - 3) Hertz: 60.
 - 4) Full-Load Amperes: **<Insert value>**.
 - 5) Minimum Circuit Ampacity: **<Insert value>**.
 - 6) Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 DOMESTIC-WATER HEATER ACCESSORIES

A. Domestic-Water Compression Tanks:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. AMTROL Inc.
 - b. Flexcon Industries.

- c. Honeywell International Inc.
 - d. Pentair Pump Group (The); Myers.
 - e. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - f. State Industries.
 - g. Taco, Inc.
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Description: Steel pressure-rated tank constructed with welded joints and factory-installed butyl-rubber diaphragm. Include air precharge to minimum system-operating pressure at tank.
 3. Construction:
 - a. Tappings: Factory-fabricated steel, welded to tank before testing and labeling. Include ASME B1.20.1 pipe thread.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - c. Air-Charging Valve: Factory installed.
 4. Capacity and Characteristics:
 - a. Working-Pressure Rating: [100 psig (690 kPa)] [150 psig (1035 kPa)] **<Insert value>**.
 - b. Capacity Acceptable: [2 gal. (7.6 L)] [4 gal. (15.1 L)] [7 gal. (26.5 L)] [10 gal. (37.9 L)] **<Insert value>** minimum.
 - c. Air Precharge Pressure: **<Insert system pressure>**.
- B. Drain Pans: Corrosion-resistant metal with raised edge. Comply with ANSI/CSA LC 3. Include dimensions not less than base of domestic-water heater, and include drain outlet not less than **NPS 3/4 (DN 20)** with ASME B1.20.1 pipe threads or with ASME B1.20.7 garden-hose threads.
- C. Piping-Type Heat Traps: Field-fabricated piping arrangement according to ASHRAE/IESNA 90.1[**or ASHRAE 90.2**].
- D. Heat-Trap Fittings: ASHRAE 90.2.
- E. Manifold Kits: Domestic-water heater manufacturer's factory-fabricated inlet and outlet piping for field installation, for multiple domestic-water heater installation. Include ball-, butterfly-, or gate-type shutoff valves to isolate each domestic-water heater and **[calibrated] [memory-stop]** balancing valves to provide balanced flow through each domestic-water heater.
1. Comply with requirements for ball-, butterfly-, or gate-type shutoff valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 2. Comply with requirements for balancing valves specified in Section 221119 "Domestic Water Piping Specialties."
- F. Pressure-Reducing Valves: ASSE 1003 for water. Set at **25-psig- (172.5-kPa-)** maximum outlet pressure unless otherwise indicated.

- G. Combination Temperature-and-Pressure Relief Valves: ASME rated and stamped. Include relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select relief valves with sensing element that extends into storage tank.
- H. Pressure Relief Valves: ASME rated and stamped. Include pressure setting less than domestic-water heater working-pressure rating.
- I. Vacuum Relief Valves: ANSI Z21.22/CSA 4.4.
- J. Shock Absorbers: ASSE 1010 or PDI-WH 201, Size A water hammer arrester.
- K. Domestic-Water Heater Stands: Manufacturer's factory-fabricated steel stand for floor mounting, capable of supporting domestic-water heater and water. Include dimension that will support bottom of domestic-water heater a minimum of **18 inches** (457 mm) above the floor.
- L. Domestic-Water Heater Mounting Brackets: Manufacturer's factory-fabricated steel bracket for wall mounting, capable of supporting domestic-water heater and water.

2.4 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect domestic-water heaters specified to be ASME-code construction, according to ASME Boiler and Pressure Vessel Code.
- B. Hydrostatically test[**commercial**] domestic-water heaters to minimum of one and one-half times pressure rating before shipment.
- C. Electric, domestic-water heaters will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 DOMESTIC-WATER HEATER INSTALLATION

- A. Coordinate with plumbing piping and related electrical work to achieve operating system.
- B. Commercial, Electric, Domestic-Water Heater Mounting: Install commercial, electric, domestic-water heaters on concrete base. Comply with requirements for concrete bases specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

1. Exception: Omit concrete bases for commercial, electric, domestic-water heaters if installation on stand, bracket, suspended platform, or directly on floor is indicated.
 2. Maintain manufacturer's recommended clearances.
 3. Arrange units so controls and devices that require servicing are accessible.
 4. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on **18-inch (450-mm)** centers around the full perimeter of concrete base.
 5. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 6. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 7. Install anchor bolts to elevations required for proper attachment to supported equipment.
 8. Anchor domestic-water heaters to substrate.
- C. Electric, Tankless, Domestic-Water Heater Mounting: Install electric, tankless, domestic-water heaters[**at least 18 inches (457 mm) above floor**] on wall bracket.
1. Maintain manufacturer's recommended clearances.
 2. Arrange units so controls and devices that require servicing are accessible.
 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
 5. Anchor domestic-water heaters to substrate.
- D. Install electric, domestic-water heaters level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.
1. Install shutoff valves on domestic-water-supply piping to domestic-water heaters and on domestic-hot-water outlet piping. Comply with requirements for shutoff valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- E. Install commercial, electric, domestic-water heaters with seismic-restraint devices. Comply with requirements for seismic-restraint devices specified in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment."
- F. Install combination temperature-and-pressure relief valves in top portion of storage tanks. Use relief valves with sensing elements that extend into tanks. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- G. Install [**combination temperature-and-**]pressure relief valves in water piping for electric, domestic-water heaters without storage. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.

- H. Install water-heater drain piping as indirect waste to spill by positive air gap into open drains or over floor drains. Install hose-end drain valves at low points in water piping for electric, domestic-water heaters that do not have tank drains. Comply with requirements for hose-end drain valves specified in Section 221119 "Domestic Water Piping Specialties."
- I. Install thermometers on outlet piping of electric, domestic-water heaters. Comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- J. Install thermometers on inlet and outlet piping of residential, solar, electric, domestic-water heaters. Comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- K. Assemble and install inlet and outlet piping manifold kits for multiple electric, domestic-water heaters. Fabricate, modify, or arrange manifolds for balanced water flow through each electric, domestic-water heater. Include shutoff valve and thermometer in each domestic-water heater inlet and outlet, and throttling valve in each electric, domestic-water heater outlet. Comply with requirements for valves specified in Section 220523 "General-Duty Valves for Plumbing Piping," and comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- L. Install pressure-reducing valve with integral bypass relief valve in electric, domestic-water booster-heater inlet piping and water hammer arrester in booster-heater outlet piping. Set pressure-reducing valve for outlet pressure of [25 psig (172 kPa)] <Insert value>. Comply with requirements for pressure-reducing valves and water hammer arresters specified in Section 221119 "Domestic Water Piping Specialties."
- M. Install piping-type heat traps on inlet and outlet piping of electric, domestic-water heater storage tanks without integral or fitting-type heat traps.
- N. Fill electric, domestic-water heaters with water.
- O. Charge domestic-water compression tanks with air.

3.2 CONNECTIONS

- A. Comply with requirements for piping specified in Section 221116 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to electric, domestic-water heaters, allow space for service and maintenance of water heaters. Arrange piping for easy removal of domestic-water heaters.

3.3 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Electric, domestic-water heaters will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- C. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain **[commercial]** **[and]** **[tankless]**, electric, domestic-water heaters.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 223300

SECTION 223400 - FUEL-FIRED, DOMESTIC-WATER HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Commercial, atmospheric, gas-fired, storage, domestic-water heaters.
 - 2. Commercial, power-burner, gas-fired, storage, domestic-water heaters.
 - 3. Commercial, power-vent, gas-fired, storage, domestic-water heaters.
 - 4. Commercial, gas-fired, high-efficiency, storage, domestic-water heaters.
 - 5. Commercial, coil-type, finned-tube, gas-fired, domestic-water heaters.
 - 6. Commercial, grid-type, finned-tube, gas-fired, domestic-water heaters.
 - 7. Gas-fired, tankless, domestic-water heaters.
 - 8. Domestic-water heater accessories.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Commercial domestic-water heaters shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and size of domestic-water heater indicated. **[Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.]**
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1, Section 7, "Service Water Heating."

C. Shop Drawings:

1. Wiring Diagrams: For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For fuel-fired, domestic-water heaters, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

B. Product Certificates: For each type of [**commercial, gas-fired,**] [**gas-fired, tankless,**] [**residential, gas-fired,**] [**commercial, oil-fired,**] [**residential, oil-fired,**] [**and**] [**commercial, gas- and oil-fired,**] domestic-water heater, from manufacturer.

C. Domestic-Water Heater Labeling: Certified and labeled by testing agency acceptable to authorities having jurisdiction.

D. Source quality-control reports.

E. Field quality-control reports.

F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For fuel-fired, domestic-water heaters to include in emergency, operation, and maintenance manuals.

1. Include operation, maintenance, and inspection data, replacement part numbers and availability, and service depot location and telephone number.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE/IESNA Compliance: Fabricate and label fuel-fired, domestic-water heaters to comply with ASHRAE/IESNA 90.1.
- C. ASME Compliance:
 - 1. Where ASME-code construction is indicated, fabricate and label commercial, domestic-water heater storage tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - 2. Where ASME-code construction is indicated, fabricate and label commercial, finned-tube, domestic-water heaters to comply with ASME Boiler and Pressure Vessel Code: Section IV.
- D. NSF Compliance: Fabricate and label equipment components that will be in contact with potable water to comply with NSF 61, "Drinking Water System Components - Health Effects."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products under provisions of Section 220400 "Basic Plumbing Requirements" and Division 01
- B. Provide temporary inlet and outlet caps. Maintain caps in place until installation.

1.10 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of fuel-fired, domestic-water heaters that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures including storage tank and supports.
 - b. Faulty operation of controls.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal use.
 - 2. Warranty Periods: From date of Substantial Completion.

- a. Commercial, Gas-Fired, Storage, Domestic-Water Heaters:
 - 1) Storage Tank: Minimum[**three (3)**] [**five (5)**] <Insert number> years.
 - 2) Controls and Other Components: Minimum[**one (1)**] [**two (2)**] <Insert number> year(s).

- b. Commercial, Finned-Tube, Gas-Fired, Domestic-Water Heaters:
 - 1) Heat Exchanger: Minimum[**three (3)**] [**five (5)**] <Insert number> years.
 - 2) Controls and Other Components: Minimum[**one (1)**] [**two (2)**] <Insert number> year(s).
 - 3) Separate Hot-Water Storage Tanks: Minimum[**three (3)**] [**five (5)**] <Insert number> years.

- c. Gas-Fired, Tankless, Domestic-Water Heaters:
 - 1) Heat Exchanger: Minimum[**five (5)**] <Insert number> years.
 - 2) Controls and Other Components: Minimum[**three (3)**] <Insert number> years.

- d. Compression Tanks: Minimum[**five (5)**] <Insert number> years.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 COMMERCIAL, GAS-FIRED, STORAGE, DOMESTIC-WATER HEATERS

- A. Commercial, Atmospheric, Gas-Fired, Storage, Domestic-Water Heaters:
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Water Heaters.
 - b. Bock Water Heaters, Inc.
 - c. Bradford White Corporation.
 - d. GSW Water Heating.
 - e. HESco Industries, Inc.
 - f. Lochinvar Corporation.
 - g. PVI Industries, LLC.
 - h. RECO USA.
 - i. Rheem Manufacturing Company.
 - j. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.

- k. State Industries.
 - l. **<Insert manufacturer's name>**.
 - m. or approved equal.
2. Standard: ANSI Z21.10.3/CSA 4.3.
3. Storage-Tank Construction: **[Non-]**ASME-code steel with **[150-psig (1035-kPa)]** **<Insert value>** working-pressure rating.
- a. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - c. Lining: **[Cement] [Glass] [Nickel plate] [Phenolic coating] [Sheet copper]** **<Insert material>** complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.
4. Factory-Installed Storage-Tank Appurtenances:
- a. Anode Rod: Replaceable magnesium.
 - b. Dip Tube: Required unless cold-water inlet is near bottom of tank.
 - c. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
 - d. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls.
 - e. Jacket: Steel with enameled finish.
 - f. Burner: For use with atmospheric, gas-fired, domestic-water heaters and **[natural-gas] [LP-gas] <Insert fuel gas>** fuel.
 - g. Automatic Ignition: ANSI Z21.20/CSA C22.2 No. 199, electric, automatic, gas-ignition system.
 - h. Controls: Automatic water thermostat with temperature range adjustable from 120 to 180 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, flue baffle and draft hood.
 - i. Controls: Automatic direct immersion thermostat with temperature range adjustable minimum 175 degrees F differential, automatic reset high temperature limiting thermostat, factory set at 205 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, **[intermittent electronic ignition monitoring pilot and main flame, trial for re-ignition for momentary loss of flame, shut down of pilot and main burner in 2-4 seconds after loss of flame,] [and automatic flue damper] [and power venter]**.
 - j. Safety Controls: Automatic, high-temperature-limit and low-water cutoff devices or systems.

- k. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
 5. Special Requirements: NSF 5 construction.
 6. Draft Hood: Draft diverter, complying with ANSI Z21.12.
 7. Automatic Damper: ANSI Z21.66/CSA 6.14-M, **[electrically operated]** **[mechanically activated]** **[thermally activated]**, automatic-vent-damper device with size matching draft hood.
- B. Commercial, Power-Burner, Gas-Fired, Storage, Domestic-Water Heaters:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Aldrich Company, Inc. (The).
 - b. Bock Water Heaters, Inc.
 - c. HESco Industries, Inc.
 - d. Precision Boilers.
 - e. PVI Industries, LLC.
 - f. RECO USA.
 - g. Sellers Engineering Co.
 - h. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - i. State Industries.
 - j. **<Insert manufacturer's name>**.
 - k. or approved equal.
 2. Standard: ANSI Z21.10.3/CSA 4.3.
 3. Storage-Tank Construction: **[Non-]ASME**-code steel with **[150-psig (1035-kPa)]** **<Insert value>** working-pressure rating.
 - a. Multiple flu passages, 4 inch diameter inspection port.
 - b. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - d. Lining: **[Glass]** **<Insert material>** complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.
 4. Factory-Installed Storage-Tank Appurtenances:

- a. Anode Rod: Replaceable magnesium.
 - b. Dip Tube: Required unless cold-water inlet is near bottom of tank.
 - c. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
 - d. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls. Minimum 2 inches glass fiber.
 - e. Jacket: Steel with enameled finish.
 - f. Burner: UL 795 for power-burner, gas-fired, domestic-water heaters and **[natural-gas]** fuel.
 - g. Automatic Ignition: ANSI Z21.20/CSA C22.2 No. 199, electric, automatic, gas-ignition system.
 - h. Controls: Automatic water thermostat with temperature range adjustable from 120 to 180 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, flue baffle and draft hood.
 - i. Controls: Automatic direct immersion thermostat with temperature range adjustable minimum 175 degrees F differential, automatic reset high temperature limiting thermostat, factory set at 205 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, **[intermittent electronic ignition monitoring pilot and main flame, trial for re-ignition for momentary loss of flame, shut down of pilot and main burner in 2-4 seconds after loss of flame,] [and automatic flue damper] [and power venter]**.
 - j. Safety Controls: Automatic, high-temperature-limit and low-water cutoff devices or systems.
 - k. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
5. Special Requirements: NSF 5 construction.
6. Draft Hood: **[Draft diverter, complying with ANSI Z21.12] <Insert different hood or other arrangement>**.
- C. Commercial, Power-Vent, Gas-Fired, Storage, Domestic-Water Heaters:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Water Heaters.
 - b. Bradford White Corporation.
 - c. Lochinvar Corporation.
 - d. Rheem Manufacturing Company.
 - e. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - f. State Industries.
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
 2. Standard: ANSI Z21.10.3/CSA 4.3.

3. Storage-Tank Construction: **[Non-]**ASME-code steel with **[150-psig (1035-kPa)]** **<Insert value>** working-pressure rating.
 - a. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - c. Lining: **[Glass]** **<Insert material>** complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.
4. Factory-Installed Storage-Tank Appurtenances:
 - a. Anode Rod: Replaceable magnesium.
 - b. Dip Tube: Required unless cold-water inlet is near bottom of tank.
 - c. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
 - d. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls.
 - e. Jacket: Steel with enameled finish.
 - f. Burner: For use with power-vent, gas-fired, domestic-water heaters and **[natural-gas] [LP-gas]** **<Insert fuel gas>** fuel.
 - g. Automatic Ignition: ANSI Z21.20/CSA C22.2 No. 199, electric, automatic, gas-ignition system.
 - h. Controls: Automatic water thermostat with temperature range adjustable from 120 to 180 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, flue baffle and draft hood.
 - i. Controls: Automatic direct immersion thermostat with temperature range adjustable minimum 175 degrees F differential, automatic reset high temperature limiting thermostat, factory set at 205 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, **[intermittent electronic ignition monitoring pilot and main flame, trial for re-ignition for momentary loss of flame, shut down of pilot and main burner in 2-4 seconds after loss of flame,]** **[and automatic flue damper]** **[and power venter]**.
 - j. Safety Controls: Automatic, high-temperature-limit and low-water cutoff devices or systems.
 - k. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.

5. Special Requirements: NSF 5 construction.
6. Power-Vent System: Exhaust fan, interlocked with burner.

D. Commercial, Gas-Fired, High-Efficiency, Storage, Domestic-Water Heaters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. AERCO International, Inc.
- b. Ajax Boiler Inc.
- c. American Water Heaters.
- d. Bradford White Corporation.
- e. Heat Transfer Products, Inc.
- f. Lochinvar Corporation.
- g. PVI Industries, LLC.
- h. RBI Water Heaters; a Mestek company.
- i. Rheem Manufacturing Company.
- j. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
- k. State Industries.
- l. Weben-Jarco, Inc.
- m. **<Insert manufacturer's name>**.
- n. or approved equal.

2. Standard: ANSI Z21.10.3/CSA 4.3.

3. Description: Manufacturer's proprietary design to provide at least **[84] [85] [88] [95] <Insert number>** percent combustion efficiency at optimum operating conditions.

4. Storage-Tank Construction: ASME-code steel with **[150-psig (1035-kPa)] <Insert value>** minimum working-pressure rating.

a. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.

- 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
- 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.

b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.

c. Lining: **[Glass] <Insert material>** complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.

5. Factory-Installed Storage-Tank Appurtenances:

- a. Anode Rod: Replaceable magnesium.
- b. Dip Tube: Required unless cold-water inlet is near bottom of tank.
- c. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.

- d. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls.
 - e. Jacket: Steel with enameled finish.
 - f. Burner or Heat Exchanger: Comply with UL 795 or approved testing agency requirements for gas-fired, high-efficiency, domestic-water heaters and **[natural-gas] [LP-gas] <Insert fuel gas>** fuel.
 - g. Controls: Automatic water thermostat with temperature range adjustable from 120 to 180 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, flue baffle and draft hood.
 - h. Controls: Automatic direct immersion thermostat with temperature range adjustable minimum 175 degrees F differential, automatic reset high temperature limiting thermostat, factory set at 205 degrees F, gas pressure regulator, multi-ribbon or tubular burner, 100 percent safety shut-off pilot and thermocouple, **[intermittent electronic ignition monitoring pilot and main flame, trial for re-ignition for momentary loss of flame, shut down of pilot and main burner in 2-4 seconds after loss of flame,] [and automatic flue damper] [and power venter]**.
 - i. Safety Controls: Automatic, high-temperature-limit and low-water cutoff devices or systems.
 - j. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
6. Draft Hood: **[Draft diverter, complying with ANSI Z21.12] <Insert different hood or other arrangement>**.
- E. Capacity and Characteristics:
1. Capacity: **<Insert gal. (L)>**.
 2. Recovery: **<Insert gph (L/s)>** at **[100 deg F (56 deg C)] <Insert temperature>** temperature rise.
 3. Temperature Setting: **[125 deg F (52 deg C)] [140 deg F (60 deg C)] <Insert temperature>**.
 4. Fuel Gas Demand: **<Insert cfh (L/s)>**.
 5. Fuel Gas Input: **<Insert Btu/h (W)>**.
 6. Gas Pressure Regulator:
 - a. Capacity: **<Insert cfh (L/s)>**.
 - b. Inlet Pressure: **<Insert psig (kPa) or inches (mm)>** water column.
 - c. Gas Pressure Required at Burner: **<Insert psig (kPa) or inches (mm)>** water column.
7. Electrical Characteristics:
- a. Volts: **[120] [240] [277] [480] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.

- d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
8. Minimum Vent Diameter: **<Insert inches (mm)>**.

2.2 COMMERCIAL, FINNED-TUBE, GAS-FIRED, DOMESTIC-WATER HEATERS

A. Commercial, Coil-Type, Finned-Tube, Gas-Fired, Domestic-Water Heaters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Ajax Boiler Inc.
 - b. CAMUS Hydronics Ltd.
 - c. Laars Heating Systems Company; a subsidiary of Bradford White Corporation.
 - d. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - e. Weben-Jarco, Inc.
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
2. Standard: ANSI Z21.13/CSA 4.9 for hot-water-supply boilers.
3. Description: Packaged unit with boiler, separate hot-water storage tank, pump, piping, and controls.
4. Boiler Construction: ASME code with [160-psig (1100-kPa)] **<Insert value>** working-pressure rating for hot-water-supply boiler, domestic-water heater.
- a. Heat Exchanger: Helix or spiral, finned-copper-tube coils with bronze headers.
 - b. Connections: Factory fabricated of materials compatible with boiler. Attach to boiler before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
5. Boiler Appurtenances:
- a. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire boiler except connections and controls.
 - b. Jacket: Steel with enameled finish.
 - c. Burner: For use with coil-type, finned-tube, gas-fired, domestic-water heaters and **[natural-gas]** fuel.
 - d. Automatic Ignition: ANSI Z21.20/CSA C22.2 No. 199, intermittent electronic-ignition system.

- e. Temperature Control: Adjustable, storage-tank temperature-control fitting and flow switch, interlocked with circulator and burner.
 - f. Safety Control: Automatic, high-temperature-limit cutoff device or system.
6. Support: Steel base or skids.
7. Draft Hood: **[Draft diverter, complying with ANSI Z21.12] <Insert different hood or other arrangement>**.
8. Automatic Damper: ANSI Z21.66/CSA 6.14-M, **[electrically operated] [mechanically activated] [thermally activated]**, automatic-vent-damper device with size matching draft hood.
9. Hot-Water Storage Tank: Connected with piping to circulating pump and domestic-water heater.
- a. Construction: According to ASME Boiler and Pressure Vessel Code: Section VIII, steel with **[150-psig (1035-kPa)] [125-psig (860-kPa)] <Insert value>** working-pressure rating.
 - b. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
10. Factory-Installed Storage-Tank Appurtenances:
- a. Anode Rods: Factory installed, magnesium.
 - b. Drain Valve: Corrosion-resistant metal complying with ASSE 1005, factory installed.
 - c. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls.
 - d. Jacket: Steel with enameled finish.
 - e. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
11. Circulating Pump: UL 778, all-bronze, centrifugal, overhung-impeller, separately coupled in-line pump as defined in HI 1.1-1.2 and HI 1.3. Include mechanical seals, **[125-psig (860-kPa)] <Insert value>** minimum working-pressure rating, and **225 deg F (107 deg C)** continuous-water-temperature rating.
12. Piping: Copper tubing; copper, solder-joint fittings; and brazed or flanged joints.
13. Mounting: Domestic-water heater, tank, and accessories factory mounted on skids.

B. Commercial, Grid-Type, Finned-Tube, Gas-Fired, Domestic-Water Heaters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Bradford White Corporation.
 - b. CAMUS Hydronics Ltd.
 - c. HESco Industries, Inc.
 - d. Laars Heating Systems Company; a subsidiary of Bradford White Corporation.
 - e. Lochinvar Corporation.
 - f. Raypak; a Rheem company.
 - g. RBI Water Heaters; a Mestek company.
 - h. RECO USA.
 - i. Rheem Manufacturing Company.
 - j. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - k. **<Insert manufacturer's name>**.
 - l. or approved equal.
2. Standard: ANSI Z21.13/CSA 4.9 for hot-water-supply boilers.
3. Description: Packaged unit with boiler, storage tank, pump, piping, and controls.
4. Boiler Construction: ASME code with [160-psig (1100-kPa)] **<Insert value>** working-pressure rating for hot-water-boiler-type, domestic-water heater.
 - a. Heat Exchanger: Horizontal, straight, finned-copper tubes with bronze headers.
 - b. Connections: Factory fabricated of materials compatible with boiler. Attach to boiler before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
5. Boiler Appurtenances:
 - a. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire boiler except connections and controls.
 - b. Jacket: Steel with enameled finish.
 - c. Burner: For use with grid-type, finned-tube, gas-fired, domestic-water heaters and [**natural-gas**] [**LP-gas**] **<Insert fuel gas>** fuel.
 - d. Automatic Ignition: ANSI Z21.20/CSA C22.2 No. 199, intermittent electronic-ignition system.
 - e. Temperature Control: Adjustable, storage-tank temperature-control fitting and flow switch, interlocked with circulator and burner.
 - f. Safety Control: Automatic, high-temperature-limit cutoff device or system.
6. Support: Steel base or skids.

7. Draft Hood: **[Draft diverter, complying with ANSI Z21.12] <Insert different hood or other arrangement>**.
 8. Automatic Damper: ANSI Z21.66/CSA 6.14-M, **[electrically operated] [mechanically activated] [thermally activated]**, automatic-vent-damper device with size matching draft hood.
 9. Hot-Water Storage Tank: Connected with piping to circulating pump and domestic-water heater.
 - a. Construction: According to ASME Boiler and Pressure Vessel Code: Section VIII, steel with **[150-psig (1035-kPa)] [125-psig (860-kPa)] <Insert value>** working-pressure rating.
 - b. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 10. Factory-Installed Storage-Tank Appurtenances:
 - a. Anode Rods: Factory installed, magnesium.
 - b. Drain Valve: Corrosion-resistant metal complying with ASSE 1005, factory installed.
 - c. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls.
 - d. Jacket: Steel with enameled finish.
 - e. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
 11. Circulating Pump: UL 778, all-bronze, centrifugal, overhung-impeller, separately coupled in-line pump as defined in HI 1.1-1.2 and HI 1.3. Include mechanical seals, **[125-psig (860-kPa)] <Insert value>** minimum working-pressure rating, and **225 deg F (107 deg C)** continuous-water-temperature rating.
 12. Piping: Copper tubing; copper, solder-joint fittings; and brazed or flanged joints.
 13. Mounting: Domestic-water heater, tank, and accessories factory mounted on skids.
- C. Capacity and Characteristics:
1. Hot-Water Storage-Tank Capacity: **<Insert gal. (L)>**.
 2. Recovery: **<Insert gph (L/s)>** at **[100 deg F (56 deg C)] <Insert temperature>** temperature rise.

3. Temperature Setting: [125 deg F (52 deg C)] [140 deg F (60 deg C)] **<Insert temperature>**.
4. Fuel Gas Demand: **<Insert cfh (L/s)>**.
5. Fuel Gas Input: **<Insert Btu/h (W)>**.
6. Gas Pressure Regulator:
 - a. Capacity: **<Insert cfh (L/s)>**.
 - b. Inlet Pressure: **<Insert psig (kPa) or inches (mm)>** water column.
 - c. Gas Pressure Required at Burner: **<Insert psig (kPa) or inches (mm)>** water column.
7. Electrical Characteristics:
 - a. Volts: [120] [240] [277] [480] **<Insert value>**.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
8. Minimum Vent Diameter: **<Insert inches (mm)>**.

2.3 GAS-FIRED, TANKLESS, DOMESTIC-WATER HEATERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 1. Baxi.
 2. Bosch Water Heating.
 3. Bradford White Corporation.
 4. NORITZ America Corp.
 5. Paloma Industries, Inc.
 6. Rheem Manufacturing Company; Rheem Water Heating.
 7. Rinnai Corporation.
 8. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 9. State Industries.
 10. Takagi.
 11. WaiWela.
 12. **<Insert manufacturer's name>**.
 13. or approved equal.
- B. Standard: ANSI Z21.10.3/CSA 4.3 for gas-fired, instantaneous, domestic-water heaters for indoor application.
- C. Construction: Copper piping or tubing complying with NSF 61 barrier materials for potable water, without storage capacity.
 1. Tappings: ASME B1.20.1 pipe thread.
 2. Pressure Rating: 150 psig (1035 kPa).

3. Heat Exchanger: Copper tubing.
4. Insulation: Comply with ASHRAE/IESNA 90.1[or **ASHRAE 90.2**].
5. Jacket: Metal, with enameled finish, or plastic.
6. Burner: For use with tankless, domestic-water heaters and [**natural-gas**] [**LP-gas**] <Insert fuel gas> fuel.
7. Automatic Ignition: Manufacturer's proprietary system for automatic, gas ignition.
8. Temperature Control: Adjustable thermostat.

D. Support: Bracket for wall mounting.

E. Capacity and Characteristics:

1. Flow Rate: <Insert gpm (L/s)> at [100 deg F (56 deg C)] <Insert temperature> temperature rise.
2. Temperature Setting: [125 deg F (52 deg C)] [140 deg F (60 deg C)] <Insert temperature>.
3. Fuel Gas Demand: <Insert cfh (L/s)>.
4. Fuel Gas Input: <Insert Btu/h (W)>.
5. Gas Pressure Regulator:
 - a. Capacity: <Insert cfh (L/s)>.
 - b. Inlet Pressure: <Insert psig (kPa) or inches (mm)> water column.
 - c. Gas Pressure Required at Burner: <Insert psig (kPa) or inches (mm)> water column.
6. Electrical Characteristics:
 - a. Volts: [120] <Insert value>.
 - b. Phase: Single.
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
7. Minimum Vent Diameter: <Insert inches (mm)>.

2.4 DOMESTIC-WATER HEATER ACCESSORIES

A. Domestic-Water Compression Tanks:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. AMTROL Inc.
 - b. Flexcon Industries.
 - c. Honeywell International Inc.
 - d. Pentair Pump Group (The); Myers.
 - e. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - f. State Industries.

- H. Automatic Gas Valves: ANSI Z21.21/CSA 6.5, appliance, electrically operated, on-off automatic valve.
- I. Combination Temperature-and-Pressure Relief Valves: Include relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select relief valves with sensing element that extends into storage tank.
 - 1. Gas-Fired, Domestic-Water Heaters: ANSI Z21.22/CSA 4.4-M.
 - 2. Oil-Fired, Domestic-Water Heaters: ASME rated and stamped.
- J. Pressure Relief Valves: Include pressure setting less than domestic-water heater working-pressure rating.
 - 1. Gas-Fired, Domestic-Water Heaters: ANSI Z21.22/CSA 4.4-M.
 - 2. Oil-Fired, Domestic-Water Heaters: ASME rated and stamped.
- K. Vacuum Relief Valves: ANSI Z21.22/CSA 4.4-M.
- L. Domestic-Water Heater Stands: Manufacturer's factory-fabricated steel stand for floor mounting, capable of supporting domestic-water heater and water. Provide dimension that will support bottom of domestic-water heater a minimum of **18 inches** (457 mm) above the floor.
- M. Domestic-Water Heater Mounting Brackets: Manufacturer's factory-fabricated steel bracket for wall mounting, capable of supporting domestic-water heater and water.

2.5 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect assembled domestic-water heaters[**and storage tanks**] specified to be ASME-code construction, according to ASME Boiler and Pressure Vessel Code.
- B. Hydrostatically test[**commercial**] domestic-water heaters[**and storage tanks**] to minimum of one and one-half times pressure rating before shipment.
- C. Domestic-water heaters will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 DOMESTIC-WATER HEATER INSTALLATION

- A. Coordinate with plumbing piping and related electrical work to achieve operating

system.

- B. Commercial, Domestic-Water Heater Mounting: Install commercial domestic-water heaters on concrete base. Comply with requirements for concrete base specified in **[Section 033000 "Cast-in-Place Concrete."]** **[Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
1. Exception: Omit concrete bases for commercial domestic-water heaters if installation on stand, bracket, suspended platform, or directly on floor is indicated.
 2. Maintain manufacturer's recommended clearances.
 3. Arrange units so controls and devices that require servicing are accessible.
 4. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on **18-inch (450-mm)** centers around the full perimeter of concrete base.
 5. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 6. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 7. Install anchor bolts to elevations required for proper attachment to supported equipment.
 8. Anchor domestic-water heaters to substrate.
- C. Tankless, Domestic-Water Heater Mounting: Install tankless, domestic-water heaters **[at least 18 inches (457 mm) above floor]** on wall bracket.
1. Maintain manufacturer's recommended clearances.
 2. Arrange units so controls and devices that require servicing are accessible.
 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
 5. Anchor domestic-water heaters to substrate.
- D. Install domestic-water heaters level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.
1. Install shutoff valves on domestic-water-supply piping to domestic-water heaters and on domestic-hot-water outlet piping. Comply with requirements for shutoff valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- E. Install gas-fired, domestic-water heaters according to NFPA 54.
1. Install gas shutoff valves on gas supply piping to gas-fired, domestic-water heaters without shutoff valves.
 2. Install gas pressure regulators on gas supplies to gas-fired, domestic-water heaters without gas pressure regulators if gas pressure regulators are required to reduce gas pressure at burner.

3. Install automatic gas valves on gas supplies to gas-fired, domestic-water heaters if required for operation of safety control.
 4. Comply with requirements for gas shutoff valves, gas pressure regulators, and automatic gas valves specified in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**]
- F. Install commercial domestic-water heaters with seismic-restraint devices. Comply with requirements for seismic-restraint devices specified in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment."
- G. Install combination temperature-and-pressure relief valves in top portion of storage tanks. Use relief valves with sensing elements that extend into tanks. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- H. Install [**combination temperature-and-**]pressure relief valves in water piping for domestic-water heaters without storage. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- I. Install water-heater drain piping as indirect waste to spill by positive air gap into open drains or over floor drains. Install hose-end drain valves at low points in water piping for domestic-water heaters that do not have tank drains. Comply with requirements for hose-end drain valves specified in Section 221119 "Domestic Water Piping Specialties."
- J. Install thermometer on outlet piping of domestic-water heaters. Comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- K. Assemble and install inlet and outlet piping manifold kits for multiple domestic-water heaters. Fabricate, modify, or arrange manifolds for balanced water flow through each domestic-water heater. Include shutoff valve and thermometer in each domestic-water heater inlet and outlet, and throttling valve in each domestic-water heater outlet. Comply with requirements for valves specified in Section 220523 "General-Duty Valves for Plumbing Piping," and comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- L. Install piping-type heat traps on inlet and outlet piping of domestic-water heater storage tanks without integral or fitting-type heat traps.
- M. Fill domestic-water heaters with water.
- N. Charge domestic-water compression tanks with air.

3.2 CONNECTIONS

- A. Comply with requirements for domestic-water piping specified in Section 221116 "Domestic Water Piping."
- B. Comply with requirements for fuel-oil piping specified in Section 231113 "Facility Fuel-Oil Piping."
- C. Comply with requirements for gas piping specified in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**]
- D. Drawings indicate general arrangement of piping, fittings, and specialties.
- E. Where installing piping adjacent to fuel-fired, domestic-water heaters, allow space for service and maintenance of water heaters. Arrange piping for easy removal of domestic-water heaters.

3.3 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Domestic-water heaters will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- C. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain [**commercial,**

**gas-fired, storage,] [gas-fired, tankless] [commercial, oil-fired,] [commercial, gas-
and oil-fired,] domestic-water heaters.**

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 223400

SECTION 223500 - DOMESTIC-WATER HEAT EXCHANGERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
1. Shell-and-tube, heating-fluid-in-coil, domestic-water heat exchangers.
 2. Shell-and-tube, domestic-water-in-coil, domestic-water heat exchangers.
 3. Shell-and-tube, heating-fluid-in-U-tube-coil, domestic-water heat exchangers.
 4. Circulating, compact, domestic-water heat exchangers.
 5. Circulating, storage, domestic-water heat exchangers.
 6. Noncirculating, compact, domestic-water heat exchangers.
 7. Noncirculating, storage, domestic-water heat exchangers.
 8. Brazed-plate, domestic-water heat exchangers.
 9. Frame-and-plate, domestic-water heat exchangers.
 10. Domestic-water, heat reclaimers.
 11. Domestic-water, heat-exchanger accessories.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Domestic-water heat exchangers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and size of domestic-water heat exchanger indicated.[**Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.**]
1. Include data substantiating that materials comply with requirements.

- B. Shop Drawings:
 - 1. Wiring Diagrams: For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For domestic-water heat exchangers, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Product Certificates: For each type of **[shell-and-tube] [circulating] [noncirculating] [and] [plate]**, domestic-water heat exchanger, from manufacturer.
- C. Domestic-Water, Heat-Exchanger Labeling: Certified and labeled by testing agency acceptable to authorities having jurisdiction.
- D. Source quality-control reports.
- E. Field quality-control reports.
- F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For domestic-water heat exchangers to include in emergency, operation, and maintenance manuals.
 - 1. Include operation, maintenance, and inspection data, replacement part numbers and availability, and service depot location and telephone number.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

- C. ASME Compliance: Where ASME-code construction is indicated, fabricate and label heat-exchanger storage tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- D. NSF Compliance: Fabricate and label equipment components that will be in contact with potable water to comply with NSF 61, "Drinking Water System Components - Health Effects."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Section 220400 "Basic Plumbing Requirements" and Division 01.

1.10 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of domestic-water heat exchangers that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

- a. Structural failures including heat exchanger, storage tank, and supports.
- b. Faulty operation of controls.
- c. Deterioration of metals, metal finishes, and other materials beyond normal use.

2. Warranty Periods: From date of Substantial Completion.

a. Shell-and-Tube, Domestic-Water Heat Exchangers:

- 1) Tube Coil: Minimum[**one (1)**] <Insert number> year(s).
- 2) Controls and Other Components: Minimum[**one (1)**] <Insert number> year(s).

b. Circulating, Storage, Domestic-Water Heat Exchangers:

- 1) Storage Tank: Minimum[**five (5)**] <Insert number> years.
- 2) Tube Coil: Minimum[**five (5)**] <Insert number> years.
- 3) Controls and Other Components: Minimum[**three (3)**] <Insert number> years.

c. Noncirculating, Storage, Domestic-Water Heat Exchangers:

- 1) Storage Tank: Minimum[**five (5)**] <Insert number> years.

- 2) Tube Coil: Minimum[**five (5)**] <Insert number> years.
 - 3) Controls and Other Components: Minimum[**three (3)**] <Insert number> years.
- d. Plate, Domestic-Water Heat Exchangers:
- 1) Brazed-Plate Type: Minimum[**one (1)**] <Insert number> year(s).
 - 2) Plate-and-Frame Type: Minimum[**one (1)**] <Insert number> year(s).
- e. Domestic-Water, Heat Reclaimers: Minimum[**one (1)**] <Insert number> year(s).
- f. Compression Tanks: Minimum[**one (1)**] <Insert number> year(s).

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SHELL-AND-TUBE, DOMESTIC-WATER HEAT EXCHANGERS

- A. Shell-and-Tube, Heating-Fluid-in-Coil, Domestic-Water Heat Exchangers:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [AERCO International, Inc.](#)
 - b. <Insert manufacturer's name>.
 - c. or approved equal.
 2. Description: Packaged assembly of tank, heat-exchanger coils, controls, and specialties for heating domestic water with [**heating hot water**] [**steam**] in coils.
 3. Construction: ASME-code, negligible-capacity, copper-lined, carbon-steel shell with [**150-psig (1035-kPa)**] <Insert value> minimum working-pressure rating.
 - a. Tappings: Factory fabricated of materials compatible with heat-exchanger shell. Attach tappings to shell before testing and labeling.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.

- b. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire shell and nozzle except connections and controls.
 4. Heat-Exchanger Coils: **[Copper] [Copper nickel] [Stainless-steel]**, helix-wound coils for heating fluid. Include pressure rating equal to or greater than heating-fluid supply pressure.
 5. Temperature Control: Adjustable thermostat that operates control valve and is capable of maintaining outlet-water temperature within **4 deg F (2 deg C)** of setting.
 6. Safety Control: Automatic, high-temperature-limit cutoff device or system.
 7. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than working-pressure rating of heat exchanger. Select one relief valve with sensing element that extends into storage tank.
 8. Miscellaneous Components for Heating Hot-Water Unit: Control valve, valves, and piping. **[Include components fitted for pneumatic control.]**
 9. Miscellaneous Components for Steam Unit: Strainers, steam-control valve, steam trap, valves, pressure gage, thermometer, and piping. **[Include components fitted for pneumatic control.]**
 - a. Exception: Steam trap is not required if manufacturer's written instructions direct that it not be used.
 10. Stand: Factory fabricated for floor mounting.
- B. Shell-and-Tube, Domestic-Water-in-Coil, Domestic-Water Heat Exchangers:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Electric Heater Company \(The\)](#).
 - b. [Graham Corporation](#).
 - c. [Leslie Controls, Inc.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Description: Tankless, packaged assembly of heat-exchanger coils, controls, and specialties for heating domestic water in coils with steam in shell.
 3. Construction: ASME code, with **[cast-iron] [or] [steel]** shell for steam.
 - a. Cast-Iron Shell Pressure Rating: **[50 psig (345 kPa)] [75 psig (517 kPa)]**.
 - b. Steel Shell Pressure Rating: **150 psig (1035 kPa)**.
 - c. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire shell and nozzle except connections and controls.
 4. Heat-Exchanger Coils: Spiral-wound, **[copper or copper-alloy] [stainless-steel]** coils for domestic water.

5. Temperature Control: Adjustable thermostat that operates steam-control valve and is capable of maintaining outlet-water temperature within **3 deg F (2 deg C)** of setting.
 6. Safety Control: Automatic, high-temperature-limit cutoff device or system.
 7. Miscellaneous Components: Strainers, steam-control valve, steam trap, valves, and piping.
 8. Stand: Factory fabricated for floor mounting.
- C. Shell-and-Tube, Heating-Fluid-in-U-Tube-Coil, Domestic-Water Heat Exchangers:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Adamson Global Technology Corporation.](#)
 - b. [Ajax Boiler Inc.](#)
 - c. [Armstrong International, Inc.](#)
 - d. [Cemline Corporation.](#)
 - e. [HESco Industries, Inc.](#)
 - f. [Leslie Controls, Inc.](#)
 - g. [Patterson-Kelley; a division of Harsco Corporation.](#)
 - h. [Precision Boilers, Inc.](#)
 - i. [PVI Industries, LLC.](#)
 - j. [RECO USA.](#)
 - k. [Sellers Engineering Co.](#)
 - l. **<Insert manufacturer's name>.**
 - m. or approved equal.
 2. Description: Tankless, packaged assembly of heat-exchanger coil, controls, and specialties for heating domestic water in shell with **[heating hot water] [steam]** in coil.
 3. Construction: ASME-code, negligible-capacity, copper-lined, carbon-steel or copper-alloy shell with **[150-psig (1035-kPa)] <Insert value>** minimum working-pressure rating.
 - a. Configuration: **[Horizontal] [Vertical]**.
 - b. Shell Tappings: Factory fabricated of materials compatible with domestic-water, heat-exchanger shell. Attach tappings to shell before testing and labeling.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - c. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire shell and nozzle except connections and controls.

4. Heat-Exchanger Coil: Copper, **[double]** **[single]**-wall U tubes for heating fluid. Include tube pressure rating equal to or greater than heating-fluid supply pressure.
5. Temperature Control: Adjustable thermostat that operates steam-control valve and is capable of maintaining outlet-water temperature within **5 deg F (3 deg C)** of setting.
6. Safety Control: Automatic, high-temperature-limit cutoff device or system.
7. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than working-pressure rating of heat exchanger. Select one relief valve with sensing element that extends into shell.
8. Miscellaneous Components for Heating Hot-Water Unit: Control valve, valves, and piping. **[Include components fitted for pneumatic control.]**
9. Miscellaneous Components for Steam Unit: Strainers, steam-control valve, steam trap, valves, pressure gage, thermometer, and piping. **[Include components fitted for pneumatic control.]**
10. Stand: Factory fabricated for floor mounting.

D. Capacity and Characteristics:

1. Flow Rate: **<Insert gpm (L/s)>** at **[100 deg F (56 deg C)] <Insert temperature>** temperature rise.
2. Hot-Water Temperature Setting: **<Insert deg F (deg C)>**.
3. Domestic-Water Pipe Size: **<Insert NPS (DN)>**.
4. Heating Hot-Water Supply:
 - a. Inlet Temperature: **<Insert deg F (deg C)>**.
 - b. Outlet Temperature: **<Insert deg F (deg C)>**.
 - c. Pipe Size: **<Insert NPS (DN)>**.
5. Steam Supply:
 - a. Inlet Pressure: **<Insert psig (kPa)>**.
 - b. Demand Rate: **<Insert lb/h (kg/s)>**.
 - c. Input Rating: **<Insert Btu/h (kW)>**.
 - d. Steam Pipe Size: **<Insert NPS (DN)>**.
6. Condensate Pipe Size: **<Insert NPS (DN)>**.
7. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phases: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.2 CIRCULATING, DOMESTIC-WATER HEAT EXCHANGERS

A. Circulating, Compact, Domestic-Water Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Adamson Global Technology Corporation.](#)
 - b. [Ajax Boiler Inc.](#)
 - c. [Cemline Corporation.](#)
 - d. [Patterson-Kelley; a division of Harsco Corporation.](#)
 - e. [PVI Industries, LLC.](#)
 - f. [RECO USA.](#)
 - g. **<Insert manufacturer's name>.**
 - h. or approved equal.
2. Description: Packaged, small-capacity, hot-water storage tank with heat-exchanger coil; circulator; controls; and specialties for heating domestic water with **[heating hot water] [steam]** in coil.
3. Flow Pattern: Standard-flow arrangement, with water from bottom of storage tank circulated across heat-exchanger coil and returned to tank. Include hot-water outlet located at top of tank and temperature sensor in tank.
4. Storage-Tank Construction: ASME-code, copper-silicon or corrosion-resistant metal with **150-psig (1035-kPa)** working-pressure rating. Include nozzle and head for heat-exchanger tube coil.
 - a. Configuration: Vertical.
 - b. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing and labeling.
 - 1) **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - c. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire storage tank and nozzle except connections and controls.
5. Heat-Exchanger Coil: **[NPS 3/4 (DN 20)] [NPS 1-1/4 (DN 32)] <Insert pipe size>** diameter, **[vented, double-wall,]**copper or copper-alloy U tubes with tube sheet and supporting baffles. Include heat-exchanger pressure rating equal to or greater than heating-fluid supply pressure.
6. Temperature Control: Adjustable thermostat.
7. Safety Control: Automatic, high-temperature-limit cutoff device or system. Include automatic low-water cutoff device or system.
8. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure

- setting less than working-pressure rating of heat exchanger. Select one relief valve with sensing element that extends into storage tank.
9. Gages: Factory-mounted thermometer and pressure gage.
 10. Circulating Pump: UL 778, all-bronze, centrifugal, overhung-impeller, separately coupled in-line pump as defined in HI 1.1-1.2 and HI 1.3. Include mechanical seals, [125-psig (860-kPa)] <Insert value> minimum working-pressure rating, and 225 deg F (107 deg C) continuous-water-temperature rating.
 - a. Pump Control: Sensor for operating pump and control valve.
 11. Miscellaneous Components for Heating Hot-Water Units: Control valve, valves, and piping.
 12. Miscellaneous Components for Steam Units: Strainers, steam-control valve, steam trap, valves, and piping.
 13. Support: Factory mounted on skids.
 14. Energy Management System Interface: Normally closed dry contacts for enabling and disabling heat exchanger.
- B. Circulating, Storage, Domestic-Water Heat Exchangers:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Adamson Global Technology Corporation.](#)
 - b. [Ajax Boiler Inc.](#)
 - c. [Cemline Corporation.](#)
 - d. [Electric Heater Company \(The\).](#)
 - e. [Patterson-Kelley; a division of Harsco Corporation.](#)
 - f. [PVI Industries, LLC.](#)
 - g. [RECO USA.](#)
 - h. [Sellers Engineering Co.](#)
 - i. [Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.](#)
 - j. <Insert manufacturer's name>.
 - k. or approved equal.
 2. Description: Packaged, large-capacity, hot-water storage tank with heat-exchanger coil; circulator; controls; and specialties for heating domestic water with [heating hot water] [steam] in coil.
 3. Flow Pattern: Standard-flow arrangement, with water from bottom of storage tank circulated across heat-exchanger coil and returned to tank. Include hot-water outlet located at top of tank and temperature sensor in tank.
 4. Flow Pattern: Reverse-flow arrangement, with water from storage tank drawn across heat-exchanger coil and returned to bottom of tank. Include hot-water outlet and temperature sensor located in or at coil shell.
 5. Storage-Tank Construction: ASME-code [steel] <Insert material> with [125-psig (860-kPa)] [150-psig (1035-kPa)] <Insert value> working-pressure rating. Include nozzle and head for heat-exchanger tube coil.
 - a. Configuration: [Horizontal] [Vertical].

- b. Manhole: **11 by 15 inches** (280 by 380 mm) in **[end head of horizontal]** **[sidewall of vertical]** storage-tank shell.
 - c. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing and labeling.
 - 1) **NPS 2** (DN 50) and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) **NPS 2-1/2** (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - d. Lining: **[Cement]** **[Glass]** **[Nickel plate]** **[Phenolic coating]** **[Sheet copper]** **<Insert material>** complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.
 - e. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire storage tank and nozzle except connections and controls.
 - f. Anode Rods: Factory installed, magnesium.
6. Heat-Exchanger Coil: **[NPS 3/4** (DN 20)] **[NPS 1-1/4** (DN 32)] **<Insert pipe size>** diameter, **[vented, double-wall,**]copper or copper-alloy U tubes with tube sheet and supporting baffles. Include heat-exchanger pressure rating equal to or greater than heating-fluid supply pressure.
7. Temperature Control: Adjustable temperature aquastat, mounted in storage-tank shell head unless otherwise indicated.
8. Safety Control: Automatic, high-temperature-limit cutoff device or system. Include automatic low-water cutoff device or system.
9. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than working-pressure rating of heat exchanger. Select one relief valve with sensing element that extends into storage tank.
10. Gages: Factory-mounted thermometer and pressure gage.
11. Circulating Pump: UL 778, all-bronze, centrifugal, overhung-impeller, separately coupled in-line pump as defined in HI 1.1-1.2 and HI 1.3. Include mechanical seals, **[125-psig** (860-kPa)] **<Insert value>** minimum working-pressure rating, and **225 deg F** (107 deg C) continuous-water-temperature rating.
 - a. Pump Control: Sensor for operating pump and control valve.
12. Support: Factory mounted on skids.
13. Energy Management System Interface: Normally closed dry contacts for enabling and disabling heat exchanger.
- C. Capacity and Characteristics:
- 1. Capacity: **<Insert gal. (L)>**.
 - 2. Recovery: **<Insert gph (L/s)>** at **[100 deg F** (56 deg C)] **<Insert temperature>** temperature rise.

3. Domestic-Water Pipe Size: <Insert NPS (DN)>.
4. Hot-Water Temperature Setting: <Insert deg F (deg C)>.
5. Heating Hot-Water Supply:
 - a. Inlet Temperature: <Insert deg F (deg C)>.
 - b. Outlet Temperature: <Insert deg F (deg C)>.
 - c. Pipe Size: <Insert NPS (DN)>.
6. Steam Supply:
 - a. Inlet Pressure: <Insert psig (kPa)>.
 - b. Demand Rate: <Insert lb/h (kg/s)>.
 - c. Input Rating: <Insert Btu/h (kW)>.
 - d. Steam Pipe Size: <Insert NPS (DN)>.
7. Condensate Pipe Size: <Insert NPS (DN)>.
8. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phases: <Insert value>.
 - c. Hertz: <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.3 NONCIRCULATING, DOMESTIC-WATER HEAT EXCHANGERS

A. Noncirculating, Compact, Domestic-Water Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL Inc.](#)
 - b. [Bradford White Corporation.](#)
 - c. [Burnham Hydronics.](#)
 - d. [Crown Boiler Co.](#)
 - e. [ECR International.](#)
 - f. [Electric Heater Company \(The\).](#)
 - g. [Group Thermo Inc.](#)
 - h. [GSW Water Heating.](#)
 - i. [Heat Transfer Products, Inc.](#)
 - j. [Therma-Flow/Everhot.](#)
 - k. [Vaughn Manufacturing Corporation.](#)
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
2. Description: Hot-water storage tank with integral heat-exchanger coil, controls, and specialties for heating domestic water with [heating hot water] [steam] in coil.

3. Storage-Tank Shell Construction: Steel or stainless steel with 150-psig (1035-kPa) working-pressure rating.
 - a. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing and labeling. Include ASME B1.20.1 pipe thread.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - c. Insulation: Complying with ASHRAE/IESNA 90.1 or ASHRAE 90.2, and suitable for operating temperature. Surround entire storage tank except connections and controls.
 - d. Jacket: Steel with enameled finish unless otherwise indicated.
 - e. Anode Rods: Factory installed, magnesium.
4. Heat-Exchanger Coil: Copper or stainless-steel coil assembly, permanently installed inside storage tank, for heating fluid. Include working-pressure rating equal to or greater than heating-fluid supply pressure.
5. Temperature Control: Adjustable thermostat.
6. Relief Valve: ASME rated and stamped for combination temperature-and-pressure relief valves. Include relief valve with relieving capacity at least as great as heat input, and include pressure setting less than working-pressure rating of heat exchanger. Select relief valve with sensing element that extends into storage tank.

B. Noncirculating, Storage, Domestic-Water Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Adamson Global Technology Corporation.](#)
 - b. [Ajax Boiler Inc.](#)
 - c. [Cemline Corporation.](#)
 - d. [Electric Heater Company \(The\).](#)
 - e. [HESco Industries, Inc.](#)
 - f. [Leslie Controls, Inc.](#)
 - g. [Lochinvar Corporation.](#)
 - h. [Patterson-Kelley; a division of Harsco Corporation.](#)
 - i. [Precision Boilers, Inc.](#)
 - j. [PVI Industries, LLC.](#)
 - k. [RECO USA.](#)
 - l. [Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.](#)
 - m. [Weben-Jarco, Inc.](#)
 - n. [Wendland Manufacturing Corporation.](#)
 - o. **<Insert manufacturer's name>.**
 - p. or approved equal.
2. Description: Assembly of hot-water storage tanks with separate heat-exchanger coils, controls, and specialties for heating domestic water with **[heating hot water] [steam]** in coil.

3. Storage-Tank Construction: ASME-code [**steel**] <Insert material> with [125-psig (860-kPa)] [150-psig (1035-kPa)] <Insert value> working-pressure rating. Include nozzle and head for heat-exchanger tube coil.
 - a. Configuration: [**Horizontal**] [**Vertical**].
 - b. Manhole: 11 by 15 inches (280 by 380 mm) in [**end head of horizontal**] [**sidewall of vertical**] storage-tank shell.
 - c. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing and labeling.
 - 1) NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - d. Lining: [**Cement**] [**Glass**] [**Nickel plate**] [**Phenolic coating**] [**Sheet copper**] <Insert material> complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.
 - e. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire storage tank and nozzle except connections and controls.
 - f. Anode Rods: Factory installed, magnesium.
4. Heat-Exchanger Coil: [NPS 3/4 (DN 20)] [NPS 1-1/4 (DN 32)] <Insert pipe size> diameter, [**vented, double-wall,**] copper or copper-alloy U tubes with tube sheet and supporting baffles. Include heat-exchanger pressure rating equal to or greater than heating-fluid supply pressure.
5. Temperature Control: Adjustable temperature aquastat, mounted in storage-tank shell head, unless otherwise indicated.
6. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than working-pressure rating of heat exchanger. Select one relief valve with sensing element that extends into storage tank.
7. Support: Factory mounted on skids.

C. Capacity and Characteristics:

1. Capacity: <Insert gal. (L)>.
2. Recovery: <Insert gph (L/s)> at [100 deg F (56 deg C)] <Insert temperature> temperature rise.
3. Domestic-Water Pipe Size: <Insert NPS (DN)>.
4. Heating Hot-Water Supply:
 - a. Inlet Temperature: <Insert deg F (deg C)>.
 - b. Outlet Temperature: <Insert deg F (deg C)>.
 - c. Pipe Size: <Insert NPS (DN)>.

5. Steam Supply:
 - a. Inlet Pressure: **<Insert psig (kPa)>**.
 - b. Demand Rate: **<Insert lb/h (kg/s)>**.
 - c. Input Rating: **<Insert Btu/h (kW)>**.
 - d. Steam Inlet Pipe Size: **<Insert NPS (DN)>**.
6. Condensate Outlet Pipe Size: **<Insert NPS (DN)>**.
7. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phases: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 PLATE, DOMESTIC-WATER HEAT EXCHANGERS

A. Brazed-Plate, Domestic-Water Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Alfa Laval, Inc.](#)
 - b. [API Heat Transfer Inc.](#)
 - c. [Armstrong Pumps, Inc.](#)
 - d. [Bell & Gossett; ITT Industries.](#)
 - e. [Crown Boiler Co.](#)
 - f. [Doucette Industries, Inc.](#)
 - g. [GEA PHE Systems North America, Inc.](#)
 - h. [Mueller, Paul Company.](#)
 - i. [Polaris Plate Heat Exchangers.](#)
 - j. [Tranter PHE, Inc.](#)
 - k. [Triangle Tube.](#)
 - l. **<Insert manufacturer's name>**.
 - m. or approved equal.
2. Description: Assembly of heat-exchanger plates, permanently brazed together, for using **[heating hot water] [steam]** to heat domestic water.
3. Working-Pressure Rating: **[150 psig (1035 kPa)] [200 psig (1380 kPa)] <Insert value>** minimum.
4. Plate Construction: **[Single] [Vented, double]** wall.
5. Plate Material: Stainless steel.
6. Plate Thickness: Not less than **[0.0197 inch (0.5 mm)] [0.024 inch (0.6 mm)]**.
7. Connections: Stainless steel, threaded.
8. Brazing Filler Metal: **[Copper] [or] [nickel]**.

B. Frame-and-Plate, Domestic-Water Heat Exchangers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Alfa Laval, Inc.](#)
 - b. [API Heat Transfer Inc.](#)
 - c. [APV Heat Transfer.](#)
 - d. [Armstrong Pumps, Inc.](#)
 - e. [Bell & Gossett; ITT Industries.](#)
 - f. [GEA PHE Systems North America, Inc.](#)
 - g. [Graham Corporation.](#)
 - h. [Mueller, Paul Company.](#)
 - i. [Polaris Plate Heat Exchangers.](#)
 - j. [Tranter PHE, Inc.](#)
 - k. [Triangle Tube.](#)
 - l. **<Insert manufacturer's name>**.
 - m. or approved equal.
 2. Description: Assembly of nonfixed-position, heat-exchanger plates, with frame, for using [**heating hot water**] [**steam**] to heat domestic water.
 3. Working-Pressure Rating: [**150 psig (1035 kPa)**] [**200 psig (1380 kPa)**] [**250 psig (1725 kPa)**] [**400 psig (2760 kPa)**] **<Insert value>** minimum.
 4. Frame:
 - a. Carrying and Guide Bars: [**Carbon steel**] [**Stainless steel**] **<Insert material>**.
 - b. Fixed, Frame Plate; Pressure Plate; Support Column; and Nuts and Bolts: Carbon steel.
 5. Channel Plates:
 - a. Type: [**Single**] [**Vented, double**] wall.
 - b. Material: Stainless steel.
 - c. Plate Thickness: Not less than [**0.0197 inch (0.5 mm)**] [**0.024 inch (0.6 mm)**] [**0.031 inch (0.8 mm)**].
 - d. Gasket Material: Butyl or acrylonitrile-butadiene rubber, suitable for potable water.
 6. Connections: [**Stainless steel**] **<Insert material>** suitable for potable water.
 - a. **NPS 2 (DN 50)** and Smaller: Threaded.
 - b. **NPS 2-1/2 (DN 65)** and Larger: Flanged.
 7. Protective Shroud: Steel, covering channel plates.
 8. Insulation: Complying with ASHRAE/IESNA 90.1, unless otherwise indicated, and suitable for operating temperature. Surround entire heat exchanger except connections.
- C. Capacity and Characteristics:
1. Heat-Exchanger Surface Area: **<Insert sq. ft. (sq. m)>**.

2. Number of Plates: **<Insert number>**.
3. Recovery: **<Insert gph (L/s)>** at [100 deg F (56 deg C)] **<Insert temperature>** temperature rise.
4. Domestic-Water Pipe Size: **<Insert NPS (DN)>**.
5. Domestic-Water Temperature Setting: **<Insert deg F (deg C)>**.
6. Heating Hot-Water Supply:
 - a. Inlet Temperature: **<Insert deg F (deg C)>**.
 - b. Outlet Temperature: **<Insert deg F (deg C)>**.
 - c. Pipe Size: **<Insert NPS (DN)>**.
7. Steam Supply:
 - a. Inlet Pressure: **<Insert psig (kPa)>**.
 - b. Demand Rate: **<Insert lb/h (kg/s)>**.
 - c. Input Rating: **<Insert Btu/h (kW)>**.
 - d. Steam Inlet Pipe Size: **<Insert NPS (DN)>**.
8. Condensate Outlet Pipe Size: **<Insert NPS (DN)>**.

2.5 DOMESTIC-WATER, HEAT RECLAIMERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Doucette Industries, Inc.](#)
 2. **<Insert manufacturer's name>**.
 3. or approved equal.
- B. Description: Waste-heat recovery device complying with and listed according to UL 207 for heat reclaimers. Device includes vertical drainage tube with helical, domestic-water preheat coil around drainage tube.
 1. Drainage Tube: ASTM B 306, Type DWV, center, copper drainage tube of size indicated.
 2. Water Preheat Coil: **ASTM B 88, Type L (ASTM B 88M, Type B)**, copper water tube of size indicated attached to drainage tube.
 3. Working-Pressure Rating: **150 psig (1035 kPa)** on potable-water supply tubing.
- C. Capacity and Characteristics:
 1. **NPS 2 (DN 50) Drainage Tube:**
 - a. Unit Height: [20 inches (508 mm)] [24 inches (610 mm)] [30 inches (762 mm)].
 - b. Domestic-Water Preheat Coil: **NPS 3/8 (DN 10)**.
 2. **NPS 3 (DN 80) Drainage Tube:**
 - a. Unit Height: [30 inches (762 mm)] [40 inches (1016 mm)] [60 inches (1524 mm)].

- b. Domestic-Water Preheat Coil: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)].
- 3. NPS 4 (DN 100) Drainage Tube:
 - a. Unit Height: [30 inches (762 mm)] [40 inches (1016 mm)] [60 inches (1524 mm)].
 - b. Domestic-Water Preheat Coil: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)].

2.6 DOMESTIC-WATER, HEAT-EXCHANGER ACCESSORIES

A. Domestic-Water Compression Tanks:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL Inc.](#)
 - b. [Flexcon Industries.](#)
 - c. [Honeywell International Inc.](#)
 - d. [Pentair Pump Group \(The\); Myers.](#)
 - e. [Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.](#)
 - f. [State Industries.](#)
 - g. [Taco, Inc.](#)
 - h. <Insert manufacturer's name>.
 - i. or approved equal.
 - 2. Description: Steel pressure-rated tank constructed with welded joints and factory-installed butyl-rubber diaphragm. Include air precharge to minimum system-operating pressure at tank.
 - 3. Construction:
 - a. Tappings: Factory-fabricated steel, welded to tank before testing and labeling. Include ASME B1.20.1 pipe thread.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - c. Air-Charging Valve: Factory installed.
 - 4. Capacity and Characteristics:
 - a. Working-Pressure Rating: [100 psig (690 kPa)] [150 psig (1035 kPa)] <Insert value>.
 - b. Capacity Acceptable: [2 gal. (7.6 L)] [4 gal. (15.1 L)] [7 gal. (26.5 L)] [10 gal. (37.9 L)] <Insert value> minimum.
 - c. Air Precharge Pressure: <Insert system pressure>.
- B. Piping-Type Heat Traps: Field-fabricated piping arrangement according to ASHRAE/IESNA 90.1[or ASHRAE 90.2].
- C. Heat-Trap Fittings: ASHRAE 90.2.

- D. Combination Temperature-and-Pressure Relief Valves: ASME rated and stamped. Include relieving capacity at least as great as heat input, and include pressure setting less than heat-exchanger working-pressure rating. Select relief valves with sensing element that extends into storage tank.
- E. Pressure Relief Valves: ASME rated and stamped. Include pressure setting less than heat-exchanger working-pressure rating.
- F. Vacuum Relief Valves: ANSI Z21.22/CSA 4.4-M.

2.7 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect domestic-water heat exchangers specified to be ASME-code construction, according to ASME Boiler and Pressure Vessel Code.
- B. Hydrostatically test domestic-water heat exchangers to minimum of one and one-half times pressure rating before shipment.
- C. Domestic-water heat exchangers will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 DOMESTIC-WATER, HEAT-EXCHANGER INSTALLATION

- A. Domestic-Water, Heat-Exchanger Mounting: Install domestic-water heat exchangers on concrete base. Comply with requirements for concrete bases specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
 - 5. Anchor heat exchangers to substrate.
- B. Install domestic-water heat exchangers level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.

1. Install shutoff valves on domestic-water-supply piping to heat exchangers and on domestic-hot-water outlet piping. Comply with requirements for shutoff valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 2. Install shutoff valves on heating hot-water piping to heat exchangers. Comply with requirements for shutoff valves specified in Section 230523 "General-Duty Valves for HVAC Piping."
 3. Install shutoff valves on steam and condensate piping to heat exchangers. Comply with requirements for shutoff valves specified in Section 230523 "General-Duty Valves for HVAC Piping."
- C. Install domestic-water heat exchangers with seismic-restraint devices. Comply with requirements for seismic-restraint devices specified in Section 220548 "Vibration and Seismic Controls for Plumbing Piping and Equipment."
- D. Install temperature and pressure relief valves in top portion of storage-tank shells of domestic-water heat exchangers with domestic-water storage. Use relief valves with sensing elements that extend into shells. Extend relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- E. Install [**combination temperature-and-**]pressure relief valves in water piping for domestic-water heat exchangers without storage. Extend relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- F. Install heat-exchanger drain piping as indirect waste to spill by positive air gap into open drains or over floor drains. Install hose-end drain valves at low points in water piping for domestic-water heat exchangers that do not have tank drains. Comply with requirements for hose-end drain valves specified in Section 221119 "Domestic Water Piping Specialties."
- G. Install thermometer on each domestic-water, heat-exchanger, [**inlet and**] outlet piping, and install thermometer on each domestic-water, heat-exchanger, heating-fluid [**inlet and**] outlet piping. Comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- H. Install pressure gages on domestic-water, heat-exchanger, heating-fluid piping. Comply with requirements for pressure gages specified in Section 220519 "Meters and Gages for Plumbing Piping."
- I. Fill domestic-water heat exchangers with water.
- J. Charge domestic-water compression tanks with air.
- 3.2 CONNECTIONS
- A. Comply with requirements for piping specified in Section 221116 "Domestic Water Piping."

- B. Comply with requirements for heating hot-water piping specified in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties."
- C. Comply with requirements for steam and condensate piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties."
- D. Drawings indicate general arrangement of piping, fittings, and specialties.
- E. Where installing piping adjacent to domestic-water heat exchangers, allow space for service and maintenance of heat exchangers. Arrange piping for easy removal of domestic-water heat exchangers.

3.3 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Domestic-water heat exchangers will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- C. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain [**shell-and-tube**] [**circulating**] [**and**] <Insert types> domestic-water heat exchangers.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **223500**

SECTION 224213.13 - COMMERCIAL WATER CLOSETS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Water closets.
 - 2. Flushometer valves.
 - 3. Toilet seats.
- B. Related Requirements:
 - 1. Section 224500 "Emergency Plumbing Fixtures".
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for water closets.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
 - 2. Product Data for Prerequisite WE 1: Documentation indicating flow and water consumption requirements.
 - 3. Product Data for Prerequisite WE 1[**and Credit WE 2**]: Documentation indicating flow and water consumption requirements.
- C. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For flushometer valves[**and electronic sensors**] to include in operation and maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Flushometer-Valve Repair Kits: Equal to [10] <Insert number> percent of amount of each type installed, but no fewer than [one] [six] <Insert number> of each type.

1.6 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 WALL-MOUNTED WATER CLOSETS

- A. Water Closets <Insert drawing designation>: Wall mounted, top spud[, **accessible**].
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Briggs Plumbing Products, Inc.
 - c. Capizzi.
 - d. Crane Plumbing, L.L.C.
 - e. Ferguson Enterprises, Inc.; ProFlo Brand.
 - f. Gerber Plumbing Fixtures LLC.

- g. Kohler Co.
 - h. Mansfield Plumbing Products LLC.
 - i. Peerless Pottery Sales, Inc.
 - j. TOTO USA, INC.
 - k. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - l. **<Insert manufacturer's name>**.
 2. Bowl:
 - a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
 - b. Material: Vitreous china.
 - c. Type: Siphon jet.
 - d. Style: Flushometer valve.
 - e. Height: Standard.
 - f. Rim Contour: Elongated.
 - g. Water Consumption: [1.28 gal. (4.8 L)] [1.6 gal. (6 L)] per flush.
 - h. Spud Size and Location: NPS 1-1/2 (DN 40); top.
 3. Flushometer Valve: **<Insert flushometer-valve designation>**.
 4. Toilet Seat: **<Insert toilet-seat designation>**.
 5. Support:
 - a. Standard: ASME A112.6.1M.
 - b. Description: Waste-fitting assembly as required to match drainage piping material and arrangement with faceplates, couplings gaskets, and feet; bolts and hardware matching fixture. [**Include additional extension coupling, faceplate, and feet for installation in wide pipe space.**]
 - c. Water-Closet Mounting Height: [Standard] [Child] [Handicapped/elderly according to ICC/ANSI A117.1].
- B. Water Closets **<Insert drawing designation>**: Wall mounted, back spud[, **accessible**].
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Crane Plumbing, L.L.C.
 - c. Ferguson Enterprises, Inc.; ProFlo Brand.
 - d. Gerber Plumbing Fixtures LLC.
 - e. Kohler Co.
 - f. TOTO USA, INC.
 - g. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
 2. Bowl:
 - a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
 - b. Material: Vitreous china.

- c. Type: Siphon jet.
 - d. Style: Flushometer valve.
 - e. Height: Standard.
 - f. Rim Contour: Elongated.
 - g. Water Consumption: [1.28 gal. (4.8 L)] [1.6 gal. (6 L)] per flush.
 - h. Spud Size and Location: NPS 1-1/2 (DN 40); back.
 3. Flushometer Valve: <Insert flushometer-valve designation>.
 4. Toilet Seat: <Insert toilet-seat designation>.
 5. Support:
 - a. Standard: ASME A112.6.1M.
 - b. Description: Waste-fitting assembly, as required to match drainage piping material and arrangement with faceplates, couplings gaskets, and feet; bolts and hardware matching fixture. [**Include additional extension coupling, faceplate, and feet for installation in wide pipe space.**]
 - c. Water-Closet Mounting Height: [Standard] [Child] [handicapped/elderly height according to ICC/ANSI A117.1].
- C. Water Closets <Insert drawing designation>: Wall mounted, blowout, top spud[, accessible].
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Crane Plumbing, L.L.C.
 - c. Kohler Co.
 - d. <Insert manufacturer's name>.
 - e. or approved equal.
 2. Bowl:
 - a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5:
 - b. Material: Vitreous china.
 - c. Type: Blowout.
 - d. Style: Flushometer valve.
 - e. Height: Standard.
 - f. Rim Contour: Elongated.
 - g. Water Consumption: 3.5 gal. (13.2 L) per flush.
 - h. Spud Size and Location: NPS 1-1/2 (DN 40); top.
 - i. Color: [White] <Insert color>.
 3. Flushometer Valve: <Insert flushometer-valve designation>.
 4. Toilet Seat: <Insert toilet-seat designation>.
 5. Support:
 - a. Standard: ASME A112.6.1M.
 - b. Description: Waste-fitting assembly, as required to match drainage piping material and arrangement with faceplates, couplings gaskets, and feet;

- bolts and hardware matching fixture. [**Include additional extension coupling, faceplate, and feet for installation in wide pipe space.**]
- c. Water-Closet Mounting Height: [**Standard**] [**handicapped/elderly height according to ICC/ANSI A117.1**].

D. Water Closets < **Insert drawing designation** >: Wall mounted, blowout, back spud[, **accessible**].

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Standard America.
b. Crane Plumbing, L.L.C.
c. Kohler Co.
d. < **Insert manufacturer's name** >.
e. or approved equal.

2. Bowl:

- a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
b. Material: Vitreous china.
c. Type: Blowout.
d. Style: Flushometer valve.
e. Height: Standard.
f. Rim Contour: Elongated.
g. Water Consumption: **3.5 gal. (13.2 L)** per flush.
h. Spud Size and Location: **NPS 1-1/2 (DN 40)**; back.
i. Color: [**White**] < **Insert color** >.

3. Flushometer Valve: < **Insert flushometer-valve designation** >.

4. Toilet Seat: < **Insert toilet-seat designation** >.

5. Support:

- a. Standard: ASME A112.6.1M.
b. Description: Waste-fitting assembly, as required to match drainage piping material and arrangement with faceplates, couplings gaskets, and feet; bolts and hardware matching fixture. [**Include additional extension coupling, faceplate, and feet for installation in wide pipe space.**]
c. Water-Closet Mounting Height: [**Standard height**] [**handicapped/elderly height according to ICC/ANSI A117.1**].

2.2 FLUSHOMETER VALVES

A. Lever-Handle, Diaphragm Flushometer Valves < **Insert designation** >:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Coyne & Delany Co.

- b. Gerber Plumbing Fixtures LLC.
 - c. Sloan Valve Company.
 - d. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Standard: ASSE 1037.
 3. Minimum Pressure Rating: **125 psig** (860 kPa).
 4. Features: Include integral check stop and backflow-prevention device.
 5. Material: Brass body with corrosion-resistant components.
 6. Exposed Flushometer-Valve Finish: Chrome plated.
 7. Panel Finish: Chrome plated or stainless steel.
 8. Style: **[Exposed] [Concealed]**.
 9. Consumption: **[1.28 gal. (4.8 L)] [1.6 gal. (6 L)] [3.5 gal. (13.2 L)] <Insert value>** per flush.
 10. Minimum Inlet: **NPS 1** (DN 25).
 11. Minimum Outlet: **NPS 1-1/4** (DN 32).
- B. Solenoid-Actuator, Diaphragm Flushometer Valves **<Insert designation>**:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Coyne & Delany Co.
 - b. Gerber Plumbing Fixtures LLC.
 - c. Sloan Valve Company.
 - d. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
 2. Standard: ASSE 1037.
 3. Minimum Pressure Rating: **125 psig** (860 kPa).
 4. Features: Include integral check stop and backflow-prevention device.
 5. Material: Brass body with corrosion-resistant components.
 6. Exposed Flushometer-Valve Finish: Chrome plated.
 7. Panel Finish: Chrome plated or stainless steel.
 8. Style: **[Exposed] [Concealed]**.
 9. Actuator: Solenoid complying with UL 1951, and listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 10. Trip Mechanism: **[Battery-powered] [Hard-wired]** electronic sensor complying with UL 1951, and listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 11. Consumption: **[1.28 gal. (4.8 L)] [1.6 gal. (6 L)] [3.5 gal. (13.2 L)] <Insert value>** per flush.
 12. Minimum Inlet: **NPS 1** (DN 25).
 13. Minimum Outlet: **NPS 1-1/4** (DN 32).
- C. Lever-Handle, Piston Flushometer Valves **<Insert designation>**:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Coyne & Delany Co.
 - b. Sloan Valve Company.
 - c. TOTO USA, INC.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Standard: ASSE 1037.
3. Minimum Pressure Rating: **125 psig** (860 kPa).
4. Features: Include integral check stop and backflow-prevention device.
5. Material: Brass body with corrosion-resistant components.
6. Exposed Flushometer-Valve Finish: Chrome plated.
7. Panel Finish: Chrome plated or stainless steel.
8. Style: **[Exposed] [Concealed]**.
9. Consumption: **[1.28 gal. (4.8 L)] [1.6 gal. (6 L)] [3.5 gal. (13.2 L)] <Insert value>** per flush.
10. Minimum Inlet: **NPS 1** (DN 25).
11. Minimum Outlet: **NPS 1-1/4** (DN 32).

D. Hard-Wired, Solenoid-Actuator, Piston Flushometer Valves **<Insert designation>**:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Gerber Plumbing Fixtures LLC.
 - b. Moen Incorporated.
 - c. Sloan Valve Company.
 - d. TOTO USA, INC.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Standard: ASSE 1037.
3. Minimum Pressure Rating: **125 psig** (860 kPa).
4. Features: Include integral check stop and backflow-prevention device.
5. Material: Brass body with corrosion-resistant components.
6. Exposed Flushometer-Valve Finish: Chrome plated.
7. Panel Finish: Chrome plated or stainless steel.
8. Style: **[Exposed] [Concealed]**.
9. Actuator: Solenoid complying with UL 1951, and listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
10. Trip Mechanism: Hard-wired electronic sensor complying with UL 1951, and listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
11. Consumption: **[1.28 gal. (4.8 L)] [1.6 gal. (6 L)] [3.5 gal. (13.2 L)] <Insert value>** per flush.
12. Minimum Inlet: **NPS 1** (DN 25).
13. Minimum Outlet: **NPS 1-1/4** (DN 32).

2.3 TOILET SEATS

A. Toilet Seats <Insert drawing designation>:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Bemis Manufacturing Company.
 - c. Centoco Manufacturing Corporation.
 - d. Church Seats.
 - e. Jones Stephens Corp.; Comfort Seat Brand.
 - f. Kohler Co.
 - g. Olsonite Seat Co.
 - h. Sanderson Plumbing Products, Inc.
 - i. Sperzel of Lexington.
 - j. TOTO USA, INC.
 - k. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
2. Standard: IAPMO/ANSI Z124.5.
3. Material: Plastic.
4. Type: [**Commercial (Standard)**] [**Commercial (Heavy duty)**].
5. Shape: [**Elongated rim, open front**] <Insert shape>.
6. Hinge: [**Check**] [**Self-sustaining**] [**Self-sustaining, check**] [**Self-raising**].
7. Hinge Material: Noncorroding metal.
8. Seat Cover: [**Required**] [**Not required**].
9. Color: [**White**] <Insert color>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before water-closet installation.
- B. Examine walls and floors for suitable conditions where water closets will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Water-Closet Installation:
 1. Install level and plumb according to roughing-in drawings.
 2. Install floor-mounted water closets on bowl-to-drain connecting fitting attachments to piping or building substrate.

3. Install accessible, wall-mounted water closets at mounting height for handicapped/elderly, according to ICC/ANSI A117.1.

B. Support Installation:

1. Install supports, affixed to building substrate, for floor-mounted, back-outlet water closets.
2. Use carrier supports with waste-fitting assembly and seal.
3. Install floor-mounted, back-outlet water closets attached to building floor substrate, onto waste-fitting seals; and attach to support.
4. Install wall-mounted, back-outlet water-closet supports with waste-fitting assembly and waste-fitting seals; and affix to building substrate.

C. Flushometer-Valve Installation:

1. Install flushometer-valve, water-supply fitting on each supply to each water closet.
2. Attach supply piping to supports or substrate within pipe spaces behind fixtures.
3. Install lever-handle flushometer valves for accessible water closets with handle mounted on open side of water closet.
4. Install actuators in locations that are easy for people with disabilities to reach.
5. Install fresh batteries in battery-powered, electronic-sensor mechanisms.

D. Install toilet seats on water closets.

E. Wall Flange and Escutcheon Installation:

1. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations and within cabinets and millwork.
2. Install deep-pattern escutcheons if required to conceal protruding fittings.
3. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."

F. Joint Sealing:

1. Seal joints between water closets and walls and floors using sanitary-type, one-part, mildew-resistant silicone sealant.
2. Match sealant color to water-closet color.
3. Comply with sealant requirements specified in Section 079200 "Joint Sealants."

3.3 CONNECTIONS

- A. Connect water closets with water supplies and soil, waste, and vent piping. Use size fittings required to match water closets.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Comply with soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."

- D. Where installing piping adjacent to water closets, allow space for service and maintenance.

3.4 ADJUSTING

- A. Operate and adjust water closets and controls. Replace damaged and malfunctioning water closets, fittings, and controls.
- B. Adjust water pressure at flushometer valves to produce proper flow.
- C. Install fresh batteries in battery-powered, electronic-sensor mechanisms.

3.5 CLEANING AND PROTECTION

- A. Clean water closets and fittings with manufacturers' recommended cleaning methods and materials.
- B. Install protective covering for installed water closets and fittings.
- C. Do not allow use of water closets for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 224213.13

SECTION 224213.16 - COMMERCIAL URINALS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Urinals.
 - 2. Flushometer valves.
- B. Related Requirements:
 - 1. **<Insert related requirements>**
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for urinals.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
 - 2. Product Data for Prerequisite WE 1: Documentation indicating flow and water consumption requirements.
 - 3. Product Data for Prerequisite WE 1[**and Credit WE 2**]: Documentation indicating flow and water consumption requirements.
- C. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For flushometer valves[**and electronic sensors**] to include in operation and maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Flushometer-Valve Repair Kits: Equal to [10] <Insert number> percent of amount of each type installed, but no fewer than [one] [six] <Insert number> of each type.
 - 2. Waterless Urinal Trap-Seal Cartridges: Equal to [200] <Insert number> percent of amount of each type installed, but no fewer than [12] <Insert number> of each type.
 - 3. Waterless Urinal Trap-Seal Liquid: Equal to [1 gal. (3.8 L)] <Insert volume> for each urinal installed.

1.6 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 STALL URINALS

- A. Urinals <Insert drawing designation>: Stall, washout type.
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.

- b. Kohler Co.
 - c. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Fixture:
- a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
 - b. Material: Vitreous china.
 - c. Type: [**Straight or sloped**] **<Insert type>** front.
 - d. Seam Covers: For [**21-inch (535-mm)**] [**24-inch (610-mm)**] urinal centers.
 - e. Strainer: Separate; removable.
 - f. Water Consumption: Water saving.
 - g. Spud Size and Location: **NPS 3/4 (DN 20)**; top.
 - h. Outlet Size and Location: **NPS 2 (DN 50)**; bottom for separate trap.
 - i. Color: [**White**] **<Insert color>**.
3. Flushometer Valve: **<Insert urinal flushometer-valve designation from "Urinal Flushometer Valves" Article>**.

2.2 WALL-HUNG URINALS

- A. Urinals **<Insert drawing designation>**: Wall hung, back outlet, blowout.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Capizzi.
 - c. Kohler Co.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Fixture:
 - a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
 - b. Material: Vitreous china.
 - c. Strainer or Trapway: [**Manufacturer's standard strainer**] [**Open trapway**] with integral trap.
 - d. Water Consumption: Water saving.
 - e. Spud Size and Location: **NPS 1-1/4 (DN 32)**; [**back**] [**top**].
 - f. Outlet Size and Location: **NPS 2 (DN 50)**; back.
 - g. Color: [**White**] **<Insert color>**.
 3. Flushometer Valve: **<Insert urinal-flushometer-valve designation from "Urinal Flushometer Valves" Article>**.
 4. Waste Fitting:
 - a. Standard: ASME A112.18.2/CSA B125.2 for coupling.

- b. Size: **NPS 2** (DN 50).
 5. Support: ASME A112.6.1M, Type I, urinal carrier with fixture support plates and coupling with seal and fixture bolts and hardware matching fixture. [**Include rectangular, steel uprights.**]
- B. Urinals <Insert drawing designation>: Wall hung, back outlet, siphon jet[, **accessible**].
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Briggs Plumbing Products, Inc.
 - c. Ferguson Enterprises, Inc.; ProFlo Brand.
 - d. Gerber Plumbing Fixtures LLC.
 - e. Kohler Co.
 - f. Mansfield Plumbing Products LLC.
 - g. Peerless Pottery Sales, Inc.
 - h. <Insert manufacturer's name>.
 - i. or approved equal.
 2. Fixture:
 - a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
 - b. Material: Vitreous china.
 - c. Type: Siphon jet[**with extended shields**].
 - d. Strainer or Trapway: [**Manufacturer's standard strainer**] <Insert **strainer**> with integral trap.
 - e. Water Consumption: [**Water saving**] [**Low**].
 - f. Spud Size and Location: **NPS 3/4** (DN 20); [**back**] [**top**].
 - g. Outlet Size and Location: **NPS 2** (DN 50); back.
 - h. Color: [**White**] <Insert color>.
 3. Flushometer Valve: <Insert urinal flushometer-valve designation from "**Urinal Flushometer Valves**" Article>.
 4. Waste Fitting:
 - a. Standard: ASME A112.18.2/CSA B125.2 for coupling.
 - b. Size: **NPS 2** (DN 50).
 5. Support: ASME A112.6.1M, Type I, urinal carrier with fixture support plates and coupling with seal and fixture bolts and hardware matching fixture. [**Include rectangular, steel uprights.**]
- C. Urinals <Insert drawing designation>: Wall hung, back outlet, washout[, **accessible**].
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Standard America.
 - b. Briggs Plumbing Products, Inc.
 - c. Capizzi.
 - d. Crane Plumbing, L.L.C.
 - e. Duravit USA, Inc.
 - f. Ferguson Enterprises, Inc.; ProFlo Brand.
 - g. Gerber Plumbing Fixtures LLC.
 - h. Kohler Co.
 - i. Mansfield Plumbing Products LLC.
 - j. Peerless Pottery Sales, Inc.
 - k. TOTO USA, INC.
 - l. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - m. **<Insert manufacturer's name>**.
 - n. or approved equal.
2. Fixture:
- a. Standards: ASME A112.19.2/CSA B45.1 and ASME A112.19.5.
 - b. Material: Vitreous china.
 - c. Type: Washout with extended shields.
 - d. Strainer or Trapway: **[Manufacturer's standard strainer] <Insert strainer>** with integral trap.
 - e. Water Consumption: **[Water saving] [Low]**.
 - f. Spud Size and Location: **NPS 3/4 (DN 20), [back] [top]**.
 - g. Outlet Size and Location: **NPS 2 (DN 50), back**.
 - h. Color: **[White] <Insert color>**.
3. Flushometer Valve: **<Insert urinal flushometer-valve designation from "Urinal Flushometer Valves" Article>**.
4. Waste Fitting:
- a. Standard: ASME A112.18.2/CSA B125.2 for coupling.
 - b. Size: **NPS 2 (DN 50)**.
5. Support: ASME A112.6.1M, Type I, urinal carrier with fixture support plates and coupling with seal and fixture bolts and hardware matching fixture. **[Include rectangular, steel uprights.]**
- D. Urinals **<Insert drawing designation>**: Wall hung, bottom outlet, washout.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Briggs Plumbing Products, Inc.
 - c. Ferguson Enterprises, Inc.; ProFlo Brand.
 - d. Kohler Co.
 - e. Mansfield Plumbing Products LLC.
 - f. Peerless Pottery Sales, Inc.
 - g. **<Insert manufacturer's name>**.

- b. Material: Enameled cast iron.
 - c. Style: Wash sink with back and without pedestal modified for use as urinal.
 - d. Size: [36 inches (915 mm)] [48 inches (1219 mm)] [60 inches (1525 mm)] [72 inches (1830 mm)].
 - e. Drain: Separate removable chrome-plated dome strainer with chrome-plated, NPS 1-1/2 (DN 40) tailpiece.
 - f. Water Consumption: Not applicable.
 - g. Flushing Device: Manufacturer's standard self-closing valve with washdown pipe of length matching fixture.
 - h. Outlet Size and Location: NPS 1-1/2 (DN 40); bottom.
 - i. Color: [White] <Insert color>.
3. Flushometer Valve:
- a. Standard: ASME A112.18.1/CSA B125.1.
 - b. Flushing Device: Manufacturer's standard for NPS 1/2 (DN 15) supply; self-closing valve; and wash-down pipe of length matching fixture.
4. Waste Fitting:
- a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap:
 - 1) Size: NPS 1-1/2 (DN 50).
 - 2) Material: Chrome-plated, [two-piece, cast-brass trap and swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall] [two-piece, cast-brass trap and ground-joint swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall] [one-piece, cast-brass trap with swivel 0.029-inch- (73-mm-) thick tubular brass wall bend] <Insert trap type>; and chrome-plated brass or steel wall flange.
 - 3) Material: Stainless-steel, two-piece trap and swivel elbow with 0.012-inch- (0.30-mm-) thick stainless-steel tube to wall; and stainless-steel wall flange.
5. Support: ASME A112.6.1M, Type II, sink carrier.

2.3 WATERLESS URINALS

- A. Urinals <Insert drawing designation>: Wall hung, back outlet, waterless, vitreous china, designed for liquid-trap-seal operation.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
- a. Duravit USA, Inc.
 - b. Falcon Waterfree Technologies.
 - c. Kohler Co.
 - d. Sloan Valve Company.

- e. Waterless Co.
 - f. Zero Flush.
 - g. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
 2. Fixture:
 - a. Standard: ASME A112.19.2/CSA B45.1, except without water supply.
 - b. Trap-Seal Method: Proprietary cartridge with liquid seal.
 - c. Outlet Size and Location: [NPS 2 (DN 50)] **<Insert size>** flange; back.
 - d. Trap-Sealing Liquid: Proprietary.
 - e. Color: [White] **<Insert color>**.
 3. Waste Fitting:
 - a. Standard: ASME A112.18.2/CSA B125.2 for transition coupling, trap, and waste pipe.
 - b. Size: [NPS 2 (DN 50)] **<Insert size>**.
 4. Support: ASME A112.6.1M, Type I, urinal carrier with fixture support plates and coupling with seal and fixture bolts and hardware matching fixture. [**Include rectangular, steel uprights.**]
- B. Urinals **<Insert drawing designation>**: Wall hung, back outlet, waterless, plastic, designed for liquid-trap-seal operation.
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Waterless Co.
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
 2. Fixture:
 - a. Standard: ANSI Z124.9, except without water supply.
 - b. Material: [FRP] **<Insert material>**.
 - c. Trap-Seal Method: Proprietary cartridge or trap system.
 - d. Outlet Size and Location: NPS 2 (DN 50); back. Include transition coupling.
 - e. Trap-Sealing Liquid: Proprietary.
 - f. Color: [White] **<Insert color>**.
 3. Waste Fitting:
 - a. Standard: ASME A112.18.2/CSA B125.2 for transition coupling, trap, and waste pipe.
 - b. Size: [NPS 2 (DN 50)] **<Insert size>**.
 4. Support: [Metal plate in wall] [Wood blocking in wall] [ASME A112.6.1M, Type I, urinal carrier with fixture support plates and coupling with seal and

fixture bolts and hardware matching fixture].[Include rectangular, steel uprights.]

2.4 URINAL FLUSHOMETER VALVES

A. Lever-Handle, Diaphragm Flushometer Valves <Insert designation>:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Coyne & Delany Co.
 - b. Gerber Plumbing Fixtures LLC.
 - c. Sloan Valve Company.
 - d. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - e. **<Insert manufacturer's name>**.
2. Standard: ASSE 1037.
3. Minimum Pressure Rating: **125 psig** (860 kPa).
4. Features: Include integral check stop and backflow-prevention device.
5. Material: Brass body with corrosion-resistant components.
6. Exposed Flushometer-Valve Finish: Chrome plated.
7. Panel Finish: Chrome plated or stainless steel.
8. Style: **[Exposed] [Concealed]**.
9. Consumption: **[0.5 gal. (1.9 L)] [1.0 gal. (3.8 L)] <Insert value>** per flush.
10. Minimum Inlet: **[NPS 3/4 (DN 20)] [NPS 1 (DN 25)]**.
11. Minimum Outlet: **[NPS 3/4 (DN 20)] [NPS 1-1/4 (DN 32)]**.

B. Solenoid-Actuator, Diaphragm Flushometer Valves <Insert designation>:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Coyne & Delany Co.
 - b. Gerber Plumbing Fixtures LLC.
 - c. Sloan Valve Company.
 - d. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Standard: ASSE 1037.
3. Minimum Pressure Rating: **125 psig** (860 kPa).
4. Features: Include integral check stop and backflow-prevention device.
5. Material: Brass body with corrosion-resistant components.
6. Exposed Flushometer-Valve Finish: Chrome plated.
7. Panel Finish: Chrome plated or stainless steel.
8. Style: **[Exposed] [Concealed]**.
9. Actuator: Solenoid complying with UL 1951; listed and labeled as defined in NFPA 70, by a qualified testing agency; and marked for intended location and application.

10. Trip Mechanism: **[Battery-powered]** **[Hard-wired]** electronic sensor complying with UL 1951; listed and labeled as defined in NFPA 70, by a qualified testing agency; and marked for intended location and application.
11. Consumption: **[0.5 gal. (1.9 L)]** **[1.0 gal. (3.8 L)]** **<Insert value>** per flush.
12. Minimum Inlet: **[NPS 3/4 (DN 20)]** **[NPS 1 (DN 25)]**.
13. Minimum Outlet: **[NPS 3/4 (DN 20)]** **[NPS 1-1/4 (DN 32)]**.

C. Lever-Handle, Piston Flushometer Valves **<Insert designation>**:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Coyne & Delany Co.
 - b. Sloan Valve Company.
 - c. TOTO USA, INC.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Standard: ASSE 1037.
3. Minimum Pressure Rating: **125 psig** (860 kPa).
4. Features: Include integral check stop and backflow-prevention device.
5. Material: Brass body with corrosion-resistant components.
6. Exposed Flushometer-Valve Finish: Chrome plated.
7. Panel Finish: Chrome plated or stainless steel.
8. Style: **[Exposed]** **[Concealed]**.
9. Consumption: **[0.5 gal. (1.9 L)]** **[1.0 gal. (3.8 L)]** **<Insert value>** per flush.
10. Minimum Inlet: **[NPS 3/4 (DN 20)]** **[NPS 1 (DN 25)]**.
11. Minimum Outlet: **[NPS 3/4 (DN 20)]** **[NPS 1-1/4 (DN 32)]**.

D. Hard-Wired, Solenoid-Actuator, Piston Flushometer Valves **<Insert designation>**:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Gerber Plumbing Fixtures LLC.
 - b. Moen Incorporated.
 - c. Sloan Valve Company.
 - d. TOTO USA, INC.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Standard: ASSE 1037.
3. Minimum Pressure Rating: **125 psig** (860 kPa).
4. Features: Include integral check stop and backflow-prevention device.
5. Material: Brass body with corrosion-resistant components.
6. Exposed Flushometer-Valve Finish: Chrome plated.
7. Panel Finish: Chrome plated or stainless steel.
8. Style: **[Exposed]** **[Concealed]**.

9. Actuator: Solenoid complying with UL 1951; listed and labeled as defined in NFPA 70, by a qualified testing agency; and marked for intended location and application.
10. Trip Mechanism: Hard-wired electronic sensor complying with UL 1951; listed and labeled as defined in NFPA 70, by a qualified testing agency; and marked for intended location and application.
11. Consumption: [0.5 gal. (1.9 L)] [1.0 gal. (3.8 L)] <Insert value> per flush.
12. Minimum Inlet: [NPS 3/4 (DN 20)] [NPS 1 (DN 25)].
13. Minimum Outlet: [NPS 3/4 (DN 20)] [NPS 1-1/4 (DN 32)].

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before urinal installation.
- B. Examine walls and floors for suitable conditions where urinals will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Urinal Installation:

1. Install urinals level and plumb according to roughing-in drawings.
2. Install wall-hung, back-outlet urinals onto waste fitting seals and attached to supports.
3. Install wall-hung, bottom-outlet urinals with tubular waste piping attached to supports.
4. Install accessible, wall-mounted urinals at mounting height for the handicapped/elderly, according to ICC/ANSI A117.1.
5. Install trap-seal liquid in waterless urinals.

B. Support Installation:

1. Install supports, affixed to building substrate, for wall-hung urinals.
2. Use off-floor carriers with waste fitting and seal for back-outlet urinals.
3. Use carriers without waste fitting for urinals with tubular waste piping.
4. Use chair-type carrier supports with rectangular steel uprights for accessible urinals.

C. Flushometer-Valve Installation:

1. Install flushometer-valve water-supply fitting on each supply to each urinal.
2. Attach supply piping to supports or substrate within pipe spaces behind fixtures.
3. Install lever-handle flushometer valves for accessible urinals with handle mounted on open side of compartment.

4. Install fresh batteries in battery-powered, electronic-sensor mechanisms.

D. Wall Flange and Escutcheon Installation:

1. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations.
2. Install deep-pattern escutcheons if required to conceal protruding fittings.
3. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."

E. Joint Sealing:

1. Seal joints between urinals and walls and floors using sanitary-type, one-part, mildew-resistant silicone sealant.
2. Match sealant color to urinal color.
3. Comply with sealant requirements specified in Section 079200 "Joint Sealants."

3.3 CONNECTIONS

- A. Connect urinals with water supplies and soil, waste, and vent piping. Use size fittings required to match urinals.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Comply with soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."
- D. Where installing piping adjacent to urinals, allow space for service and maintenance.

3.4 ADJUSTING

- A. Operate and adjust urinals and controls. Replace damaged and malfunctioning urinals, fittings, and controls.
- B. Adjust water pressure at flushometer valves to produce proper flow.
- C. Install fresh batteries in battery-powered, electronic-sensor mechanisms.

3.5 CLEANING AND PROTECTION

- A. Clean urinals and fittings with manufacturers' recommended cleaning methods and materials.
- B. Install protective covering for installed urinals and fittings.
- C. Do not allow use of urinals for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 224213.16

SECTION 224216.13 - COMMERCIAL LAVATORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Lavatories.
 - 2. Faucets.
- B. Related Requirements:
 - 1. Section 224500 "Emergency Plumbing Fixtures" for security lavatories.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for lavatories.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [**Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
 - 2. Product Data for Prerequisite WE 1: Documentation indicating flow and water consumption requirements.
 - 3. Product Data for Prerequisite WE 1[**and Credit WE 2**]: Documentation indicating flow and water consumption requirements.
- C. Shop Drawings: Include diagrams for power, signal, and control wiring of automatic faucets.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Counter cutout templates for mounting of counter-mounted lavatories.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For lavatories and faucets to include in operation and maintenance manuals.

1. Include fixture trim exploded view and replacement parts lists.
2. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Servicing and adjustments of automatic faucets.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Faucet Washers and O-Rings: Equal to [10] <Insert number> percent of amount of each type and size installed.
2. Faucet Cartridges and O-Rings: Equal to [5] <Insert number> percent of amount of each type and size installed.

1.7 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 VITREOUS-CHINA, COUNTER-MOUNTED LAVATORIES

- A. Lavatory **<Insert drawing designation>**: Rectangular, self-rimming, vitreous china, counter mounted.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Crane Plumbing, L.L.C.
 - c. Kohler Co.
 - d. TOTO USA, INC.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
 2. Fixture:
 - a. Standard: ASME A112.19.2/CSA B45.1.
 - b. Type: Self-rimming for above-counter mounting.
 - c. Nominal Size: Rectangular, **[21 by 19 inches (533 by 483 mm)] [24 by 20 inches (610 by 508 mm)] <Insert dimensions>**.
 - d. Faucet-Hole Punching: **[One hole] [Three holes, 2-inch (51-mm) centers] [Three holes, 4-inch (102-mm) centers]**.
 - e. Faucet-Hole Location: Top.
 - f. Color: **[White] <Insert color>**.
 - g. Mounting Material: Sealant.
 3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.
- B. Lavatory **<Insert drawing designation>**: **[Oval] [Round]**, self-rimming, vitreous china, counter mounted.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Briggs Plumbing Products, Inc.
 - c. Capizzi.
 - d. Crane Plumbing, L.L.C.
 - e. Ferguson Enterprises, Inc.; ProFlo Brand.
 - f. Gerber Plumbing Fixtures LLC.
 - g. Kohler Co.
 - h. Mansfield Plumbing Products LLC.
 - i. Peerless Pottery Sales, Inc.
 - j. TOTO USA, INC.

- k. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - l. **<Insert manufacturer's name>**.
 - m. or approved equal.
2. Fixture:
- a. Standard: ASME A112.19.2/CSA B45.1.
 - b. Type: Self-rimming for above-counter mounting.
 - c. Nominal Size: Oval, [19 by 17 inches (483 by 432 mm)] [20 by 17 inches (508 by 432 mm)] **<Insert dimensions>**.
 - d. Nominal Size: Round, [19 inches (483 mm)] **<Insert dimension>**.
 - e. Faucet-Hole Punching: [One hole] [Three holes, 2-inch (51-mm) centers] [Three holes, 4-inch (102-mm) centers].
 - f. Faucet-Hole Location: Top.
 - g. Color: [White] **<Insert color>**.
 - h. Mounting Material: Sealant.
3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.
- C. Lavatory **<Insert drawing designation>**: Oval, vitreous china, undercounter mounted.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Capizzi.
 - c. Crane Plumbing, L.L.C.
 - d. Ferguson Enterprises, Inc.; ProFlo Brand.
 - e. Gerber Plumbing Fixtures LLC.
 - f. Kohler Co.
 - g. Mansfield Plumbing Products LLC.
 - h. Peerless Pottery Sales, Inc.
 - i. TOTO USA, INC.
 - j. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - k. **<Insert manufacturer's name>**.
 - l. or approved equal.
 2. Fixture:
 - a. Standard: ASME A112.19.2/CSA B45.1.
 - b. Type: For undercounter mounting.
 - c. Nominal Size: Oval, [19 by 16 inches (483 by 406 mm)] [22 by 14 inches (559 by 356 mm)] [23 by 15 inches (584 by 381 mm)] **<Insert dimensions>**.
 - d. Faucet-Hole Punching: No holes.
 - e. Faucet-Hole Location: On countertop.
 - f. Color: [White] **<Insert color>**.
 - g. Mounting Material: Sealant and undercounter mounting kit.

3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.

2.2 VITREOUS-CHINA, WALL-MOUNTED LAVATORIES

- A. Lavatory **<Insert drawing designation>**: Vitreous china, wall mounted, with back.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Standard America.
- b. Briggs Plumbing Products, Inc.
- c. Crane Plumbing, L.L.C.
- d. Ferguson Enterprises, Inc.; ProFlo Brand.
- e. Gerber Plumbing Fixtures LLC.
- f. Kohler Co.
- g. Mansfield Plumbing Products LLC.
- h. Peerless Pottery Sales, Inc.
- i. Zurn Industries, LLC; Commercial Brass and Fixtures.
- j. **<Insert manufacturer's name>**.
- k. or approved equal.

2. Fixture:

- a. Standard: ASME A112.19.2/CSA B45.1.
- b. Type: For wall hanging.
- c. Nominal Size: Oval, [19 by 16 inches (483 by 406 mm)] [22 by 14 inches (559 by 356 mm)] [23 by 15 inches (584 by 381 mm)] **<Insert dimensions>**.
- d. Faucet-Hole Punching: [One hole] [Three holes, 2-inch (51-mm) centers] [Three holes, 4-inch (102-mm) centers].
- e. Faucet-Hole Location: Top.
- f. Color: [White] **<Insert color>**.
- g. Mounting Material: Chair carrier.

3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.
4. Support: ASME A112.6.1M, [Type I, exposed-arm lavatory carrier] [Type II, concealed-arm lavatory carrier] [Type II, concealed-arm lavatory carrier with escutcheons]. [Include rectangular, steel uprights.]

- B. Lavatory **<Insert drawing designation>**: Ledge back, vitreous china, wall mounted.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Standard America.
- b. Briggs Plumbing Products, Inc.

- c. Crane Plumbing, L.L.C.
 - d. Ferguson Enterprises, Inc.; ProFlo Brand.
 - e. Gerber Plumbing Fixtures LLC.
 - f. Kohler Co.
 - g. Mansfield Plumbing Products LLC.
 - h. Peerless Pottery Sales, Inc.
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Fixture:
- a. Standard: ASME A112.19.2/CSA B45.1.
 - b. Type: For wall hanging.
 - c. Nominal Size: Oval, [19 by 16 inches (483 by 406 mm)] [22 by 14 inches (559 by 356 mm)] [23 by 15 inches (584 by 381 mm)] **<Insert dimensions>**.
 - d. Faucet-Hole Punching: [One hole] [Three holes, 2-inch (51-mm) centers] [Three holes, 4-inch (102-mm) centers].
 - e. Faucet-Hole Location: Top.
 - f. Color: [White] **<Insert color>**.
 - g. Mounting Material: Chair carrier.
3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.
4. Support: ASME A112.6.1M, [Type I, exposed-arm lavatory carrier] [Type II, concealed-arm lavatory carrier] [Type II, concealed-arm lavatory carrier with escutcheons].[Include rectangular, steel uprights.]
- C. Lavatory **<Insert drawing designation>**: Slab type, vitreous china, wall mounted.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Standard America.
 - b. Kohler Co.
 - c. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Fixture:
 - a. Standard: ASME A112.19.2/CSA B45.1.
 - b. Type: For wall hanging.
 - c. Nominal Size: Oval, [19 by 16 inches (483 by 406 mm)] [22 by 14 inches (559 by 356 mm)] [23 by 15 inches (584 by 381 mm)] **<Insert dimensions>**.
 - d. Faucet-Hole Punching: [One hole] [Three holes, 2-inch (51-mm) centers] [Three holes, 4-inch (102-mm) centers].
 - e. Faucet-Hole Location: Top.
 - f. Color: [White] **<Insert color>**.
 - g. Mounting Material: Chair carrier.

3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.
4. Support: ASME A112.6.1M, **[Type I, exposed-arm lavatory carrier] [Type II, concealed-arm lavatory carrier] [Type II, concealed-arm lavatory carrier with escutcheons]. [Include rectangular, steel uprights.]**

D. Lavatory **<Insert drawing designation>**: Wheelchair, vitreous china, wall mounted.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Standard America.
- b. Crane Plumbing, L.L.C.
- c. Ferguson Enterprises, Inc.; ProFlo Brand.
- d. Gerber Plumbing Fixtures LLC.
- e. Kohler Co.
- f. Mansfield Plumbing Products LLC.
- g. Peerless Pottery Sales, Inc.
- h. **<Insert manufacturer's name>**.
- i. or approved equal.

2. Fixture:

- a. Standard: ASME A112.19.2/CSA B45.1.
- b. Type: Slab or wheelchair.
- c. Nominal Size: Rectangular, **27 by 20 inches** (686 by 508 mm).
- d. Faucet-Hole Punching: Three holes, **[2-inch (51-mm)] <Insert dimension>** centers.
- e. Faucet-Hole Location: Top.
- f. Color: **[White] <Insert color>**.
- g. Mounting: For concealed-arm carrier.

3. Faucet: **<Insert lavatory faucet designation from "Solid-Brass, Manually Operated Faucets" or "Solid-Brass, Automatically Operated Lavatory Faucets" Article>**.

4. Support: ASME A112.6.1M, Type II, concealed-arm lavatory carrier with rectangular, steel uprights.

2.3 SOLID-BRASS, AUTOMATICALLY OPERATED LAVATORY FAUCETS

A. NSF Standard: Comply with NSF/ANSI 61, "Drinking Water System Components - Health Effects," for faucet materials that will be in contact with potable water.

B. Lavatory Faucets **<Insert designation>**: Automatic-type, **[hard-wired,] electronic-sensor-operated, [mixing] [nonmixing]**, solid-brass valve.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. American Standard America.
 - b. Bradley Corporation.
 - c. Chicago Faucets.
 - d. Gerber Plumbing Fixtures LLC.
 - e. Grohe America, Inc.
 - f. Hydrotek International, Inc.
 - g. Kohler Co.
 - h. Moen Incorporated.
 - i. Sloan Valve Company.
 - j. Speakman Company.
 - k. T & S Brass and Bronze Works, Inc.
 - l. TOTO USA, INC.
 - m. Zurn Industries, LLC; Commercial Brass and Fixtures.
 - n. **<Insert manufacturer's name>**.
 - o. or approved equal.
2. Standards: ASME A112.18.1/CSA B125.1 and UL 1951.
 3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 4. General: Include hot- and cold-water indicators; coordinate faucet inlets with supplies and fixture hole punchings; coordinate outlet with spout and fixture receptor.
 5. Body Type: **[Single hole] <Insert type>**.
 6. Body Material: **[Commercial] [General-duty]**, solid brass.
 7. Finish: **[Polished chrome plate] <Insert finish>**.
 8. Maximum Flow Rate: **[0.5 gpm (1.5 L/min.)] <Insert value>**.
 9. Mounting Type: **[Deck, concealed] [Back/wall, concealed] <Insert type>**.
 10. Spout: **[Rigid] [Swing] [Rigid, gooseneck] [Swivel, gooseneck]** type.
 11. Spout Outlet: **[Aerator] [Laminar flow] [Spray] <Insert type>**.
 12. Drain: **[Not part of faucet] <Insert type>**.

2.4 SUPPLY FITTINGS

- A. NSF Standard: Comply with NSF/ANSI 61, "Drinking Water System Components - Health Effects," for supply-fitting materials that will be in contact with potable water.
- B. Standard: ASME A112.18.1/CSA B125.1.
- C. Supply Piping: Chrome-plated-brass pipe or chrome-plated copper tube matching water-supply piping size. Include chrome-plated-brass or stainless-steel wall flange.
- D. Supply Stops: Chrome-plated-brass, one-quarter-turn, ball-type or compression valve with inlet connection matching supply piping.
- E. Operation: **[Loose key] [Wheel handle] <Insert type>**.
- F. Risers:

1. [NPS 3/8 (DN 10)] [NPS 1/2 (DN 15)].
2. **[Chrome-plated, rigid-copper-pipe and brass straight or offset tailpieces]** **[Chrome-plated, soft-copper flexible tube]** **[ASME A112.18.6, braided- or corrugated-stainless-steel, flexible hose]** riser.

2.5 WASTE FITTINGS

- A. Standard: ASME A112.18.2/CSA B125.2.
- B. Drain: Grid type with NPS 1-1/4 (DN 32) offset and straight tailpiece.
- C. Trap:
 1. Size: [NPS 1-1/2 by NPS 1-1/4 (DN 40 by DN 32)] [NPS 1-1/4 (DN 32)].
 2. Material: Chrome-plated, **[two-piece, cast-brass trap and swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall]** **[two-piece, cast-brass trap and ground-joint swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall]** **[one-piece, cast-brass trap with swivel 0.029-inch- (73-mm-) thick tubular brass wall bend]** <Insert trap type>; and chrome-plated, brass or steel wall flange.
 3. Material: Stainless-steel, two-piece trap and swivel elbow with 0.012-inch- (0.30-mm-) thick stainless-steel tube to wall; and stainless-steel wall flange.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before lavatory installation.
- B. Examine counters and walls for suitable conditions where lavatories will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install lavatories level and plumb according to roughing-in drawings.
- B. Install supports, affixed to building substrate, for wall-mounted lavatories.
- C. Install accessible wall-mounted lavatories at handicapped/elderly mounting height for people with disabilities or the elderly, according to ICC/ANSI A117.1.
- D. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons if required to conceal protruding fittings. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."

- E. Seal joints between lavatories, counters, and walls using sanitary-type, one-part, mildew-resistant silicone sealant. Match sealant color to fixture color. Comply with sealant requirements specified in Section 079200 "Joint Sealants."
- F. Install protective shielding pipe covers and enclosures on exposed supplies and waste piping of accessible lavatories. Comply with requirements in Section 220719 "Plumbing Piping Insulation."

3.3 CONNECTIONS

- A. Connect fixtures with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Comply with soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."

3.4 ADJUSTING

- A. Operate and adjust lavatories and controls. Replace damaged and malfunctioning lavatories, fittings, and controls.
- B. Adjust water pressure at faucets to produce proper flow.
- C. Install fresh batteries in battery-powered, electronic-sensor mechanisms.

3.5 CLEANING AND PROTECTION

- A. After completing installation of lavatories, inspect and repair damaged finishes.
- B. Clean lavatories, faucets, and other fittings with manufacturers' recommended cleaning methods and materials.
- C. Provide protective covering for installed lavatories and fittings.
- D. Do not allow use of lavatories for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 224216.13

SECTION 224216.16 - COMMERCIAL SINKS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Service basins.
2. Service sinks.
3. Utility sinks.
4. Handwash sinks.
5. Sink faucets.
6. Supply fittings.
7. Waste fittings.

- B. Related Requirements:

1. Section 224100 "Residential Plumbing Fixtures" for residential sinks.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for sinks.
2. Include rated capacities, operating characteristics[, **electrical characteristics,**] and furnished specialties and accessories.
3. Include data substantiating that materials comply with requirements.

- B. LEED Submittals:

1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
2. Product Data for Prerequisite WE 1: Documentation indicating flow and water consumption requirements.

3. Product Data for Prerequisite WE 1[**and Credit WE 2**]: Documentation indicating flow and water consumption requirements.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Counter cutout templates for mounting of counter-mounted lavatories.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sinks to include in maintenance manuals.
 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Faucet Washers and O-Rings: Equal to [10] <Insert number> percent of amount of each type and size installed.
 2. Faucet Cartridges and O-Rings: Equal to [5] <Insert number> percent of amount of each type and size installed.

1.7 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SERVICE BASINS

- A. Service Basins <Insert drawing designation>: Terrazzo, floor mounted.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Engineering Company.](#)
 - b. [Crane Plumbing, L.L.C.](#)
 - c. [Florestone Products Co., Inc.](#)
 - d. [Stern-Williams Co., Inc.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.

 2. Fixture:
 - a. Standard: IAPMO PS 99.
 - b. Shape: **[Square] [Rectangular] [Five sided] [Radial front] <Insert shape>.**
 - c. Nominal Size: **[24 by 24 inches (610 by 610 mm)] [30 by 30 inches (762 by 762 mm)] [24 by 36 inches (610 by 915 mm)] [32 by 32 inches (815 by 815 mm)] [36 by 36 inches (915 by 915 mm)] <Insert dimensions>.**
 - d. Height: **[6 inches (150 mm)] [10 inches (255 mm)] [12 inches (305 mm)] [12 inches (305 mm) with dropped front] <Insert dimensions>.**
 - e. Tiling Flange: **[Not required] [On one side] [On two sides] [On three sides].**
 - f. Rim Guard: On **[front] [all]** top surfaces.
 - g. Color: **[Not applicable] <Insert color>.**
 - h. Drain: Grid with **[NPS 2 (DN 50)] [NPS 3 (DN 80)]** outlet.

 3. Mounting: On floor and flush to wall.
 4. Faucet: **<Insert sink-faucet designation from "Sink Faucets" Article>.**
- B. Service Basins **<Insert drawing designation>**: Plastic, floor mounted.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Crane Plumbing, L.L.C.](#)
 - b. [Ferguson Enterprises, Inc.: ProFlo Brand.](#)
 - c. [Florestone Products Co., Inc.](#)
 - d. [Mustee, E. L., & Sons, Inc.](#)
 - e. [Swan Corporation \(The\).](#)
 - f. [Zurn Industries, LLC; Light Commercial Specialty Plumbing Products.](#)
 - g. **<Insert manufacturer's name>.**
 - h. or approved equal.

 2. Fixture:
 - a. Standard: IAPMO/ANSI Z124.6.
 - b. Material: **[Cast polymer] <Insert material>.**
 - c. Nominal Size: **[24 by 36 by 10 inches (610 by 915 mm by 255 mm)] [36 by 36 by 10 inches (915 by 915 by 255 mm)] <Insert dimensions>.**

- d. Tiling Flange: **[Not required]** **[On one side]** **[On two sides]** **[On three sides]**.
 - e. Rim Guard: On **[front]** **[all]** top surfaces.
 - f. Color: **[Not applicable]** **<Insert color>**.
 - g. Drain: Grid with **[NPS 2 (DN 50)]** **[NPS 3 (DN 80)]** outlet.
3. Mounting: On floor and flush to wall.
 4. Faucet: **<Insert sink-faucet designation from "Sink Faucets" Article>**.

2.2 SERVICE SINKS

A. Service Sinks **<Insert drawing designation>**: Vitreous china, trap standard mounted.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Crane Plumbing, L.L.C.](#)
 - b. [Kohler Co.](#)
 - c. [Zurn Industries, LLC; Commercial Brass and Fixtures.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Fixture:
 - a. Standard: ASME A112.19.2/CSA B45.1.
 - b. Type: Service sink with back.
 - c. Back: **[Two faucet holes]** **[Plain]**.
 - d. Nominal Size: **[22 by 20 inches (560 by 508 mm)]** **<Insert dimensions>**.
 - e. Color: White.
 - f. Mounting: **[NPS 2 (DN 50)]** **[NPS 3 (DN 80)]** P-trap standard with grid strainer inlet, cleanout, and floor flange.
 - g. Rim Guard: On front and sides.
3. Faucet: **<Insert sink-faucet designation from "Sink Faucets" Article>**.
4. Support: ASME A112.6.1M, Type II, sink carrier.

2.3 UTILITY SINKS

A. Utility Sinks **<Insert drawing designation>**: Stainless steel, counter mounted.

1. Manufacturers: Subject to compliance with requirements, **provide products by one of the following**:
 - a. [Advance Tabco.](#)
 - b. [Eagle Group; Foodservice Equipment Division.](#)
 - c. [Elkay Manufacturing Co.](#)
 - d. [Griffin Products, Inc.](#)
 - e. [Just Manufacturing.](#)
 - f. **<Insert manufacturer's name>**.

- g. or approved equal.
2. Fixture:
- a. Standard: ASME A112.19.3/CSA B45.4.
 - b. Type: Ledge back.
 - c. Number of Compartments: **[One] [Two] [Three]**.
 - d. Overall Dimensions: **<Insert dimensions>**.
 - e. Metal Thickness: **[0.050 inch (1.3 mm)] <Insert dimension>**.
 - f. Compartment:
 - 1) Dimensions: **<Insert dimensions>**.
 - 2) Drain: **[Grid with NPS 1-1/2 (DN 40) tailpiece and twist drain] [Grid with NPS 2 (DN 50) tailpiece and twist drain] [NPS 1-1/2 (DN 40) tailpiece with stopper] <Insert drain>**.
 - 3) Drain Location: **[Centered in compartment] [Near back of compartment] [Near left side of compartment] [Near right side of compartment] <Insert location>**.
 - g. Each Compartment:
 - 1) Dimensions: **<Insert dimensions>**.
 - 2) Drains: **[Grid with NPS 1-1/2 (DN 40) tailpiece and twist drain] [Grid with NPS 2 (DN 50) tailpiece and twist drain] [NPS 1-1/2 (DN 40) tailpiece with stopper] <Insert drain>**.
 - 3) Drain Location: **[Centered in compartment] [Near back of compartment] <Insert location>**.
3. Faucet(s): **<Insert sink-faucet designation from "Sink Faucets" Article>**.
- a. Number Required: **[One] [Two]**.
 - b. Mounting: On ledge.
4. Supply Fittings:
- a. Standard: ASME A112.18.1/CSA B125.1.
 - b. Supplies: Chrome-plated brass compression stop with inlet connection matching water-supply piping type and size.
 - 1) Operation: **[Loose key] [Wheel handle] <Insert type>**.
 - 2) Risers: **NPS 1/2 (DN 15), [chrome-plated, rigid-copper pipe] [chrome-plated, soft-copper flexible tube] [ASME A112.18.6, braided or corrugated stainless-steel flexible hose]**.
5. Waste Fittings:
- a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap(s):
 - 1) Size: **[NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)]**.

- 2) Material: Chrome-plated, **[two-piece, cast-brass trap and swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall] [two-piece, cast-brass trap and ground-joint swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall]** <Insert trap type>; and chrome-plated brass or steel wall flange.
 - 3) Material: Stainless-steel, two-piece trap and swivel elbow with **0.012-inch- (0.30-mm-) thick stainless-steel tube to wall;** and stainless-steel wall flange.
 - c. Continuous Waste:
 - 1) Size: **[NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)].**
 - 2) Material: Chrome-plated, **0.032-inch- (0.83-mm-) thick brass tube.**
 6. Mounting: On counter with sealant.
- B. Utility Sinks <Insert drawing designation>: Stainless steel, freestanding.
1. Manufacturers: Subject to compliance with requirements, **provide products by one of the following:**
 - a. [Advance Tabco.](#)
 - b. [AERO Manufacturing Company.](#)
 - c. [Amtekco Industries, Inc.](#)
 - d. [Eagle Group; Foodservice Equipment Division.](#)
 - e. [Elkay Manufacturing Co.](#)
 - f. [Griffin Products, Inc.](#)
 - g. [Just Manufacturing.](#)
 - h. **<Insert manufacturer's name>.**
 - i. or approved equal.
 2. Fixture:
 - a. Standard: ASME A112.19.3/CSA B45.4.
 - b. Type: With backsplash.
 - c. Number of Compartments: **[One] [Two] [Three].**
 - d. Overall Dimensions: **<Insert dimensions>.**
 - e. Metal Thickness: **[0.050 inch (1.3 mm)] [0.063 inch (1.6 mm)] <Insert dimension>.**
 - f. Compartment:
 - 1) Dimensions: **<Insert dimensions>.**
 - 2) Drain: **[Grid with NPS 1-1/2 (DN 40) tailpiece and twist drain] [Grid with NPS 2 (DN 50) tailpiece and twist drain] [NPS 1-1/2 (DN 40) tailpiece with stopper]** <Insert drain>.
 - 3) Drain Location: **[Centered in compartment] [Near back of compartment] [Near left side of compartment] [Near right side of compartment]** <Insert location>.
 - g. Each Compartment:

- 1) Dimensions: **<Insert dimensions>**.
 - 2) Drains: **[Grid with NPS 1-1/2 (DN 40) tailpiece and twist drain]**
[Grid with NPS 2 (DN 50) tailpiece and twist drain] **[NPS 1-1/2 (DN 40) tailpiece with stopper]** **<Insert drain>**.
 - 3) Drain Location: **[Centered in compartment]** **[Near back of compartment]** **<Insert location>**.
- h. Drainboard(s): **[Not required]** **[Both]** **[Left]** **[Right]** side(s).
- 1) Dimensions Each: **[Not applicable]** **<Insert dimensions>**.
3. Supports: Adjustable-length steel legs.
4. Faucet(s): **<Insert sink-faucet designation from "Sink Faucets" Article>**.
- a. Number Required: **[One]** **[Two]**.
 - b. Mounting: On backsplash.
5. Supply Fittings:
- a. Standard: ASME A112.18.1/CSA B125.1.
 - b. Supplies: Chrome-plated brass compression stop with inlet connection matching water-supply piping type and size.
 - 1) Operation: **[Loose key]** **[Wheel handle]** **<Insert type>**.
 - 2) Risers: **NPS 1/2 (DN 15)**, **[chrome-plated, rigid-copper pipe]**
[chrome-plated, soft-copper flexible tube] **[ASME A112.18.6, braided or corrugated stainless-steel flexible hose]**.
6. Waste Fittings:
- a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap(s):
 - 1) Size: **[NPS 1-1/2 (DN 40)]** **[NPS 2 (DN 50)]**.
 - 2) Material: Chrome-plated, **[two-piece, cast-brass trap and swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall]**
[two-piece, cast-brass trap and ground-joint swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall] **<Insert trap type>**;
and chrome-plated brass or steel wall flange.
 - 3) Material: Stainless-steel, two-piece trap and swivel elbow with **0.012-inch- (0.30-mm-) thick stainless-steel tube to wall;** and stainless-steel wall flange.
 - c. Continuous Waste:
 - 1) Size: **[NPS 1-1/2 (DN 40)]** **[NPS 2 (DN 50)]**.
 - 2) Material: Chrome-plated, **0.032-inch- (0.83-mm-) thick brass tube.**

2.4 HANDWASH SINKS

- A. Handwash Sinks **<Insert drawing designation>**: Stainless steel, wall mounted.
1. Manufacturers: Subject to compliance with requirements, **provide products by one of the following**:
 - a. [Advance Tabco.](#)
 - b. [AERO Manufacturing Company.](#)
 - c. [Amtekco Industries, Inc.](#)
 - d. [Eagle Group; Foodservice Equipment Division.](#)
 - e. [Elkay Manufacturing Co.](#)
 - f. [Griffin Products, Inc.](#)
 - g. [Just Manufacturing.](#)
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
 2. Fixture:
 - a. Standards: ASME A112.19.3/CSA B45.4 and NSF/ANSI 2.
 - b. Type: Basin with radius corners, back for faucet, and support brackets.
 - c. Nominal Size: **17 by 16 by 5 inches** (432 by 406 by 127 mm).
 3. Faucet: **<Insert sink-faucet designation from "Sink Faucets" Article>**.
 4. Supply Fittings: Comply with requirements in "Supply Fittings" Article.
 5. Waste Fittings: Comply with requirements in "Waste Fittings" Article.
 6. Support: ASME A112.6.1M, Type II, sink carrier.

2.5 SINK FAUCETS

- A. NSF Standard: Comply with NSF/ANSI 61, "Drinking Water System Components - Health Effects," for faucet-spout materials that will be in contact with potable water.
- B. Sink Faucets **<Insert drawing designation>**: Manual type, **[single-control]** **[two-lever-handle]** **<Insert type>** mixing valve.
1. Commercial, Solid-Brass Faucets.
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) [American Standard America.](#)
 - 2) [Bradley Corporation.](#)
 - 3) [Chicago Faucets.](#)
 - 4) [Delta Faucet Company.](#)
 - 5) [Elkay Manufacturing Co.](#)
 - 6) [GROHE America, Inc.](#)
 - 7) [Just Manufacturing.](#)
 - 8) [Kohler Co.](#)
 - 9) [Moen Incorporated.](#)

- 10) [Speakman Company.](#)
- 11) [T & S Brass and Bronze Works, Inc.](#)
- 12) [Zurn Plumbing Products Group.](#)
- 13) **<Insert manufacturer's name>.**
- 14) or approved equal.

2. General-Duty, Solid-Brass Faucets.

- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1) [American Standard America.](#)
- 2) [Bradley Corporation.](#)
- 3) [BrassTech Inc.](#)
- 4) [Central Brass Company.](#)
- 5) [Chicago Faucets.](#)
- 6) [Danze, Inc.](#)
- 7) [Delta Faucet Company.](#)
- 8) [Eljer, Inc.](#)
- 9) [Elkay Manufacturing Co.](#)
- 10) [Franke Consumer Products, Inc.](#)
- 11) [Gerber Plumbing Fixtures LLC.](#)
- 12) [Griffin Products, Inc.](#)
- 13) [GROHE America, Inc.](#)
- 14) [Hansgrohe USA.](#)
- 15) [Hydrotek International, Inc.](#)
- 16) [Intersan Manufacturing Company.](#)
- 17) [Just Manufacturing.](#)
- 18) [Kohler Co.](#)
- 19) [Matco-Norca.](#)
- 20) [Moen Incorporated.](#)
- 21) [Price Pfister, Inc.](#)
- 22) [Speakman Company.](#)
- 23) [T & S Brass and Bronze Works, Inc.](#)
- 24) [WhiteRock Corp.](#)
- 25) [Wolverine Brass, Inc.](#)
- 26) [Zurn Plumbing Products Group.](#)
- 27) **<Insert manufacturer's name>.**
- 28) or approved equal.

3. Copper- or Brass-Underbody Faucets.

- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1) [American Standard America.](#)
- 2) [Briggs Plumbing Products, Inc.](#)
- 3) [Danze, Inc.](#)
- 4) [Delta Faucet Company.](#)
- 5) [Eljer, Inc.](#)

- 6) [Ferguson Enterprises, Inc.](#)
- 7) [Gerber Plumbing Fixtures LLC.](#)
- 8) [Matco-Norca.](#)
- 9) [Moen Incorporated.](#)
- 10) [Sterling.](#)
- 11) [WhiteRock Corp.](#)
- 12) [Wolverine Brass, Inc.](#)
- 13) **<Insert manufacturer's name>.**
- 14) or approved equal.

4. Standard: ASME A112.18.1/CSA B125.1.
5. General: Include hot- and cold-water indicators; coordinate faucet inlets with supplies and fixture hole punchings; coordinate outlet with spout and sink receptor.
6. Body Type: **[Centerset] [Widespread] [Single hole] <Insert type>.**
7. Body Material: **[Commercial, solid brass] [General-duty, solid brass] [Copper or brass underbody].**
8. Finish: **[Chrome plated] [Polished chrome plate] <Insert finish>.**
9. Maximum Flow Rate: **[2.2 gpm (8.3 L/min.)] [4.0 gpm (15 L/min.)] <Insert value>.**
10. Handle(s): **[Lever] [Cross, four arm] [Wrist blade, 4 inches (102 mm)] [Elbow, 6 inches (152 mm)] [Not applicable] <Insert handles>.**
11. Mounting Type: **[Deck, concealed] [Deck, exposed] [Back/wall, exposed].**
12. Spout Type: **[Rigid, solid brass] [Rigid, solid brass with wall brace] [Swing, round tubular] [Swing, shaped tube] [Swing, solid brass] [Rigid gooseneck] [Swivel gooseneck] <Insert type>.**
13. Vacuum Breaker: **[Required] [Not required] for hose outlet.**
14. Spout Outlet: **[Aerator] [Laminar flow] [Hose thread according to ASME B1.20.7] [Plain end] [Spray] <Insert type>.**

2.6 SUPPLY FITTINGS

- A. NSF Standard: Comply with NSF/ANSI 61, "Drinking Water System Components - Health Effects," for supply-fitting materials that will be in contact with potable water.
- B. Standard: ASME A112.18.1/CSA B125.1.
- C. Supply Piping: Chrome-plated brass pipe or chrome-plated copper tube matching water-supply piping size. Include chrome-plated brass or stainless-steel wall flange.
- D. Supply Stops: Chrome-plated brass, one-quarter-turn, ball-type or compression valve with inlet connection matching supply piping.
- E. Operation: **[Loose key] [Wheel handle] <Insert type>.**
- F. Risers:
 1. **[NPS 3/8 (DN 10)] [NPS 1/2 (DN 15)]**
 2. **[Chrome-plated, rigid-copper pipe] [Chrome-plated, soft-copper flexible tube] [ASME A112.18.6, braided or corrugated stainless-steel flexible hose].**

2.7 WASTE FITTINGS

- A. Standard: ASME A112.18.2/CSA B125.2.
- B. Drain: Grid type with NPS 1-1/2 (DN 40) offset and straight tailpiece.
- C. Trap:
 - 1. Size: NPS 1-1/2 (DN 40).
 - 2. Material: Chrome-plated, **[two-piece, cast-brass trap and swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall] [two-piece, cast-brass trap and ground-joint swivel elbow with 0.032-inch- (0.83-mm-) thick brass tube to wall] [one-piece, cast-brass trap with swivel 0.029-inch- (73-mm-) thick tubular brass wall bend] <Insert trap type>**; and chrome-plated brass or steel wall flange.
 - 3. Material: Stainless-steel, two-piece trap and swivel elbow with 0.012-inch- (0.30-mm-) thick stainless-steel tube to wall; and stainless-steel wall flange.

2.8 GROUT

- A. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- B. Characteristics: Nonshrink; recommended for interior and exterior applications.
- C. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before sink installation.
- B. Examine walls, floors, and counters for suitable conditions where sinks will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install sinks level and plumb according to roughing-in drawings.
- B. Install supports, affixed to building substrate, for wall-hung sinks.

- C. Install accessible wall-mounted sinks at handicapped/elderly mounting height according to ICC/ANSI A117.1.
- D. Set floor-mounted sinks in leveling bed of cement grout.
- E. Install water-supply piping with stop on each supply to each sink faucet.
 - 1. Exception: Use ball, gate, or globe valves if supply stops are not specified with sink. Comply with valve requirements specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 - 2. Install stops in locations where they can be easily reached for operation.
- F. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons if required to conceal protruding fittings. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."
- G. Seal joints between sinks and counters, floors, and walls using sanitary-type, one-part, mildew-resistant silicone sealant. Match sealant color to fixture color. Comply with sealant requirements specified in Section 079200 "Joint Sealants."
- H. Install protective shielding pipe covers and enclosures on exposed supplies and waste piping of accessible sinks. Comply with requirements in Section 220719 "Plumbing Piping Insulation."

3.3 CONNECTIONS

- A. Connect sinks with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Comply with soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."

3.4 ADJUSTING

- A. Operate and adjust sinks and controls. Replace damaged and malfunctioning sinks, fittings, and controls.
- B. Adjust water pressure at faucets to produce proper flow.

3.5 CLEANING AND PROTECTION

- A. After completing installation of sinks, inspect and repair damaged finishes.

- B. Clean sinks, faucets, and other fittings with manufacturers' recommended cleaning methods and materials.
- C. Provide protective covering for installed sinks and fittings.
- D. Do not allow use of sinks for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **224216.16**

SECTION 224223 - COMMERCIAL SHOWERS, RECEPTORS, AND BASINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Individual shower receptors.
2. Shower faucets.
3. Shower basins.
4. Group showers.
5. Grout.

- B. Related Requirements:

1. Section 224500 "Emergency Plumbing Fixtures" for emergency showers.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for showers[**and basins**].
2. Include rated capacities, operating characteristics, and furnished specialties and accessories.
3. Include data substantiating that materials comply with requirements.

- B. LEED Submittals:

1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
2. Product Data for Prerequisite WE 1: Documentation indicating flow and water consumption requirements.
3. Product Data for Prerequisite WE 1[**and Credit WE 2**]: Documentation indicating flow and water consumption requirements.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For shower faucets to include in maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Faucet Washers and O-Rings: Equal to [10] <Insert number> percent of amount of each type and size installed.
 - 2. Faucet Cartridges and O-Rings: Equal to [5] <Insert number> percent of amount of each type and size installed.

1.6 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 INDIVIDUAL SHOWERS

- A. Individual FRP Showers <Insert drawing designation>:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Aqua Glass Corporation.](#)
 - b. [Clarion Bathware.](#)
 - c. [Florestone Products Co., Inc.](#)
 - d. [LASCO Bathware.](#)
 - e. [MAAX.](#)
 - f. [MAAX; Aker Division.](#)

- g. [Praxis Industries, LLC.; Aquarius Bathware.](#)
 - h. [Sterling; a Kohler company.](#)
 - i. [Swan Corporation \(The\).](#)
 - j. **<Insert manufacturer's name>.**
 - k. or approved equal.
2. General: FRP[, **accessible,**] shower enclosure with faucet and receptor[**and appurtenances**].
 3. Standard: ANSI Z124.1.2.
 4. Type: [**One-piece unit with top**] [**One-piece unit without top**] [**Sectional unit with top**] [**Sectional unit without top**].
 5. Style: [**Standard residential**] [**Handicapped/wheelchair**].
 6. Faucet: **<Insert faucet designation from "Shower Faucets" Article>.**
 7. Nominal Size and Shape: [**30 by 30 inches (762 by 762 mm) square**] [**32 by 32 inches (813 by 813 mm) square**] [**34 by 34 inches (864 by 864 mm) square**] [**36 by 36 inches (915 by 915 mm) square**] [**48 by 34 to 36 inches (1219 by 864 to 915 mm) rectangular**] [**60 by 34 to 36 inches (1524 by 864 to 915 mm) rectangular**] [**36 inches (915 mm) neo-corner (two walls)**] [**36 inches (915 mm) neo-corner (four walls)**] [**38 inches (965 mm) neo-corner (two walls)**] [**38 inches (965 mm) neo-corner (four walls)**] [**42 inches (1067 mm) neo-corner (two walls)**] [**42 inches (1067 mm) neo-corner (four walls)**] **<Insert dimensions>.**
 8. Color: [**White**] **<Insert color>.**
 9. Bathing Surface: Slip resistant according to ASTM F 462.
 10. Outlet: Drain with [**NPS 2 (DN 50)**] **<Insert size>** outlet.
 11. Shower Rod and Curtain: [**Not required**] [**Required**].
 12. Grab Bar: [**ASTM F 446, mounted on support area back wall**] [**Not required**].

B. Individual PMMA Showers **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acryline USA, Inc.](#)
 - b. [Aqua Bath Company, Inc.](#)
 - c. [Aqua Glass Corporation.](#)
 - d. [Aquatic Industries, Inc.](#)
 - e. [Clarion Bathware.](#)
 - f. [Crane Plumbing, L.L.C.](#)
 - g. [Jacuzzi Inc.](#)
 - h. [Kohler Co.](#)
 - i. [LASCO Bathware.](#)
 - j. [MAAX.](#)
 - k. [Praxis Industries, LLC.; Aquarius Bathware.](#)
 - l. **<Insert manufacturer's name>.**
 - m. or approved equal.
2. General: PMMA shower enclosure with faucet and receptor[**and appurtenances**].
3. Standard: ANSI Z124.1.2.

4. Type: [**One-piece unit with top**] [**One-piece unit without top**] [**Sectional unit with top**] [**Sectional unit without top**].
5. Style: [**Standard residential**] [**Handicapped/wheelchair**].
6. Faucet: <Insert faucet designation from "Shower Faucets" Article>.
7. Nominal Size and Shape: [**30 by 30 inches (762 by 762 mm) square**] [**32 by 32 inches (813 by 813 mm) square**] [**34 by 34 inches (864 by 864 mm) square**] [**36 by 36 inches (915 by 915 mm) square**] [**48 by 34 to 36 inches (1219 by 864 to 915 mm) rectangular**] [**60 by 34 to 36 inches (1524 by 864 to 915 mm) rectangular**] [**36 inches (915 mm) neo-corner (two walls)**] [**36 inches (915 mm) neo-corner (four walls)**] [**38 inches (965 mm) neo-corner (two walls)**] [**38 inches (965 mm) neo-corner (four walls)**] [**42 inches (1067 mm) neo-corner (two walls)**] [**42 inches (1067 mm) neo-corner (four walls)**] <Insert dimensions>.
8. Color: [**White**] <Insert color>.
9. Bathing Surface: Slip resistant according to ASTM F 462.
10. Outlet: Drain with [**NPS 2 (DN 50)**] <Insert size> outlet.
11. Shower Rod and Curtain: [**Not required**] [**Required**].
12. Grab Bar: [**ASTM F 446, mounted on support area back wall**] [**Not required**].

C. Individual Cabinet Showers <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Bradley Corporation](#).
 - b. [Crane Plumbing, L.L.C.](#)
 - c. [Mustee, E. L. & Sons, Inc.](#)
 - d. [Stern-Williams Co., Inc.](#)
 - e. [Swan Corporation \(The\)](#).
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
2. General: Factory-fabricated[, **accessible**] cabinet shower, with faucet and receptor.
3. Nominal Size: [**30 by 30 inches (762 by 762 mm)**] [**32 by 32 inches (813 by 813 mm)**] [**36 by 36 inches (915 by 915 mm)**] [**36 by 39 inches (915 by 990 mm)**] [**45 by 39 inches (1145 by 990 mm)**] <Insert dimensions>.
4. Material: [**Steel**] [**Stainless steel**] [**Composite**] [**Plastic**], [**front**] [**corner**] [**front and rear**] access.
5. Color: [**Not applicable**] <Insert color>.
6. Accessibility Options: Grab bar and bench.
7. Faucet: [**Manufacturer's standard fitting assembly**] <Insert faucet designation from "Shower Faucets" Article>.
8. Supplies: **NPS 1/2 (DN 15) copper tubing** [**with ball, gate, or globe valves**].
9. Drain: Grid, **NPS 2 (DN 50)**.

2.2 SHOWER FAUCETS

- A. NSF Standard: Comply with NSF 61, "Drinking Water System Components - Health Effects," for shower materials that will be in contact with potable water.

B. Shower Faucets <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [American Standard America.](#)
 - b. [Chicago Faucets.](#)
 - c. [Ferguson Enterprises, Inc.; ProFlo Brand.](#)
 - d. [Kohler Co.](#)
 - e. [Lawler Manufacturing Co., Inc.](#)
 - f. [Leonard Valve Company.](#)
 - g. [Matco-Norca.](#)
 - h. [Moen Incorporated.](#)
 - i. [Powers; a division of Watts Water Technologies, Inc.](#)
 - j. [Speakman Company.](#)
 - k. [Zurn Industries, LLC; AquaSpec Commercial Faucet Products.](#)
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
2. Description: Single-handle, pressure-balance mixing valve with hot- and cold-water indicators; check stops; and shower head.
3. Faucet:
 - a. Standards: ASME A112.18.1/CSA B125.1 and ASSE 1016.
 - b. Body Material: Solid brass.
 - c. Finish: Polished chrome plate.
 - d. Maximum Flow Rate: [2.5 gpm (9.5 L/min.)] <Insert value> unless otherwise indicated.
 - e. Mounting: [**Concealed**] [**Exposed**].
 - f. Operation: Single-handle, [**push-pull**] [**or**] [**twist or rotate**] control.
 - g. Antiscald Device: [**Integral with mixing valve**] [**Separate unit**] [**Not required**].
 - h. Check Stops: Check-valve type, integral with or attached to body; on hot- and cold-water supply connections.
4. Supply Connections: **NPS 1/2 (DN 15)**.
5. Shower Head:
 - a. Standard: ASME A112.18.1/CSA B125.1.
 - b. Type: [**Ball joint with arm and flange**] [**Without ball joint, but with arm and flange**] [**Ball joint and head integral with mounting flange**] [**Integral with mounting flange**] <Insert type>.
 - c. Shower Head Material: Metallic with chrome-plated finish.
 - d. Spray Pattern: [**Adjustable**] [**Fixed**].
 - e. Integral Volume Control: [**Not required**] [**Required**].
 - f. Shower-Arm, Flow-Control Fitting: [**Not required**] [**1.5 gpm (5.7 L/min.)**] [**2.0 gpm (7.6 L/min.)**].
 - g. Temperature Indicator: [**Integral with faucet**] [**Not required**].

C. Shower Faucets <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Chicago Faucets](#).
 - b. [Lawler Manufacturing Co., Inc.](#)
 - c. [Leonard Valve Company](#).
 - d. [Powers; a division of Watts Water Technologies, Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Description: Single-handle, thermostatic mixing valve with hot- and cold-water indicators; check stops; and shower head.
3. Faucet:
 - a. Standards: ASME A112.18.1/CSA B125.1 and ASSE 1016.
 - b. Body Material: Solid brass.
 - c. Finish: Polished chrome plate.
 - d. Maximum Flow Rate: [2.5 gpm (9.5 L/min.)] **<Insert value>** unless otherwise indicated.
 - e. Mounting: [**Concealed**] [**Exposed**].
 - f. Operation: Single-handle, [**push-pull**] [**or**] [**twist or rotate**] control.
 - g. Antiscald Device: [**Integral with mixing valve**] [**Separate unit**] [**Not required**].
 - h. Check Stops: Check-valve type, integral with or attached to body; on hot- and cold-water supply connections.
4. Supply Connections: **NPS 1/2 (DN 15)**.
5. Shower Head:
 - a. Standard: ASME A112.18.1/CSA B125.1.
 - b. Type: [**Ball joint with arm and flange**] [**Without ball joint, but with arm and flange**] [**Ball joint and head integral with mounting flange**] [**Integral with mounting flange**] **<Insert type>**.
 - c. Shower Head Material: Metallic with chrome-plated finish.
 - d. Spray Pattern: [**Adjustable**] [**Fixed**].
 - e. Integral Volume Control: [**Not required**] [**Required**].
 - f. Shower-Arm, Flow-Control Fitting: [**Not required**] [**1.5 gpm (5.7 L/min.)**] [**2.0 gpm (7.6 L/min.)**].
 - g. Temperature Indicator: [**Integral with faucet**] [**Not required**].

2.3 SHOWER BASINS

- A. Shower Basins **<Insert drawing designation>**: [**Cast-polymer**] [**FRP**] [**PMMA**] [**Precast-terrazzo**] [**Solid-surface**] shower basin.

1. Cast-Polymer Shower Basins:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1) [Crane Plumbing, L.L.C.](#)
 - 2) [Florestone Products Co., Inc.](#)
 - 3) **<Insert manufacturer's name>**.
 - 4) or approved equal.
2. FRP Shower Basins:
- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) [Crane Plumbing, L.L.C.](#)
 - 2) [Florestone Products Co., Inc.](#)
 - 3) [LASCO Bathware.](#)
 - 4) [MAAX.](#)
 - 5) [Mustee, E. L. & Sons, Inc.](#)
 - 6) [Sterling.](#)
 - 7) [Swan Corporation \(The\).](#)
 - 8) **<Insert manufacturer's name>**.
 - 9) or approved equal.
3. PMMA (Acrylic) Shower Basins:
- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) [American Standard America.](#)
 - 2) [Crane Plumbing, L.L.C.](#)
 - 3) [Florestone Products Co., Inc.](#)
 - 4) [Jason International, Inc.](#)
 - 5) [Kohler Co.](#)
 - 6) [LASCO Bathware.](#)
 - 7) [MAAX.](#)
 - 8) [Royal Baths Manufacturing Co.](#)
 - 9) **<Insert manufacturer's name>**.
 - 10) or approved equal.
4. Precast-Terrazzo Shower Basins:
- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) [Acorn Engineering Company.](#)
 - 2) [Crane Plumbing, L.L.C.](#)
 - 3) [Florestone Products Co., Inc.](#)
 - 4) [Stern-Williams Co., Inc.](#)
 - 5) **<Insert manufacturer's name>**.
 - 6) or approved equal.
5. Solid-Surface Shower Basins:

- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) [Swan Corporation \(The\)](#).
 - 2) [Tower Industries](#).
 - 3) **<Insert manufacturer's name>**.
 - 4) or approved equal.
6. General: [**Cast-polymer**] [**FRP**] [**PMMA**] [**Precast-terrazzo**] [**Solid-surface**] base for built-up-type shower fixture.
7. Standard: ANSI Z124.1.3 for [**cast-polymer**] [**FRP**] [**PMMA**] bases.
8. Standard: IAPMO PS 99 for precast-terrazzo material.
9. Standard: ANSI/ICPA SS-1 for solid-surface material.
10. Type: [**Standard residential**] [**Handicapped/wheelchair**].
11. Nominal Size and Shape: [**30 by 30 inches** (762 by 762 mm) **square**] [**32 by 32 inches** (813 by 813 mm) **square**] [**36 by 36 inches** (915 by 915 mm) **square**] [**42 by 34 to 36 inches** (1067 by 864 to 915 mm) **rectangular**] [**48 by 34 to 36 inches** (1219 by 864 to 915 mm) **rectangular**] [**36 inches** (915 mm) **neo-corner**] [**42 inches** (1067 mm) **neo-corner**] **<Insert dimensions>**.
12. Color: [**White**] **<Insert color>**.
13. Outlet: Drain with [**NPS 2** (DN 50)] **<Insert size>** outlet.
14. Bathing Surface: Slip resistant according to ASTM F 462.

2.4 GROUP SHOWERS

A. Group Column Showers **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Engineering Company](#).
 - b. [Bradley Corporation](#).
 - c. [Willoughby Industries, Inc.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Description: Stainless-steel, column shower fixture with individual nozzles.
3. Standards: ASME A112.18.1/CSA B125.1 and ASSE 1016.
4. Metal Nominal Thickness: [**0.050 inch** (1.3 mm) **minimum**] [**0.063 inch** (1.6 mm)].
5. Number of Shower Nozzles: [**Two**] [**Three**] [**Four**] [**Five**] [**Six**].
6. Height to Nozzles: [**66 inches** (1675 mm)] [**72 inches** (1830 mm)] **<Insert dimension>**.
7. Control: [**Thermostatic**] [**Pressure-balance**] mixing valve with hot- and cold-water operation.
8. Control: Thermostatic mixing valve with individual, tempered-water supply and push-button operation.
9. Flow Control: [**2 gpm** (7.6 L/min.)] [**2.5 gpm** (9.5 L/min.)] for each shower head.
10. Liquid Soap Dispenser: [**Not required**] [**Required**] for each shower head.
11. Soap Dish: [**Not required**] [**Required**] for each shower head.

12. Mounting: Floor flange.
13. Supplies: [NPS 3/4 (DN 20)] [NPS 1 (DN 25)] copper tubing with shutoff valve from [bottom] [top].
14. Shroud: [Not required] [Stainless steel of size to cover supplies and vent piping].
15. Drain Fitting: [NPS 3 (DN 80)] [NPS 4 (DN 100)] outlet with NPS 2 (DN 50) vent, integral with base of column.

B. Group Wall-Mounted Showers <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Engineering Company](#).
 - b. [Bradley Corporation](#).
 - c. [Willoughby Industries, Inc.](#)
 - d. <Insert manufacturer's name>.
 - e. or approved equal.
2. Description: Stainless-steel, wall-mounted, surface-enclosure shower fixture with individual nozzles.
3. Standards: ASME A112.18.1/CSA B125.1 and ASSE 1016.
4. Metal Nominal Thickness: [0.050 inch (1.3 mm) minimum] [0.063 inch (1.6 mm)].
5. Number of Shower Nozzles: [Two] [Three].
6. Height to Nozzles: [66 inches (1675 mm)] [72 inches (1830 mm)] <Insert dimension>.
7. Control: [Thermostatic] [Pressure-balance] valve with individual hot- and cold-water mixing-valve operation.
8. Control: Thermostatic valve with individual, tempered-water supply and push-button operation.
9. Flow Control: [2 gpm (7.6 L/min.)] [2.5 gpm (9.5 L/min.)] for each shower head.
10. Liquid Soap Dispenser: [Not required] [Required] for each shower head.
11. Soap Dish: [Not required] [Required] for each shower head.
12. Mounting: Wall bracket.
13. Supplies: NPS 3/4 (DN 20) copper tubing with valves.

2.5 GROUT

- A. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- B. Characteristics: Nonshrink; recommended for interior and exterior applications.
- C. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water-supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before shower installation.
- B. Examine walls and floors for suitable conditions where showers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Assemble shower components according to manufacturers' written instructions.
- B. Install showers level and plumb according to roughing-in drawings.
- C. Install water-supply piping with stop on each supply to each shower faucet.
 - 1. Exception: Use ball, gate, or globe valves if supply stops are not specified with shower. Comply with valve requirements specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 - 2. Install stops in locations where they can be easily reached for operation.
- D. Install shower flow-control fittings with specified maximum flow rates in shower arms.
- E. Set [**shower receptors**] [**and**] [**shower basins**] in leveling bed of cement grout.
- F. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons if required to conceal protruding fittings. Comply with escutcheons requirements specified in Section 220518 "Escutcheons for Plumbing Piping."
- G. Seal joints between showers and floors and walls using sanitary-type, one-part, mildew-resistant silicone sealant. Match sealant color to fixture color. Comply with sealant requirements specified in Section 079200 "Joint Sealants."

3.3 CONNECTIONS

- A. Connect fixtures with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Comply with traps and soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."

3.4 ADJUSTING

- A. Operate and adjust showers and controls. Replace damaged and malfunctioning showers, fittings, and controls.
- B. Adjust water pressure at faucets to produce proper flow.

3.5 CLEANING AND PROTECTION

- A. After completing installation of showers[**and basins**], inspect and repair damaged finishes.
- B. Clean showers[**and basins**], faucets, and other fittings with manufacturers' recommended cleaning methods and materials.
- C. Provide protective covering for installed fixtures and fittings.
- D. Do not allow use of showers[**and basins**] for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **224223**

SECTION 224233 - WASH FOUNTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Circular wash fountains.
 - 2. Semicircular wash fountains.
 - 3. Corner wash fountains.
 - 4. Linear wash fountains.
- B. Related Requirements:
 - 1. Section 224216.13 "Commercial Lavatories."
 - 2. Section 224216.16 "Commercial Sinks."
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for wash fountains.
 - 2. Include rated capacities, operating characteristics, [**electrical characteristics,**] and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1 [**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
 - 2. Product Data for Prerequisite WE 1 [**and Credit WE 1**]: Documentation indicating flow and water consumption requirements.
 - 3. Product Data for Prerequisite WE 1 [**and Credit WE 2**]: Documentation indicating flow and water consumption requirements.

- C. Shop Drawings: For each type of wash fountain.
1. Include plans, elevations, sections, and **[mounting] [attachment]** details.
 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For wash fountains and components to include in operation and maintenance manuals.
1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".\

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Faucet Washers and O-Rings: Equal to **[10] <Insert number>** percent of quantity of each type and size installed.
 2. Faucet Cartridges and O-Rings: Equal to **[5] <Insert number>** percent of quantity of each type and size installed.
 3. Retain article below if required for Project. Coordinate requirements with DIA Project Manager.

1.6 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PRECAST-TERRAZZO, CIRCULAR WASH FOUNTAINS

A. Wash Fountains <Insert drawing designation>: Precast-terrazzo, circular receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Bradley Corporation.
 - b. <Insert manufacturer's name>.
 - c. or approved equal.
2. Standard: IAPMO IGC 156.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Receptor:
 - a. Standard: IAPMO PS 99 for precast-terrazzo receptor.
 - b. Nominal Diameter: [36 to 39 inches (914 to 990 mm)] [39 inches (990 mm)] [42 inches (1067 mm)] [54 inches (1372 mm)].
 - c. Height to Rim: 29 inches (737 mm) above floor.
 - d. Color or Finish: [Not applicable] <Insert if required>.
 - e. Drain: Grid with [NPS 2 (DN 50)] <Insert size> tailpiece.
5. Spray Head:
 - a. Material: Stainless steel.
 - b. Number of User Stations: [Five] [Six] [Eight].
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: [Collective, foot-rail] [Individual foot-pedal] [Individual push-button] [Individual, hardwired sensor] [Individual, battery-powered sensor] actuation with [pressure-balancing] [thermostatic] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
 - e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
6. Liquid-Soap Dispensers: [Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required], for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
7. Pedestal: [Manufacturer's standard] [Painted or coated steel] [Stainless steel] with access panel.
8. Supply Fittings:
 - a. Piping: [NPS 3/4 (DN 20)] [NPS 1 (DN 25)] copper tubing.
 - b. Valves: Shutoff valve on each supply.

- c. Supply Piping: From **[bottom]** **[top]**.
- 9. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: **[NPS 2 (DN 50)]**.
 - c. Vent Piping: **[Not required]** **[NPS 1-1/2 (DN 40) to ceiling]**.
- 10. Shroud: **[Not required]** **[Stainless steel of size to cover supply and vent piping]**.
- 11. Mounting: Floor bracket.

2.2 SOLID-SURFACE, CIRCULAR WASH FOUNTAINS

A. Wash Fountains **<Insert drawing designation>**: Solid-surface, circular receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Bradley Corporation.
 - b. Intersan Manufacturing Company.
 - c. Willoughby Industries.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Standard: IAPMO IGC 156.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Receptor:
 - a. Standard: ICPA SS-1 for solid-surface receptor.
 - b. Nominal Diameter: **[36 to 39 inches (914 to 990 mm)]** **[39 inches (990 mm)]** **[42 inches (1067 mm)]** **[54 inches (1370 mm)]**.
 - c. Height to Rim: **34 inches (864 mm)** above floor.
 - d. Color or Finish: **[Not applicable]** **<Insert if required>**.
 - e. Drain: Grid with **[NPS 2 (DN 50)]** **<Insert size>** tailpiece.
5. Spray Head:
 - a. Material: Stainless steel.
 - b. Number of User Stations: **[Five]** **[Six]** **[Eight]**.
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: **[Collective, foot-rail]** **[Individual foot-pedal]** **[Individual push-button]** **[Individual, hardwired sensor]** **[Individual, battery-powered sensor]** actuation with **[pressure-balancing]** **[thermostatic]** mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.

- e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
- 6. Liquid-Soap Dispensers: **[Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required]**, for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
- 7. Pedestal: **[Manufacturer's standard] [Painted or coated steel] [Stainless steel]** with access panel.
- 8. Supply Fittings:
 - a. Piping: **[NPS 3/4 (DN 20)] [NPS 1 (DN 25)]** copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From **[bottom] [top]**.
- 9. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: **[NPS 2 (DN 50)]**.
 - c. Vent Piping: **[Not required] [NPS 1-1/2 (DN 40) to ceiling]**.
- 10. Shroud: **[Not required] [Stainless steel of size to cover supply and vent piping]**.
- 11. Mounting: Floor bracket.

2.3 STAINLESS-STEEL, CIRCULAR WASH FOUNTAINS

A. Wash Fountains **<Insert drawing designation>**: Stainless-steel, circular receptor.

- 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Acorn Engineering Company.
 - b. Bradley Corporation.
 - c. Intersan Manufacturing Company.
 - d. Willoughby Industries.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
- 2. Standard: IAPMO IGC 156.
- 3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- 4. Receptor:
 - a. Standard: IAPMO IGC 156 for stainless-steel receptor.
 - b. Nominal Diameter: **[36 to 39 inches (914 to 990 mm)] [39 inches (990 mm)] [42 inches (1067 mm)] [54 inches (1372 mm)]**.
 - c. Height to Rim: **34 inches (864 mm)** above floor.
 - d. Color or Finish: **[Not applicable] <Insert if required>**.

- e. Drain: Grid with [NPS 2 (DN 50)] <Insert size> tailpiece.
 - 5. Spray Head:
 - a. Material: Stainless steel.
 - b. Number of User Stations: [Five] [Six] [Eight].
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: [Collective, foot-rail] [Individual foot-pedal] [Individual push-button] [Individual, hardwired sensor] [Individual, battery-powered sensor] actuation with [pressure-balancing] [thermostatic] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
 - e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
 - 6. Liquid-Soap Dispensers: [Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required], for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
 - 7. Pedestal: Stainless steel with access panel.
 - 8. Supply Fittings:
 - a. Piping: [NPS 3/4 (DN 20)] [NPS 1 (DN 25)] copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From [bottom] [top].
 - 9. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: [NPS 2 (DN 50)].
 - c. Vent Piping: [Not required] [NPS 1-1/2 (DN 40) to ceiling].
 - 10. Shroud: [Not required] [Stainless steel of size to cover supply and vent piping].
 - 11. Mounting: Floor bracket.
- 2.4 PRECAST-TERRAZZO, SEMICIRCULAR WASH FOUNTAINS
- A. Wash Fountains <Insert drawing designation>: [Off] [On]-floor, precast-terrazzo, semicircular receptor.
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bradley Corporation.
 - b. <Insert manufacturer's name>.
 - c. or approved equal.
 - 2. Standard: IAPMO IGC 156.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Receptor:
 - a. Standard: IAPMO PS 99 for precast-terrazzo receptor.
 - b. Nominal Diameter: [36 to 39 inches (914 to 990 mm)] [39 inches (990 mm)] [42 inches (1067 mm)] [54 inches (1372 mm)].
 - c. Height to Rim: 29 inches (737 mm) above floor.
 - d. Color or Finish: [Not applicable] <Insert if required>.
 - e. Drain: Grid with [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] tailpiece.
5. Spray Head:
 - a. Material: Stainless steel or integral part of receptor back.
 - b. Number of User Stations: [Two] [Three] [Four].
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: [Collective, foot-rail] [Individual foot-pedal] [Individual push-button] [Individual, hardwired sensor] [Individual, battery-powered sensor] actuation with [pressure-balancing] [thermostatic] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
 - e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
6. Liquid-Soap Dispensers: [Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required], for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
7. Supply Fittings:
 - a. Piping: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From [bottom] [top] [wall].
8. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)].
 - c. Vent Piping: [Not required] [NPS 1-1/2 (DN 40) to ceiling].
9. Shroud: [Not required] [Stainless steel of size to cover supply and vent piping].
10. Off-Floor Mounting: Wall bracket and ASME A112.6.1M, Type II urinal carrier.
11. On-Floor Mounting: Floor bracket and wall bracket attached to [reinforcement in wall] [concrete or block wall].
 - a. Supplies: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] copper tubing with ball, gate, or globe valves.

- b. Drain: Grid with [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] tailpiece.
- c. Drain Piping: [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] P-trap, waste to wall, and wall flange.

2.5 SOLID-SURFACE, SEMICIRCULAR WASH FOUNTAINS

- A. Wash Fountains <Insert drawing designation>: [Off] [On]-floor, solid-surface, semicircular receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Acorn Engineering Company.
- b. Bradley Corporation.
- c. Intersan Manufacturing Company.
- d. Willoughby Industries.
- e. <Insert manufacturer's name>.
- f. or approved equal.

2. Standard: IAPMO IGC 156.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

4. Receptor:

- a. Standard: ICPA SS-1 for solid-surface receptor.
- b. Nominal Diameter: [36 to 39 inches (914 to 990 mm)] [39 inches (990 mm)] [42 inches (1067 mm)] [54 inches (1372 mm)].
- c. Height to Rim: 34 inches (864 mm) above floor.
- d. Color or Finish: [Not applicable] <Insert if required>.
- e. Drain: Grid with [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] tailpiece.

5. Spray Head:

- a. Material: Stainless steel or integral part of receptor back.
- b. Number of User Stations: [Two] [Three] [Four].
- c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
- d. Control: [Collective, foot-rail] [Individual foot-pedal] [Individual push-button] [Individual, hardwired sensor] [Individual, battery-powered sensor] actuation with [pressure-balancing] [thermostatic] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
- e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.

6. Liquid-Soap Dispensers: [Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required], for each user station.

- a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.

7. Supply Fittings:
 - a. Piping: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From [bottom] [top] [wall].
8. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)].
 - c. Vent Piping: [Not required] [NPS 1-1/2 (DN 40) to ceiling].
9. Shroud: [Not required] [Stainless steel of size to cover supply and vent piping].
10. Off-Floor Mounting: Wall bracket and ASME A112.6.1M, Type II urinal carrier.
11. On-Floor Mounting: Floor bracket and wall bracket attached to [reinforcement in wall] [concrete or block wall].
 - a. Supplies: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] copper tubing with ball, gate, or globe valves.
 - b. Drain: Grid with [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] tailpiece.
 - c. Drain Piping: [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] P-trap, waste to wall, and wall flange.

2.6 STAINLESS-STEEL, SEMICIRCULAR WASH FOUNTAINS

- A. Wash Fountains <Insert drawing designation>: [Off] [On]-floor, stainless-steel, semicircular receptor.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Acorn Engineering Company.
 - b. Bradley Corporation.
 - c. Intersan Manufacturing Company.
 - d. Willoughby Industries.
 - e. <Insert manufacturer's name>.
 - f. or approved equal.
 2. Standard: IAPMO IGC 156.
 3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 4. Receptor:
 - a. Standard: ASME A112.19.3/CSA B45.4 for stainless-steel receptor.
 - b. Nominal Diameter: [36 to 39 inches (914 to 990 mm)] [39 inches (990 mm)] [42 inches (1067 mm)] [54 inches (1372 mm)].
 - c. Height to Rim: [34 inches (864 mm)] <Insert dimension> above floor.

- d. Color or Finish: [**Not applicable**] <Insert if required>.
 - e. Drain: Grid with [**NPS 1-1/2 (DN 40)**] [**NPS 2 (DN 50)**] tailpiece.
5. Spray Head:
- a. Material: Stainless steel or integral part of receptor back.
 - b. Number of User Stations: [**Two**] [**Three**] [**Four**].
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: [**Collective, foot-rail**] [**Individual foot-pedal**] [**Individual push-button**] [**Individual, hardwired sensor**] [**Individual, battery-powered sensor**] actuation with [**pressure-balancing**] [**thermostatic**] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
 - e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
6. Liquid-Soap Dispensers: [**Manual**] [**Hardwired, sensor actuated**] [**Battery powered, sensor actuated**] [**Not required**], for each user station.
- a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
7. Supply Fittings:
- a. Piping: [**NPS 1/2 (DN 15)**] [**NPS 3/4 (DN 20)**] copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From [**bottom**] [**top**] [**wall**].
8. Waste Fittings:
- a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: [**NPS 1-1/2 (DN 40)**] [**NPS 2 (DN 50)**].
 - c. Vent Piping: [**Not required**] [**NPS 1-1/2 (DN 40) to ceiling**].
9. Shroud: [**Not required**] [**Stainless steel of size to cover supply and vent piping**].
10. Off-Floor Mounting: Wall bracket and ASME A112.6.1M, Type II urinal carrier.
11. On-Floor Mounting: Floor bracket and wall bracket attached to [**reinforcement in wall**] [**concrete or block wall**].
- a. Supplies: [**NPS 1/2 (DN 15)**] [**NPS 3/4 (DN 20)**] copper tubing with ball, gate, or globe valves.
 - b. Drain: Grid with [**NPS 1-1/2 (DN 40)**] [**NPS 2 (DN 50)**] tailpiece.
 - c. Drain Piping: [**NPS 1-1/2 (DN 40)**] [**NPS 2 (DN 50)**] P-trap, waste to wall, and wall flange.

2.7 PRECAST-TERRAZZO, CORNER WASH FOUNTAINS

- A. Wash Fountains <Insert drawing designation>: Precast-terrazzo, corner receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Acorn Engineering Company.
 - b. Bradley Corporation.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Standard: IAPMO IGC 156.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Receptor:
 - a. Standard: IAPMO PS 99 for precast-terrazzo receptor.
 - b. Nominal Side Width: **[27 inches (686 mm)] [37 inches (940 mm)]**.
 - c. Height to Rim: **[34 inches (864 mm)] <Insert dimension>** above floor.
 - d. Color or Finish: **[Not applicable] <Insert if required>**.
 - e. Drain: Grid with **NPS 1-1/2 (DN 40)** tailpiece.
5. Spray Head:
 - a. Material: Stainless steel or integral part of receptor back.
 - b. Number of User Stations: **[Two] [Three]**.
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: **[Individual push-button] [Individual, hardwired sensor] [Individual, battery-powered sensor]** actuation with **[pressure-balancing] [thermostatic]** mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
 - e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
6. Liquid-Soap Dispensers: **[Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required]**, for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
7. Supply Fittings:
 - a. Piping: **[NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)]** copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From wall.
8. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: **NPS 1-1/2 (DN 40)**.
9. Off-Floor Mounting: Wall bracket and ASME A112.6.1M, Type II urinal carrier.

2.8 SOLID-SURFACE, CORNER WASH FOUNTAINS

A. Wash Fountains <Insert drawing designation>: Solid-surface, corner receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Acorn Engineering Company.
- b. Bradley Corporation.
- c. Willoughby Industries.
- d. <Insert manufacturer's name>.
- e. or approved equal.

2. Standard: IAPMO IGC 156.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

4. Receptor:

- a. Standard: ICPA SS-1 for solid-surface receptor.
- b. Nominal Side Width: [27 inches (686 mm)] [37 inches (940 mm)].
- c. Height to Rim: [34 inches (864 mm)] <Insert dimension> above floor.
- d. Color or Finish: [Not applicable] <Insert if required>.
- e. Drain: Grid with NPS 1-1/2 (DN 40) tailpiece.

5. Spray Head:

- a. Material: Stainless steel or integral part of receptor back.
- b. Number of User Stations: [Two] [Three].
- c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
- d. Control: [Individual push-button] [Individual, hardwired sensor] [Individual, battery-powered sensor] actuation with [pressure-balancing] [thermostatic] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
- e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.

6. Liquid-Soap Dispensers: [Manual] [Hardwired, sensor actuated] [Battery powered, sensor actuated] [Not required], for each user station.

- a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.

7. Supply Fittings:

- a. Piping: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] copper tubing.
- b. Valves: Shutoff valve on each supply.
- c. Supply Piping: From wall.

8. Waste Fittings:

- a. Standard: ASME A112.18.2/CSA B125.2.

- b. Trap and Drain Piping: **NPS 1-1/2 (DN 40)**.
- 9. Off-Floor Mounting: Wall bracket and ASME A112.6.1M, Type II urinal carrier.

2.9 STAINLESS-STEEL, CORNER WASH FOUNTAINS

A. Wash Fountains <Insert drawing designation>: Stainless-steel, corner receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Acorn Engineering Company.
 - b. Bradley Corporation.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Standard: IAPMO IGC 156.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Receptor:
 - a. Standard: ASME A112.19.3/CSA B45.4 for stainless-steel receptor.
 - b. Nominal Side Width: [**27 inches (686 mm)**] [**37 inches (940 mm)**].
 - c. Height to Rim: [**34 inches (864 mm)**] **<Insert dimension>** above floor.
 - d. Color or Finish: [**Not applicable**] **<Insert if required>**.
 - e. Drain: Grid with **NPS 1-1/2 (DN 40)** tailpiece.
5. Spray Head:
 - a. Material: Stainless steel or integral part of receptor back.
 - b. Number of User Stations: [**Two**] [**Three**].
 - c. Spray Nozzles: Chrome-plated brass or stainless steel complying with NSF 61 and ASME A112.18.1/CSA B125.1.
 - d. Control: [**Individual push-button**] [**Individual, hardwired sensor**] [**Individual, battery-powered sensor**] actuation with [**pressure-balancing**] [**thermostatic**] mixing valve complying with ASSE 1016 and having check stops; comply with NSF 61.
 - e. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
6. Liquid-Soap Dispensers: [**Manual**] [**Hardwired, sensor actuated**] [**Battery powered, sensor actuated**] [**Not required**], for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
7. Supply Fittings:
 - a. Piping: [**NPS 1/2 (DN 15)**] [**NPS 3/4 (DN 20)**] copper tubing.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From wall.

8. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: **NPS 1-1/2 (DN 40)**.
9. Off-Floor Mounting: Wall bracket and ASME A112.6.1M, Type II urinal carrier.

2.10 SOLID-SURFACE, LINEAR WASH FOUNTAINS

- A. Wash Fountains **<Insert drawing designation>**: Solid-surface, linear (side-by-side) receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Acorn Engineering Company.
 - b. Intersan Manufacturing Company.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Standard: IAPMO IGC 156.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Bowl(s) and Counter:
 - a. Standard: ICPA SS-1 for solid-surface bowls.
 - b. Height to Rim: [**34 inches (864 mm)**] **<Insert dimension>** above floor.
 - c. Color or Finish: [**Not applicable**] **<Insert if required>**.
 - d. Number of Bowls: [**One**] [**Two**] [**Three**] [**Four**].
 - e. Drain: Grid with **NPS 1-1/2 (DN 40)** tailpiece, each bowl.
5. Pedestal: [**Not required**] [**Required, with access panel**].
6. Faucets:
 - a. Standards: ASME A112.18.1/CSA B125.1 and NSF 61.
 - b. Type: Manufacturer's standard, chrome-plated solid brass, each bowl.
 - c. Control: [**Manual, push-button**] [**Hardwired, sensor-actuated**] [**Battery-powered, sensor-actuated**], [**pressure-balancing**] mixing valve with check stops for each user station.
 - d. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
7. Liquid-Soap Dispensers: [**Manual**] [**Hardwired, sensor actuated**] [**Battery powered, sensor actuated**] [**Not required**], for each user station.
 - a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.
8. Mounting: Off floor on wall brackets and ASME A112.6.1M, Type II urinal carriers[, **each bowl**].
9. Supply Fittings:

- a. Piping: **NPS 1/2 (DN 15)** copper tubing, each bowl.
- b. Valves: Shutoff valve on each supply.
- c. Supply Piping: From wall.

10. Waste Fittings:

- a. Standard: ASME A112.18.2/CSA B125.2.
- b. Trap and Drain Piping: **NPS 1-1/2 (DN 40)**, each bowl.

2.11 STAINLESS-STEEL, LINEAR WASH FOUNTAINS

A. Wash Fountains **<Insert drawing designation>**: Stainless-steel, linear (side-by-side) receptor.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Acorn Engineering Company.
- b. **<Insert manufacturer's name>**.
- c. or approved equal.

2. Standard: IAPMO IGC 156.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

4. Bowl(s) and Counter:

- a. Standard: ASME A112.19.3/CSA B45.4 for stainless-steel bowls.
- b. Height to Rim: [**34 inches (864 mm)**] **<Insert dimension>** above floor.
- c. Color or Finish: [**Not applicable**] **<Insert if required>**.
- d. Number of Bowls: [**One**] [**Two**] [**Three**] [**Four**].
- e. Drain: Grid with **NPS 1-1/2 (DN 40)** tailpiece, each bowl.

5. Pedestal: [**Not required**] [**Required, with access panel**].

6. Faucets:

- a. Standards: ASME A112.18.1/CSA B125.1 and NSF 61.
- b. Type: Manufacturer's standard, chrome-plated solid brass, each bowl.
- c. Control: [**Manual, push-button**] [**Hardwired, sensor-actuated**] [**Battery-powered, sensor-actuated**], [**pressure-balancing**] mixing valve with check stops for each user station.
- d. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.

7. Liquid-Soap Dispensers: [**Manual**] [**Hardwired, sensor actuated**] [**Battery powered, sensor actuated**] [**Not required**], for each user station.

- a. Sensor: ASME A112.18.1/CSA B125.1 and UL 1951.

8. Mounting: Off floor on wall brackets and ASME A112.6.1M, Type II urinal carriers[, **each bowl**].

9. Supply Fittings:
 - a. Piping: NPS 1/2 (DN 15) copper tubing, each bowl.
 - b. Valves: Shutoff valve on each supply.
 - c. Supply Piping: From wall.

10. Waste Fittings:
 - a. Standard: ASME A112.18.2/CSA B125.2.
 - b. Trap and Drain Piping: NPS 1-1/2 (DN 40), each bowl.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water-supply, sanitary drainage, and vent piping systems to verify actual locations of piping connections before wash-fountain installation.
- B. Examine walls and floors for suitable conditions where wash fountains will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install wash fountains level and plumb according to roughing-in drawings.
- B. Set freestanding wash fountains on floor.
- C. Install off-floor carrier supports, affixed to building substrate, for wall-mounted wash fountains.
- D. Install accessible, wall-mounted wash fountains at mounting height for handicapped/elderly according to ICC A117.1.
- E. Install water-supply piping with shutoff valve on each supply to each wash fountain to be connected to domestic-water distribution piping. Use ball, gate, or globe valve. Install valves in locations where they can be easily reached for operation. Valves are specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- F. Install trap and waste piping on each drain outlet of each wash fountain to be connected to sanitary drainage system.
- G. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons if required to conceal protruding fittings. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."

- H. Seal joints between fixtures and walls using sanitary-type, one-part, mildew-resistant, silicone sealant. Match sealant color to fixture color. Comply with sealant requirements specified in Section 079200 "Joint Sealants."

3.3 CONNECTIONS

- A. Connect wash fountains with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.
- B. Comply with requirements for water piping specified in Section 221116 "Domestic Water Piping."
- C. Comply with requirements for soil and waste drainage piping[**and vent piping**] specified in Section 221316 "Sanitary Waste and Vent Piping."
- D. Install protective-shielding pipe covers and enclosures on exposed supplies and waste piping of accessible wash fountains. Comply with requirements in Section 220719 "Plumbing Piping Insulation."

3.4 ADJUSTING

- A. Operate and adjust wash fountains and controls. Replace damaged and malfunctioning wash fountains, fittings, and controls.
- B. Adjust water pressure at faucets to produce proper flow.
- C. Install fresh batteries in battery-powered, electronic-sensor mechanisms.

3.5 CLEANING AND PROTECTION

- A. After installing wash fountains, inspect and repair damaged finishes.
- B. Clean wash fountains, faucets, and other fittings with manufacturers' recommended cleaning methods and materials.
- C. Provide protective covering for installed wash fountains and fittings.
- D. Do not allow use of wash fountains for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 224233

SECTION 224500 - EMERGENCY PLUMBING FIXTURES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Emergency showers.
 - 2. Eyewash equipment.
 - 3. Eye/face wash equipment.
 - 4. Combination units.
 - 5. Supplemental equipment.
 - 6. Water-tempering equipment.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Accessible Fixture: Emergency plumbing fixture that can be approached, entered, and used by people with disabilities.
- B. Plumbed Emergency Plumbing Fixture: Fixture with fixed, potable-water supply.
- C. Self-Contained Emergency Plumbing Fixture: Fixture with flushing-fluid-solution supply.
- D. Tepid: Moderately warm.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include flow rates and capacities, furnished specialties, and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Diagram power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: Submit certificates of performance testing specified in "Source Quality Control" Article.
- B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For emergency plumbing fixtures to include in operation and maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Flushing-Fluid Solution: Separate lot and equal to at least **[200] <Insert number>** percent of amount of solution installed for each self-contained unit.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ANSI Standard: Comply with ANSI Z358.1, "Emergency Eyewash and Shower Equipment."
- C. NSF Standard: Comply with NSF 61, "Drinking Water System Components - Health Effects," for fixture materials that will be in contact with potable water.
- D. Regulatory Requirements: Comply with requirements in ICC/ANSI A117.1, "Accessible and Usable Buildings and Facilities"[; **Public Law 90-480, "Architectural Barriers Act"; and Public Law 101-336, "Americans with Disabilities Act";**] for plumbing fixtures for people with disabilities.
- E. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 EMERGENCY SHOWERS

- A. Freestanding, Plumbed Emergency Showers, <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Acorn Safety; a division of Acorn Engineering Company.](#)
- b. [Bradley Corporation.](#)
- c. [Encon Safety Products.](#)
- d. [Guardian Equipment Co.](#)
- e. [Haws Corporation.](#)
- f. [Sellstrom Manufacturing Company.](#)
- g. [Speakman Company.](#)
- h. [WaterSaver Faucet Co.](#)
- i. <Insert manufacturer's name>.
- j. or approved equal.

2. Capacity: Not less than 20 gpm (76 L/min.) for at least 15 minutes.
3. Supply Piping: [NPS 1 (DN 25)] [NPS 1-1/4 (DN 32)] [galvanized steel] [chrome-plated brass or stainless steel] [PVC] with flow regulator and stay-open control valve.
4. Control-Valve Actuator: [Pull rod] [Foot treadle] <Insert actuator>.
5. Shower Head: 8-inch- (200-mm-) minimum diameter, [chrome-plated brass, stainless steel, or plastic] <Insert material>.
6. Mounting: Pedestal.

- B. Off-Floor, Plumbed Emergency Showers, <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Acorn Safety; a division of Acorn Engineering Company.](#)
- b. [Bradley Corporation.](#)
- c. [Chicago Faucet Company.](#)
- d. [Encon Safety Products.](#)
- e. [Guardian Equipment Co.](#)
- f. [Haws Corporation.](#)
- g. [Sellstrom Manufacturing Company.](#)
- h. [Speakman Company.](#)

- i. [WaterSaver Faucet Co.](#)
 - j. <Insert manufacturer's name>.
 - k. or approved equal.
2. Capacity: Not less than **20 gpm** (76 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1 (DN 25)** [**galvanized steel**] [**chrome-plated brass or stainless steel**] [**PVC**] with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: Pull rod.
 5. Shower Head: **8-inch-** (200-mm-) minimum diameter, [**chrome-plated brass, stainless steel, or plastic**] <Insert material>.
 6. Mounting: [**Horizontal from wall**] [**Vertical from ceiling**] and supported from piping.
- C. Freeze-Protected, Plumbed Emergency Showers, <Insert drawing designation>:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [B-L-S Industries, Inc.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Speakman Company.](#)
 - g. <Insert manufacturer's name>.
 - h. or approved equal.
 2. Capacity: Not less than **20 gpm** (76 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1-1/4 (DN 32)** galvanized steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: Pull rod.
 5. Shower Head: **8-inch-** (200-mm-) minimum diameter, [**chrome-plated brass, stainless steel, or plastic**] <Insert material>.
 6. Heating System: [**120**] [**240**]-V ac electric, and insulation with protective jacket.
 7. Mounting: Pedestal.

2.2 EYEWASH EQUIPMENT

- A. Standard, Freestanding, Plumbed Eyewash Units, <Insert drawing designation>:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)

- g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
 2. Capacity: Not less than **0.4 gpm (1.5 L/min.)** for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] [**Treadle**] **<Insert actuator>.**
 5. Spray-Head Assembly: Two receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] [**Plastic**] bowl.
 7. Drain Piping: [**NPS 1-1/4 (DN 32) minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2**] [**Include galvanized-steel indirect connection to drainage system**].
 8. Mounting: Pedestal.
- B. Accessible, Freestanding, Plumbed Eyewash Units, **<Insert drawing designation>:**
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [WaterSaver Faucet Co.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
 2. Capacity: Not less than **0.4 gpm (1.5 L/min.)** for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] **<Insert actuator>.**
 5. Spray-Head Assembly: Two receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] [**Plastic**] bowl.
 7. Drain Piping: [**NPS 1-1/4 (DN 32) minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2**] [**Include galvanized-steel indirect connection to drainage system**].
 8. Mounting: Offset pedestal.
 9. Special Construction: Comply with ICC/ANSI A117.1.
- C. Standard, Wall-Mounted, Plumbed Eyewash Units, **<Insert drawing designation>:**
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)

- c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2** (DN 15) chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] **<Insert actuator>.**
 5. Spray-Head Assembly: Two receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] **<Insert material>** bowl.
 7. Drain Piping: **NPS 1-1/4** (DN 32) minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2.
 8. Mounting: Wall bracket.
- D. Accessible, Wall-Mounted, Plumbed Eyewash Units, **<Insert drawing designation>:**
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Speakman Company.](#)
 - g. **<Insert manufacturer's name>.**
 - h. or approved equal.
 2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2** (DN 15) chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] **<Insert actuator>.**
 5. Spray-Head Assembly: Two receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] **<Insert material>** bowl.
 7. Drain Piping: **NPS 1-1/4** (DN 32) minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2.
 8. Mounting: Wall bracket.
 9. Special Construction: Comply with ICC/ANSI A117.1.
- E. Sink, Fixed-Position, Plumbed Eyewash Unit, **<Insert drawing designation>:**
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: Paddle.
 5. Spray-Head Assembly: Two spray heads positioned over sink.
 6. Mounting: Attached to sink receptor.
- F. Sink, Swivel-Type, Plumbed Eyewash Unit, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
 2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: Movement of spray-head assembly to position over sink.
 5. Spray-Head Assembly: Two spray heads with offset piping.
 6. Mounting: Deck next to sink.
- G. Portable, Self-Contained Eyewash Units, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Bradley Corporation.](#)
 - b. [Encon Safety Products.](#)
 - c. [Guardian Equipment Co.](#)
 - d. [Haws Corporation.](#)

- e. [Sellstrom Manufacturing Company](#).
 - f. [WaterSaver Faucet Co](#).
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Pressure Tank: [**10 gal.** (38 L)] **<Insert value>**, stainless steel, cylindrical, with pressure gage, and suitable for on-floor installation.
 4. Flushing Fluid: Medically acceptable solution manufactured and labeled according to applicable regulations.
 5. Spray-Head Assembly: Chrome-plated copper alloy or stainless-steel piping with flow regulator; paddle-actuated, stay-open control valve; and two spray heads mounted on tank.
 6. Drench Hose: Hand-held spray head with squeeze-handle actuation and hose attached to tank.
- H. Standard, Self-Contained Eyewash Units, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Bradley Corporation](#).
 - b. [Encon Safety Products](#).
 - c. [Fend-all](#).
 - d. [Guardian Equipment Co](#).
 - e. [Haws Corporation](#).
 - f. [Sellstrom Manufacturing Company](#).
 - g. [Speakman Company](#).
 - h. [WaterSaver Faucet Co](#).
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
 2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Gravity Tank: [**14 gal.** (53 L) **minimum**] **<Insert value>**, plastic, and suitable for shelf mounting.
 4. Flushing Fluid: Medically acceptable solution manufactured and labeled according to applicable regulations.
 5. Actuator: Pull-down front panel.
 6. Spray Heads: Protected, two mounted on tank.
- I. Freeze-Protected, Self-Contained Eyewash Units, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Bradley Corporation](#).
 - b. [Encon Safety Products](#).
 - c. [Fend-all](#).
 - d. [Guardian Equipment Co](#).
 - e. [Haws Corporation](#).

- f. [Speakman Company](#).
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
2. Capacity: Not less than **0.4 gpm** (1.5 L/min.) for at least 15 minutes.
 3. Gravity Tank: [**14 gal. (53 L) minimum**] [**20 gal. (76 L) minimum**] **<Insert value>**, plastic, and suitable for shelf mounting.
 4. Flushing Fluid: Medically acceptable solution manufactured and labeled according to applicable regulations.
 5. Actuator: Pull-down front panel.
 6. Spray Heads: Protected, two mounted on tank.
 7. Heating System: Electric, 120-V ac; and insulation with protective jacket.

2.3 EYE/FACE WASH EQUIPMENT

A. Standard, Freestanding, Plumbed, Eye/Face Wash Units, **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company](#).
 - b. [Bradley Corporation](#).
 - c. [Encon Safety Products](#).
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation](#).
 - f. [Sellstrom Manufacturing Company](#).
 - g. [Speakman Company](#).
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Capacity: Not less than **3.0 gpm** (11.4 L/min.) for at least 15 minutes.
3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
4. Control-Valve Actuator: [**Paddle**] [**Treadle**] **<Insert actuator>**.
5. Spray-Head Assembly: Two or four receptor-mounted spray heads.
6. Receptor: [**Chrome-plated brass or stainless-steel**] [**Plastic**] bowl.
7. Drain Piping: [**NPS 1-1/4 (DN 32) minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2**] [**Include galvanized-steel indirect connection to drainage system**].
8. Mounting: Pedestal.

B. Accessible, Freestanding, Plumbed, Eye/Face Wash Units, **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [WaterSaver Faucet Co.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
2. Capacity: Not less than **3 gpm** (11.4 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] **<Insert actuator>.**
 5. Spray-Head Assembly: Two or four receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] [**Plastic**] bowl.
 7. Drain Piping: [**NPS 1-1/4 (DN 32) minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2**] [**Include galvanized-steel indirect connection to drainage system**].
 8. Mounting: Offset pedestal.
 9. Special Construction: Comply with ICC/ANSI A117.1.
- C. Standard, Wall-Mounted, Plumbed, Eye/Face Wash Units, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
 2. Capacity: Not less than **3.0 gpm** (11.4 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] **<Insert actuator>.**
 5. Spray-Head Assembly: Two or four receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] **<Insert material>** bowl.
 7. Drain Piping: **NPS 1-1/4 (DN 32)** minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2.
 8. Mounting: Wall bracket.

- D. Accessible, Wall-Mounted, Plumbed, Eye/Face Wash Units, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Bradley Corporation](#).
 - b. [Encon Safety Products](#).
 - c. [Guardian Equipment Co.](#)
 - d. [Haws Corporation](#).
 - e. [WaterSaver Faucet Co.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 2. Capacity: Not less than **3.0 gpm** (11.4 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: [**Paddle**] **<Insert actuator>**.
 5. Spray-Head Assembly: Two or four receptor-mounted spray heads.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] **<Insert material>** bowl.
 7. Mounting: Wall bracket.
 8. Special Construction: Comply with ICC/ANSI A117.1.
- E. Sink, Fixed-Position, Plumbed, Eye/Face Wash Unit, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company](#).
 - b. [Bradley Corporation](#).
 - c. [Encon Safety Products](#).
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation](#).
 - f. [Sellstrom Manufacturing Company](#).
 - g. [WaterSaver Faucet Co.](#)
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
 2. Capacity: Not less than **3 gpm** (11.4 L/min.) for at least 15 minutes.
 3. Supply Piping: **NPS 1/2 (DN 15)** chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 4. Control-Valve Actuator: Paddle.
 5. Spray-Head Assembly: Two or four spray heads positioned over sink.
 6. Receptor: [**Chrome-plated brass or stainless-steel**] **<Insert material>** bowl.
 7. Mounting: Attached to sink receptor.

2.4 COMBINATION UNITS

A. Standard, Plumbed Emergency Shower with Eyewash Combination Units, **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Piping:
 - a. Material: **[Galvanized steel] [Chrome-plated brass or stainless steel] [PVC]**.
 - b. Unit Supply: **[NPS 1-1/4 (DN 32) minimum] [NPS 1-1/2 (DN 40)]**.
 - c. Unit Drain: Outlet at back or side near bottom.
3. Shower:
 - a. Capacity: Not less than **20 gpm (76 L/min.)** for at least 15 minutes.
 - b. Supply Piping: **NPS 1 (DN 25)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: **[Pull rod] [Treadle] <Insert actuator>**.
 - d. Shower Head: **8-inch- (200-mm-)** minimum diameter, **[chrome-plated brass or stainless steel] [plastic]**.
 - e. Mounting: Pedestal.
4. Eyewash Unit:
 - a. Capacity: Not less than **0.4 gpm (1.5 L/min.)** for at least 15 minutes.
 - b. Supply Piping: **NPS 1/2 (DN 15)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: Paddle.
 - d. Spray-Head Assembly: Two receptor-mounted spray heads.
 - e. Receptor: **[Chrome-plated brass or stainless-steel] [Plastic]** bowl.
 - f. Mounting: Attached shower pedestal.
 - g. Drench-Hose Option: May be provided instead of eyewash unit.
 - 1) Capacity: Not less than **0.4 gpm (1.5 L/min.)** for at least 15 minutes.
 - 2) Drench Hose: Hand-held spray head with squeeze-handle actuator and hose.

3) Mounting: Bracket on shower pedestal.

B. Accessible, Plumbed Emergency Shower with Eyewash Combination Units, <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. <Insert manufacturer's name>.
 - j. or approved equal.
2. Piping:
 - a. Material: **[Galvanized steel] [Chrome-plated brass or stainless steel] [PVC]**.
 - b. Unit Supply: **[NPS 1-1/4 (DN 32) minimum] [NPS 1-1/2 (DN 40)]**.
 - c. Unit Drain: Outlet at back or side near bottom.
3. Shower:
 - a. Capacity: Not less than **20 gpm (76 L/min.)** for at least 15 minutes.
 - b. Supply Piping: **NPS 1 (DN 25)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: **[Pull rod] <Insert actuator>**.
 - d. Shower Head: **8-inch- (200-mm-)** minimum diameter, **[chrome-plated brass or stainless steel] [plastic]**.
 - e. Mounting: Pedestal.
4. Eyewash Unit:
 - a. Capacity: Not less than **0.4 gpm (1.5 L/min.)** for at least 15 minutes.
 - b. Supply Piping: **NPS 1/2 (DN 15)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: Paddle.
 - d. Spray-Head Assembly: Two receptor-mounted spray heads.
 - e. Receptor: **[Chrome-plated brass or stainless-steel] [Plastic]** bowl.
 - f. Mounting: Attached shower pedestal.
 - g. Drench-Hose Option: May be provided instead of eyewash unit.
 - 1) Capacity: Not less than **0.4 gpm (1.5 L/min.)** for at least 15 minutes.
 - 2) Drench Hose: Hand-held spray head with squeeze-handle actuator and hose.

3) Mounting: Bracket on shower pedestal.

C. Standard, Plumbed Emergency Shower with Eye/Face Wash Combination Units,
<Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. <Insert manufacturer's name>.
 - j. or approved equal.
2. Piping:
 - a. Material: **[Galvanized steel] [Chrome-plated brass or stainless steel] [PVC]**.
 - b. Unit Supply: **[NPS 1-1/4 (DN 32) minimum] [NPS 1-1/2 (DN 40)]**.
 - c. Unit Drain: Outlet at back or side near bottom.
3. Shower:
 - a. Capacity: Not less than **20 gpm** (76 L/min.) for at least 15 minutes.
 - b. Supply Piping: **NPS 1 (DN 25)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: **[Pull rod] [Treadle] <Insert actuator>**.
 - d. Shower Head: **8-inch-** (200-mm-) minimum diameter, **[chrome-plated brass or stainless steel] [plastic]**.
 - e. Mounting: Pedestal.
4. Eye/Face Wash Unit:
 - a. Capacity: Not less than **3 gpm** (11.4 L/min.) for at least 15 minutes.
 - b. Supply Piping: **NPS 1/2 (DN 15)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: Paddle.
 - d. Spray-Head Assembly: Two or four receptor-mounted spray heads.
 - e. Receptor: **[Chrome-plated brass or stainless-steel] [Plastic]** bowl.
 - f. Mounting: Attached shower pedestal.
 - g. Drench-Hose Option: May be provided instead of eye/face wash unit.
 - 1) Capacity: Not less than **3 gpm** (11.4 L/min.) for at least 15 minutes.
 - 2) Drench Hose: Hand-held spray head with squeeze-handle actuator and hose.

3) Mounting: Bracket on shower pedestal.

D. Accessible, Plumbed Emergency Shower with Eye/Face Wash Combination Units,
<Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. <Insert manufacturer's name>.
 - j. or approved equal.
2. Piping:
 - a. Material: **[Galvanized steel] [Chrome-plated brass or stainless steel] [PVC]**.
 - b. Unit Supply: **[NPS 1-1/4 (DN 32) minimum] [NPS 1-1/2 (DN 40)]**.
 - c. Unit Drain: Outlet at back or side near bottom.
3. Shower:
 - a. Capacity: Not less than **20 gpm** (76 L/min.) for at least 15 minutes.
 - b. Supply Piping: **NPS 1 (DN 25)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: **[Pull rod] <Insert actuator>**.
 - d. Shower Head: **8-inch-** (200-mm-) minimum diameter, **[chrome-plated brass or stainless steel] [plastic]**.
 - e. Mounting: Pedestal.
4. Eye/Face Wash Unit:
 - a. Capacity: Not less than **3 gpm** (11.4 L/min.) for at least 15 minutes.
 - b. Supply Piping: **NPS 1/2 (DN 15)** with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: Paddle.
 - d. Spray-Head Assembly: Two or four receptor-mounted spray heads.
 - e. Receptor: **[Chrome-plated brass or stainless-steel] [Plastic]** bowl.
 - f. Mounting: Attached to shower pedestal.
 - g. Drench-Hose Option: May be provided instead of eye/face wash unit.
 - 1) Capacity: Not less than **3 gpm** (11.4 L/min.) for at least 15 minutes.
 - 2) Drench Hose: Hand-held spray head with squeeze-handle actuator and hose.

3) Mounting: Bracket on shower pedestal.

- E. Freeze-Protected, Plumbed Emergency Shower with Eyewash Combination Units, <Insert drawing designation>:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [B-L-S Industries, Inc.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Speakman Company.](#)
 - g. <Insert manufacturer's name>.
 - h. or approved equal.
 2. Piping: Galvanized steel.
 - a. Unit Supply: [NPS 1-1/4 (DN 32) minimum] [NPS 1-1/2 (DN 40)] from bottom.
 3. Heating System: Electric, [120] [240]-V ac; and insulation with protective jacket and thermometer.
 - a. Heating Capacity: [10 deg F (6 deg C)] <Insert temperature> minimum above ambient temperature.
 - b. Design Ambient Temperature: <Insert temperature>.
 4. Shower:
 - a. Shower Capacity: Not less than 20 gpm (76 L/min.) for at least 15 minutes.
 - b. Supply Piping: NPS 1 (DN 25) with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: [Pull rod] <Insert actuator>.
 - d. Shower Head: 8-inch- (200-mm-) minimum diameter, [chrome-plated brass or stainless steel] [plastic].
 - e. Mounting: Pedestal.
 5. Eyewash Unit:
 - a. Capacity: Not less than 0.4 gpm (1.5 L/min.) for at least 15 minutes.
 - b. Supply Piping: NPS 1/2 (DN 15) with flow regulator and stay-open control valve.
 - c. Control-Valve Actuator: [Paddle] <Insert actuator>.
 6. Eye/Face Wash Unit:
 - a. Capacity: Not less than 3 gpm (11.4 L/min.) for at least 15 minutes.
 - b. Control-Valve Actuator: [Paddle] <Insert actuator>.

7. Appurtenances:
 - a. **<Insert appurtenances>**.

2.5 SUPPLEMENTAL EQUIPMENT

A. Self-Contained, Personal Eyewash Units, **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Bradley Corporation](#).
 - b. [Encon Safety Products](#).
 - c. [Guardian Equipment Co.](#)
 - d. [Haws Corporation](#).
 - e. [Sellstrom Manufacturing Company](#).
 - f. [Speakman Company](#).
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
2. Capacity: Not less than **0.4 gpm** (1.5 L/min.).
3. Pressure Tank: [**5 gal.** (19 L)] **<Insert value>**, stainless steel, cylindrical, with pressure gage and base suitable for on-floor installation.
4. Flushing Fluid: Medically acceptable solution manufactured and labeled according to applicable regulations.
5. Spray-Head Assembly: Chrome-plated copper alloy or stainless-steel piping with flow regulator; paddle-actuated, stay-open control valve; and two spray heads mounted on tank.

B. Deck-Mounted, Plumbed Drench Hoses, **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company](#).
 - b. [Bradley Corporation](#).
 - c. [Encon Safety Products](#).
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation](#).
 - f. [Speakman Company](#).
 - g. [WaterSaver Faucet Co.](#)
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Capacity: Not less than **0.4 gpm** (1.5 L/min).
3. Supply Fitting: **NPS 1/2** (DN 15) brass with flow regulator.
4. Drench Hose: Hand-held spray head with squeeze-handle actuation and hose.
5. Mounting: In hole in deck.

- C. Wall-Mounted, Plumbed Drench Hoses, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Bradley Corporation.](#)
 - c. [Encon Safety Products.](#)
 - d. [Guardian Equipment Co.](#)
 - e. [Haws Corporation.](#)
 - f. [Sellstrom Manufacturing Company.](#)
 - g. [Speakman Company.](#)
 - h. [WaterSaver Faucet Co.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
 2. Capacity: Not less than **3.0 gpm** (11.4 L/min.) for at least 15 minutes.
 3. Supply Fitting: **NPS 1/2 (DN 15)** brass with flow regulator.
 4. Drench Hose: Hand-held spray head with squeeze-handle actuation and hose.
 5. Mounting: Wall bracket.

2.6 WATER-TEMPERING EQUIPMENT

- A. Hot- and Cold-Water, Water-Tempering Equipment, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Acorn Safety; a division of Acorn Engineering Company.](#)
 - b. [Armstrong International, Inc.](#)
 - c. [Bradley Corporation.](#)
 - d. [Encon Safety Products.](#)
 - e. [Guardian Equipment Co.](#)
 - f. [Haws Corporation.](#)
 - g. [Lawler Manufacturing Co., Inc.](#)
 - h. [Leonard Valve Company.](#)
 - i. [Powers; a division of Watts Water Technologies, Inc.](#)
 - j. [Speakman Company.](#)
 - k. **<Insert manufacturer's name>**.
 - l. or approved equal.
 2. Description: Factory-fabricated equipment with thermostatic mixing valve.
 - a. Thermostatic Mixing Valve: Designed to provide [**85 deg F (29 deg C)**] **<Insert temperature>** tepid, potable water at emergency plumbing fixtures, to maintain temperature at plus or minus [**5 deg F (3 deg C)**] **<Insert temperature>** throughout required 15-minute test period, and in case of unit failure to continue cold-water flow, with union connections, controls, metal piping, and corrosion-resistant enclosure.

- b. Supply Connections: For hot and cold water.
- B. Steam and Cold-Water, Water-Tempering Equipment, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Encon Safety Products](#).
 - b. [Therm-Omega-Tech, Inc.](#)
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Description: Factory-fabricated equipment with thermostatic mixing valve.
 - a. Thermostatic Mixing Valve: Designed to provide [85 deg F (29 deg C)] **<Insert temperature>** tepid, potable water at emergency plumbing fixtures, to maintain temperature at plus or minus [5 deg F (3 deg C)] **<Insert temperature>** throughout required 15-minute test period, and in case of unit failure to continue cold-water flow, with union connections, steam controls, heat exchanger, high-temperature-limit and freeze-protection devices, metal piping, and corrosion-resistant enclosure.
 - b. Supply Connections: For steam and cold water.
- C. Electric Water-Tempering Equipment, **<Insert drawing designation>**:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Chronomite Laboratories, Inc.; a division of Acorn Engineering Company](#).
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
 2. Description: Factory-fabricated equipment with electric heating.
 - a. Heating System: Electric, designed to provide [85 deg F (29 deg C)] **<Insert temperature>** tepid, potable water at emergency plumbing fixtures, to maintain temperature at plus or minus [5 deg F (3 deg C)] **<Insert temperature>** throughout required 15-minute test period, and in case of unit failure to continue cold-water flow, with union connections, controls, heating coils, high-temperature-limit device, metal piping, and corrosion-resistant enclosure.
 - 1) Electrical Characteristics: **[208-V ac, 38] [220-V ac, 40] [277-V ac, 32]** A, single phase, 60 Hz.

2.7 SOURCE QUALITY CONTROL

- A. Certify performance of emergency plumbing fixtures by independent testing organization acceptable to authorities having jurisdiction.

1. Exception: <Insert manufacturer's name>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for water[**and waste**] piping systems to verify actual locations of piping connections before plumbed emergency plumbing fixture installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EMERGENCY PLUMBING FIXTURE INSTALLATION

- A. Assemble emergency plumbing fixture piping, fittings, control valves, and other components.
- B. Install fixtures level and plumb.
- C. Fasten fixtures to substrate.
- D. Install shutoff valves in water-supply piping to fixtures. Use ball, gate, or globe valve if specific type valve is not indicated. Install valves chained or locked in open position if permitted. Install valves in locations where they can easily be reached for operation. Comply with requirements for valves specified in Section 220523 "General-Duty Valves for Plumbing Piping."
 1. Exception: Omit shutoff valve on supply to group of plumbing fixtures that includes emergency equipment.
 2. Exception: Omit shutoff valve on supply to emergency equipment if prohibited by authorities having jurisdiction.
- E. Install shutoff valve and strainer in steam piping and shutoff valve in condensate return piping. Comply with requirements for steam and condensate piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Piping Specialties."
- F. Install dielectric fitting in supply piping to emergency equipment if piping and equipment connections are made of different metals. Comply with requirements for dielectric fittings specified in Section 221116 "Domestic Water Piping."
- G. Install thermometers in supply and outlet piping connections to water-tempering equipment. Comply with requirements for thermometers specified in Section 220519 "Meters and Gages for Plumbing Piping."
- H. Install trap and waste piping on drain outlet of emergency equipment receptors that are indicated to be directly connected to drainage system. Comply with requirements for waste piping specified in Section 221316 "Sanitary Waste and Vent Piping."

- I. Install indirect waste piping on drain outlet of emergency equipment receptors that are indicated to be indirectly connected to drainage system. Comply with requirements for waste piping specified in Section 221316 "Sanitary Waste and Vent Piping."
- J. Install escutcheons on piping wall and ceiling penetrations in exposed, finished locations. Comply with requirements for escutcheons specified in Section 220518 "Escutcheons for Plumbing Piping."
- K. Fill self-contained fixtures with flushing fluid.

3.3 CONNECTIONS

- A. Connect cold-water-supply piping to plumbed emergency plumbing fixtures not having water-tempering equipment. Comply with requirements for cold-water piping specified in Section 221116 "Domestic Water Piping."
- B. Connect hot- and cold-water-supply piping to hot- and cold-water, water-tempering equipment. Connect output from water-tempering equipment to emergency plumbing fixtures. Comply with requirements for hot- and cold-water piping specified in Section 221116 "Domestic Water Piping."
- C. Connect steam and cold-water-supply and condensate return piping to steam and cold water-tempering equipment. Connect output from water-tempering equipment to emergency plumbing fixtures. Comply with requirements for cold-water piping specified in Section 221116 "Domestic Water Piping" and comply with requirements for steam and condensate piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Piping Specialties."
- D. Connect cold water and electrical power to electric heating water-tempering equipment. Comply with requirements for cold-water piping specified in Section 221116 "Domestic Water Piping."
- E. Directly connect emergency plumbing fixture receptors with trapped drain outlet to sanitary waste and vent piping. Comply with requirements for waste piping specified in Section 221316 "Sanitary Waste and Vent Piping."
- F. Indirectly connect emergency plumbing fixture receptors without trapped drain outlet to sanitary waste or storm drainage piping.
- G. Where installing piping adjacent to emergency plumbing fixtures, allow space for service and maintenance of fixtures.

3.4 IDENTIFICATION

- A. Install equipment nameplates or equipment markers on emergency plumbing fixtures and equipment and equipment signs on water-tempering equipment. Comply with requirements for identification materials specified in Section 220553 "Identification for Plumbing Piping and Equipment."

3.5 FIELD QUALITY CONTROL

- A. Mechanical-Component Testing: After plumbing connections have been made, test for compliance with requirements. Verify ability to achieve indicated capacities.
- B. Tests and Inspections:
 - 1. Perform each visual and mechanical inspection.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Emergency plumbing fixtures[**and water-tempering equipment**] will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Adjust or replace fixture flow regulators for proper flow.
- B. Adjust equipment temperature settings.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **224500**

SECTION 224713 - DRINKING FOUNTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes drinking fountains and related components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of drinking fountain.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Include operating characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For drinking fountains to include in maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.

1.5 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with

other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

PART 2 - PRODUCTS

2.1 DRINKING FOUNTAINS

A. Drinking Fountains <Insert drawing designation>: **[Stainless steel]**, wall mounted.

1. Stainless-Steel Drinking Fountains:

a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1) [Elkay Manufacturing Co.](#)
- 2) [Filtrine Manufacturing Company.](#)
- 3) [Halsey Taylor.](#)
- 4) [Haws Corporation.](#)
- 5) [Murdock-Super Secur; a division of Acorn Engineering Company.](#)
- 6) [Stern-Williams Co., Inc.](#)
- 7) [Tri Palm International, LLC.](#)
- 8) <Insert manufacturer's name>.
- 9) or approved equal.

2. Standards:

- a. Comply with **[ASME A112.19.3/CSA B45.4]** **[ASME A112.19.2/CSA B45.1]**.
- b. Comply with NSF 61.

3. Type Receptor: **[Slab]** **[With back]** **[On horizontal support]**.

4. Receptor Shape: **[Rectangular]** **[Round]** <Insert shape>.

5. Back Panel: **[Stainless-steel]** <Insert material> wall plate behind drinking fountain.

6. Bubblers: **[One]** **[Two]** **[Three]**, with adjustable stream regulator, located on deck.

7. Control: **[Push button]** **[Push bar]** <Insert control>.

8. Drain: Grid type with **NPS 1-1/4 (DN 32)** tailpiece.

9. Supply: **NPS 3/8 (DN 10)** with shutoff valve.

10. Waste Fitting: ASME A112.18.2/CSA B125.2, **NPS 1-1/4 (DN 32)** chrome-plated brass P-trap and waste.

11. Support: ASME A112.6.1M, Type III lavatory carrier.

B. Drinking Fountains <Insert drawing designation>: **[Stainless steel]** **[Vitreous china]**, wall mounted, semirecessed.

1. Stainless-Steel Drinking Fountains:

a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1) [Elkay Manufacturing Co.](#)
 - 2) [Filtrine Manufacturing Company.](#)
 - 3) [Halsey Taylor.](#)
 - 4) [Haws Corporation.](#)
 - 5) [Tri Palm International, LLC.](#)
 - 6) **<Insert manufacturer's name>.**
2. Standards: Comply with [ASME A112.19.3/CSA B45.4] [ASME A112.19.2/CSA B45.1].
 3. Standards: Comply with NSF 61.
 4. Receptor Shape: Concave with projecting bowl.
 5. Bubbler: One, with adjustable stream regulator, located on deck.
 6. Control: **[Push button] [Push bar] <Insert control>.**
 7. Drain: Grid type with NPS 1-1/4 (DN 32) tailpiece.
 8. Supply: NPS 3/8 (DN 10) with shutoff valve.
 9. Waste Fitting: ASME A112.18.2/CSA B125.2, NPS 1-1/4 (DN 32) brass P-trap.
 10. Support: Mounting frame or brackets for attaching to wood blocking or substrate.
- C. Drinking Fountains **<Insert drawing designation>**: Stainless steel, recessed.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Elkay Manufacturing Co.](#)
 - b. [Filtrine Manufacturing Company.](#)
 - c. [Halsey Taylor.](#)
 - d. [Haws Corporation.](#)
 - e. [Tri Palm International, LLC; Oasis Brand.](#)
 - f. [Tri Palm International, LLC; Sunroc Brand.](#)
 - g. **<Insert manufacturer's name>.**
 - h. or approved equal.
 2. Standard: Comply with NSF 61.
 3. Receptor Shape: Concave with flush wall flange.
 4. Bubbler: One, with adjustable stream regulator, located on deck.
 5. Control: **[Push button] [Push bar] <Insert control>.**
 6. Drain: Grid with NPS 1-1/4 (DN 32) minimum horizontal waste and trap, complying with ASME A112.18.2/CSA B125.2.
 7. Supply: NPS 3/8 (DN 10) with shutoff valve.
 8. Support: Mounting frame or brackets for attaching to substrate.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for water-supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before fixture installation.

- B. Examine walls and floors for suitable conditions where fixtures will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install fixtures level and plumb according to roughing-in drawings. For fixtures indicated for children, install at height required by authorities having jurisdiction.
- B. Set pedestal drinking fountains on floor.
- C. Install recessed drinking fountains secured to wood blocking in wall construction.
- D. Install off-the-floor carrier supports, affixed to building substrate, for wall-mounted fixtures.
- E. Install water-supply piping with shutoff valve on supply to each fixture to be connected to domestic-water distribution piping. Use ball, gate, or globe valve. Install valves in locations where they can be easily reached for operation. Valves are specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- F. Install trap and waste piping on drain outlet of each fixture to be connected to sanitary drainage system.
- G. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons where required to conceal protruding fittings. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."
- H. Seal joints between fixtures and walls using sanitary-type, one-part, mildew-resistant, silicone sealant. Match sealant color to fixture color. Comply with sealant requirements specified in Section 079200 "Joint Sealants."

3.3 CONNECTIONS

- A. Connect fixtures with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Install ball, gate, or globe shutoff valve on water supply to each fixture. Comply with valve requirements specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- D. Comply with soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."

3.4 ADJUSTING

- A. Adjust fixture flow regulators for proper flow and stream height.

3.5 CLEANING

- A. After installing fixtures, inspect unit. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.
- B. Clean fixtures, on completion of installation, according to manufacturer's written instructions.
- C. Provide protective covering for installed fixtures.
- D. Do not allow use of fixtures for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **224713**

SECTION 224716 - PRESSURE WATER COOLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes pressure water coolers and related components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of pressure water cooler.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
- C. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For pressure water coolers to include in maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Filter Cartridges: Equal to **<Insert number>** percent of quantity installed for each type and size indicated, but no fewer than **<Insert number>** of each.

1.6 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PRESSURE WATER COOLERS

- A. Pressure Water Coolers **<Insert drawing designation>**: **[Freestanding] [Flush to wall]**.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Elkay Manufacturing Co.
- b. Halsey Taylor.
- c. Haws Corporation.
- d. Larco Inc.
- e. Tri Palm International, LLC; Oasis Brand.
- f. Tri Palm International, LLC; Sunroc Brand.
- g. **<Insert manufacturer's name>**.
- h. or approved equal.

2. Standards:

- a. Comply with NSF 61.
- b. Comply with ASHRAE 34, "Designation and Safety Classification of Refrigerants," for water coolers. Provide HFC 134a (tetrafluoroethane) refrigerant unless otherwise indicated.

3. Cabinet: **[All stainless steel] [Steel with powder-coat finish] [Vinyl-covered steel with stainless-steel top] <Insert material>**.

4. Bubbler: One, with adjustable stream regulator, located on deck.
 5. Control: **[Push button] [Foot pedal] <Insert control>**.
 6. Drain: Grid with **NPS 1-1/4 (DN 32)** tailpiece.
 7. Supply: **NPS 3/8 (DN 10)** with shutoff valve.
 8. Waste Fitting: ASME A112.18.2/CSA B125.2, **NPS 1-1/4 (DN 32)** brass P-trap.
 9. Filter: One or more water filters complying with NSF 42 and NSF 53 for cyst and lead reduction to below EPA standards, with capacity sized for unit peak flow rate.
 10. Cooling System: Electric, with **[precooler,]** hermetically sealed compressor, cooling coil, air-cooled condensing unit, corrosion-resistant tubing, refrigerant, corrosion-resistant-metal storage tank, and adjustable thermostat.
 - a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 11. Capacities and Characteristics:
 - a. Cooled Water: **[5 gph (0.0053 L/s)] [8 gph (0.0084 L/s)] [10 gph (0.0105 L/s)] [14 gph (0.0147 L/s)] <Insert value>**.
 - b. Ambient-Air Temperature: **90 deg F (32 deg C)**.
 - c. Inlet-Water Temperature: **80 deg F (27 deg C)**.
 - d. Cooled-Water Temperature: **50 deg F (10 deg C)**.
 - e. Cooled-Water Storage: **<Insert gal. (L)>**.
 - f. Electrical Characteristics:
 - 1) Motor Horsepower: **[1/6] [1/5] [1/4] <Insert value>**.
 - 2) Volts: 120-V ac.
 - 3) Phase: Single.
 - 4) Hertz: 60.
 - 5) Full-Load Amperes: **<Insert value>**.
 - 6) Minimum Circuit Ampacity: **<Insert value>**.
 - 7) Maximum Overcurrent Protection: **<Insert amperage>**.
- B. Pressure Water Coolers **<Insert drawing designation>**: Wall mounted[, **standard**] [, **wheelchair accessible**].
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Elkay Manufacturing Co.
 - b. Halsey Taylor.
 - c. Haws Corporation.
 - d. Larco Inc.
 - e. Tri Palm International, LLC; Oasis Brand.
 - f. Tri Palm International, LLC; Sunroc Brand.
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.

2. Cabinet: **[Single] [Bi-level with two attached cabinets] [Bi-level with two attached cabinets and with a bi-level skirt kit], [all stainless steel] [vinyl-covered steel with stainless-steel top] <Insert material>**.
 3. Bubbler: One, with adjustable stream regulator, located on each cabinet deck.
 4. Control: **[Push button] [Push bar] <Insert control>**.
 5. Drain: Grid with **NPS 1-1/4 (DN 32)** tailpiece.
 6. Supply: **NPS 3/8 (DN 10)** with shutoff valve.
 7. Waste Fitting: ASME A112.18.2/CSA B125.2, **NPS 1-1/4 (DN 32)** brass P-trap.
 8. Filter: One or more water filters complying with NSF 42 and NSF 53 for cyst and lead reduction to below EPA standards; with capacity sized for unit peak flow rate.
 9. Cooling System: Electric, with hermetically sealed compressor, cooling coil, air-cooled condensing unit, corrosion-resistant tubing, refrigerant, corrosion-resistant-metal storage tank, and adjustable thermostat.
 - a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 10. Capacities and Characteristics:
 - a. Cooled Water: **[5 gph (0.0053 L/s)] [8 gph (0.0084 L/s)] <Insert value>**.
 - b. Ambient-Air Temperature: **90 deg F (32 deg C)**.
 - c. Inlet-Water Temperature: **80 deg F (27 deg C)**.
 - d. Cooled-Water Temperature: **50 deg F (10 deg C)**.
 - e. Cooled-Water Storage: **<Insert value>**.
 - f. Electrical Characteristics:
 - 1) Motor Horsepower: **[1/6] [1/5] [1/4] [1/3] <Insert value>**.
 - 2) Volts: 120-V ac.
 - 3) Phase: Single.
 - 4) Hertz: 60.
 - 5) Full-Load Amperes: **<Insert value>**.
 - 6) Minimum Circuit Ampacity: **<Insert value>**.
 - 7) Maximum Overcurrent Protection: **<Insert amperage>**.
 11. Support: ASME A112.6.1M, Type I water-cooler carrier.
- C. Pressure Water Coolers **<Insert drawing designation>**: Semirecessed[, **standard**] [, **wheelchair accessible**].
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Elkay Manufacturing Co.
 - b. Halsey Taylor.
 - c. Haws Corporation.
 - d. Tri Palm International, LLC; Oasis Brand.
 - e. Tri Palm International, LLC; Sunroc Brand.
 - f. **<Insert manufacturer's name>**.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Elkay Manufacturing Co.
 - b. Halsey Taylor.
 - c. Haws Corporation.
 - d. Tri Palm International, LLC; Oasis Brand.
 - e. Tri Palm International, LLC; Sunroc Brand.
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.

2. **Standards:**
 - a. Comply with NSF 61.
 - b. Comply with ASHRAE 34, "Designation and Safety Classification of Refrigerants," for water coolers. Provide HFC 134a (tetrafluoroethane) refrigerant unless otherwise indicated.

3. Cabinet: All stainless steel.
4. Bubbler: One, with adjustable stream regulator, located on deck.
5. Control: **[Push button] [Push bar] <Insert control>**.
6. Drain: Grid with **NPS 1-1/4 (DN 32)** tailpiece.
7. Supply: **NPS 3/8 (DN 10)** with shutoff valve.
8. Waste Fitting: ASME A112.18.2/CSA B125.2, **NPS 1-1/4 (DN 32)** brass P-trap.
9. Filter: One or more water filters complying with NSF 42 and NSF 53 for cyst and lead reduction to below EPA standards; with capacity sized for unit peak flow rate.
10. Cooling System: Electric, with **[precooler,]**hermetically sealed compressor, cooling coil, air-cooled condensing unit, corrosion-resistant tubing, refrigerant, corrosion-resistant-metal storage tank, and adjustable thermostat.
 - a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

11. **Capacities and Characteristics:**
 - a. Cooled Water: **[8 gph (0.0084 L/s)] [12 gph (0.0126 L/s)] <Insert value>**.
 - b. Ambient-Air Temperature: **90 deg F (32 deg C)**.
 - c. Inlet-Water Temperature: **80 deg F (27 deg C)**.
 - d. Cooled-Water Temperature: **50 deg F (10 deg C)**.
 - e. Cooled-Water Storage: **<Insert value>**.
 - f. Electrical Characteristics:
 - 1) Motor Horsepower: **[1/6] [1/5] <Insert value>**.
 - 2) Volts: 120-V ac.
 - 3) Phase: Single.
 - 4) Hertz: 60.
 - 5) Full-Load Amperes: **<Insert value>**.
 - 6) Minimum Circuit Ampacity: **<Insert value>**.

7) Maximum Overcurrent Protection: <Insert amperage>.

12. Ventilation Grille: Stainless steel, located [**above**] [**below**] water cooler.
13. Support: Mounting frame for attaching to substrate.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for water-supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before fixture installation.
- B. Examine walls and floors for suitable conditions where fixtures will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install fixtures level and plumb according to roughing-in drawings. For fixtures indicated for children, install at height required by authorities having jurisdiction.
- B. Set freestanding pressure water coolers on floor.
- C. Install off-the-floor carrier supports, affixed to building substrate, for wall-mounted fixtures.
- D. Install mounting frames, affixed to building construction, and attach recessed, pressure water coolers to mounting frames.
- E. Install water-supply piping with shutoff valve on supply to each fixture to be connected to domestic-water distribution piping. Use ball, gate, or globe valve. Install valves in locations where they can be easily reached for operation. Valves are specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- F. Install trap and waste piping on drain outlet of each fixture to be connected to sanitary drainage system.
- G. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons where required to conceal protruding fittings. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."
- H. Seal joints between fixtures and walls using sanitary-type, one-part, mildew-resistant, silicone sealant. Match sealant color to fixture color. Comply with sealant requirements specified in Section 079200 "Joint Sealants."

3.3 CONNECTIONS

- A. Connect fixtures with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Install ball, gate, or globe shutoff valve on water supply to each fixture. [**Install valve upstream from filter for water cooler.**] Comply with valve requirements specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- D. Comply with soil and waste piping requirements specified in Section 221316 "Sanitary Waste and Vent Piping."

3.4 ADJUSTING

- A. Adjust fixture flow regulators for proper flow and stream height.
- B. Adjust pressure water-cooler temperature settings.

3.5 CLEANING

- A. After installing fixture, inspect unit. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.
- B. Clean fixtures, on completion of installation, according to manufacturer's written instructions.
- C. Provide protective covering for installed fixtures.
- D. Do not allow use of fixtures for temporary facilities unless approved in writing by Owner.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 224716

SECTION 224723 - REMOTE WATER COOLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes remote water coolers and related components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of remote water coolers.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite WE 1[**and Credit WE 3**] [, **Credit WE 2, and Credit WE 3**]: Documentation indicating flow and water consumption requirements.
- C. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For remote water coolers to include in maintenance manuals.
 - 1. Include fixture trim exploded view and replacement parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filter Cartridges: Equal to **<Insert number>** percent of quantity installed for each type and size indicated, but no fewer than **<Insert number>** of each.

1.6 QUALITY ASSURANCE

- A. Field Measurements: Verify that field measurements are as indicated on shop drawings or instructed by the manufacturer.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 REMOTE WATER COOLERS

- A. Remote Water Coolers **<Insert drawing designation>**: Remote chiller equipment.
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Elkay Manufacturing Co.
 - b. Filtrine Manufacturing Company.
 - c. Halsey Taylor.
 - d. Haws Corporation.
 - e. Tri Palm International, LLC; Oasis Brand.
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 - 2. Standards:
 - a. Comply with NSF 61.
 - b. Comply with UL 1951.
 - c. Comply with ASHRAE 34, "Designation and Safety Classification of Refrigerants," for water coolers. Provide HFC 134a (tetrafluoroethane) refrigerant unless otherwise indicated.
 - 3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

4. Chassis: Galvanized or corrosion-resistant-coated steel.
5. Chiller: Hermetically sealed compressor, cooling coil, air-cooled condensing unit, corrosion-resistant tubing, and refrigerant.
6. Storage Tank: [0.5 gal. (1.9 L)] [4 gal. (15.1 L)] <Insert value>, stainless steel.
7. Controls: Adjustable thermostat.
8. Capacities and Characteristics:
 - a. Cooled Water: [5 gph (0.0053 L/s)] [8 gph (0.0084 L/s)] [14 gph (0.0147 L/s)] <Insert value>.
 - b. Ambient-Air Temperature: 90 deg F (32 deg C).
 - c. Inlet-Water Temperature: 80 deg F (27 deg C).
 - d. Cooled-Water Temperature: 50 deg F (10 deg C).
 - e. Cooled-Water Storage: <Insert gal. (L)>.
 - f. Electrical Characteristics:
 - 1) Motor Horsepower: [1/5] [1/4] [1/3] <Insert value>.
 - 2) Volts: 120-V ac.
 - 3) Phase: Single.
 - 4) Hertz: 60.
 - 5) Full-Load Amperes: <Insert value>.
 - 6) Minimum Circuit Ampacity: <Insert value>.
 - 7) Maximum Overcurrent Protection: <Insert amperage>.
9. Ventilation Grille: Stainless steel, <Insert size>.
10. Filter: One or more water filters complying with NSF 42 and NSF 53 for cyst and lead reduction to below EPA standards; with capacity sized for unit peak flow rate.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for water-supply and sanitary drainage piping systems to verify actual locations of piping connections before fixture installation.
- B. Examine walls and floors for suitable conditions where remote water coolers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install remote water coolers level and plumb according to roughing-in drawings.
- B. Install water-supply piping with shutoff valve on supply to each remote water cooler to be connected to domestic-water distribution piping. Use ball, gate, or globe valve. Install valves in locations where they can be easily reached for operation. Valves are specified in Section 220523 "General-Duty Valves for Plumbing Piping."

- C. Set remote water coolers on floor unless otherwise indicated.
- D. Install wall flanges or escutcheons at piping wall penetrations in exposed, finished locations. Use deep-pattern escutcheons where required to conceal protruding fittings. Comply with escutcheon requirements specified in Section 220518 "Escutcheons for Plumbing Piping."

3.3 CONNECTIONS

- A. Connect fixtures with water supplies. Use size fittings required to match fixtures.
- B. Comply with water piping requirements specified in Section 221116 "Domestic Water Piping."
- C. Install ball, gate, or globe shutoff valve on water supply to each fixture. [**Install valve upstream from filter for water cooler.**] Comply with valve requirements specified in Section 220523 "General-Duty Valves for Plumbing Piping."
- D. Install ball, gate, or globe isolation valves with valved bypass on water connections to [**remote water coolers**] [**and**] [**water filters**]. Comply with valve requirements specified in Section 220523 "General-Duty Valves for Plumbing Piping."

3.4 ADJUSTING

- A. Adjust water-cooler temperature settings.

3.5 CLEANING

- A. After installing remote water cooler, inspect unit. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 224723

SECTION 230130.51 - HVAC AIR-DISTRIBUTION SYSTEM CLEANING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes cleaning HVAC air-distribution equipment, ducts, plenums, and system components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. ASCS: Air systems cleaning specialist.
- B. NADCA: National Air Duct Cleaners Association.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For an ASCS.
- B. Strategies and procedures plan.
- C. Cleanliness verification report.

1.5 QUALITY ASSURANCE

- A. ASCS Qualifications: **[A certified member of NADCA] <Insert objective qualifications>**.
 - 1. Certification: Employ **[an ASCS certified by NADCA on a full-time basis] <Insert objective qualifications>**.
 - 2. Supervisor Qualifications: Certified **[as an ASCS by NADCA] <Insert objective qualifications>**.
- B. UL Compliance: Comply with UL 181 and UL 181A for fibrous-glass ducts.

- C. Cleaning Conference: Conduct conference at **[Project site] [location and time as determined by DEN Project Manager]<Insert location>**.
 - 1. Review methods and procedures related to HVAC air-distribution system cleaning including, but not limited to, review of the cleaning strategies, procedures plan, and possible interruption of Owner's activities.

1.6 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine HVAC air-distribution equipment, ducts, plenums, and system components to determine appropriate methods, tools, and equipment required for performance of the Work.
- B. Perform "Project Evaluation and Recommendation" according to NADCA ACR 2006.
- C. Prepare written report listing conditions detrimental to performance of the Work.
- D. Proceed with work only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Prepare a written plan that includes strategies and step-by-step procedures. At a minimum, include the following:
 - 1. Supervisor contact information.
 - 2. Work schedule including location, times, and impact on occupied areas.
 - 3. Methods and materials planned for each HVAC component type.
 - 4. Required support from other trades.
 - 5. Equipment and material storage requirements.
 - 6. Exhaust equipment setup locations.
- B. Use the existing service openings, as required for proper cleaning, at various points of the HVAC system for physical and mechanical entry and for inspection.
- C. Comply with NADCA ACR 2006, "Guidelines for Constructing Service Openings in HVAC Systems" Section.

3.3 CLEANING

- A. Comply with NADCA ACR 2006.
- B. Remove visible surface contaminants and deposits from within the HVAC system.
- C. Systems and Components to Be Cleaned:
 - 1. Air devices for supply and return air.
 - 2. Air-terminal units.
 - 3. Ductwork:
 - a. Supply-air ducts, including turning vanes[**and reheat coils**], to the air-handling unit.
 - b. Return-air ducts to the air-handling unit.
 - c. Exhaust-air ducts.
 - 4. Air-Handling Units:
 - a. Interior surfaces of the unit casing.
 - b. Coil surfaces compartment.
 - c. Condensate drain pans.
 - d. Fans, fan blades, and fan housings.
 - 5. Filters and filter housings.
- D. Collect debris removed during cleaning. Ensure that debris is not dispersed outside the HVAC system during the cleaning process.
- E. Particulate Collection:
 - 1. For particulate collection equipment, include adequate filtration to contain debris removed. Locate equipment downwind and away from all air intakes and other points of entry into the building.
 - 2. HEPA filtration with 99.97 percent collection efficiency for particles sized 0.3 micrometer or larger shall be used where the particulate collection equipment is exhausting inside the building,
- F. Control odors and mist vapors during the cleaning and restoration process.
- G. Mark the position of manual volume dampers and air-directional mechanical devices inside the system prior to cleaning. Restore them to their marked position on completion of cleaning.
- H. System components shall be cleaned so that all HVAC system components are visibly clean. On completion, all components must be returned to those settings recorded just prior to cleaning operations.
- I. Clean all air-distribution devices, registers, grilles, and diffusers.

- J. Clean visible surface contamination deposits according to NADCA ACR 2006 and the following:
1. Clean air-handling units, airstream surfaces, components, condensate collectors, and drains.
 2. Ensure that a suitable operative drainage system is in place prior to beginning wash-down procedures.
 3. Clean evaporator coils, reheat coils, and other airstream components.
- K. Duct Systems:
1. Create service openings in the HVAC system as necessary to accommodate cleaning.
 2. Mechanically clean duct systems specified to remove all visible contaminants so that the systems are capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).
- L. Debris removed from the HVAC system shall be disposed of according to applicable Federal, state, and local requirements.
- M. Mechanical Cleaning Methodology:
1. Source-Removal Cleaning Methods: The HVAC system shall be cleaned using source-removal mechanical cleaning methods designed to extract contaminants from within the HVAC system and to safely remove these contaminants from the facility. No cleaning method, or combination of methods, shall be used that could potentially damage components of the HVAC system or negatively alter the integrity of the system.
 - a. Use continuously operating vacuum-collection devices to keep each section being cleaned under negative pressure.
 - b. Cleaning methods that require mechanical agitation devices to dislodge debris that is adhered to interior surfaces of HVAC system components shall be equipped to safely remove these devices. Cleaning methods shall not damage the integrity of HVAC system components or damage porous surface materials such as duct and plenum liners.
 2. Cleaning Mineral-Fiber Insulation Components:
 - a. Fibrous-glass thermal or acoustical insulation elements present in equipment or ductwork shall be thoroughly cleaned with HEPA vacuuming equipment while the HVAC system is under constant negative pressure and shall not be permitted to get wet according to NADCA ACR 2006.
 - b. Cleaning methods used shall not cause damage to fibrous-glass components and will render the system capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).
 - c. Fibrous materials that become wet shall be discarded and replaced.
- N. Coil Cleaning:

1. Measure static-pressure differential across each coil.
2. See NADCA ACR 2006, "Coil Surface Cleaning" Section. Type 1, or Type 1 and Type 2, cleaning methods shall be used to render the coil visibly clean and capable of passing Coil Cleaning Verification (see applicable NADCA ACR 2006).
3. Coil drain pans shall be subject to NADCA ACR 2006, "Non-Porous Surfaces Cleaning Verification." Ensure that condensate drain pans are operational.
4. Electric-resistance coils shall be de-energized, locked out, and tagged before cleaning.
5. Cleaning methods shall not cause any appreciable damage to, cause displacement of, inhibit heat transfer, or cause erosion of the coil surface or fins, and shall comply with coil manufacturer's written recommendations when available.
6. Rinse thoroughly with clean water to remove any latent residues.

O. Antimicrobial Agents and Coatings:

1. Apply antimicrobial agents and coatings if active fungal growth is reasonably suspected or where unacceptable levels of fungal contamination have been verified. Apply antimicrobial agents and coatings according to manufacturer's written recommendations and EPA registration listing after the removal of surface deposits and debris.
2. When used, antimicrobial treatments and coatings shall be applied after the system is rendered clean.
3. Apply antimicrobial agents and coatings directly onto surfaces of interior ductwork.
4. Sanitizing agent products shall be registered by the EPA as specifically intended for use in HVAC systems and ductwork.

3.4 CLEANLINESS VERIFICATION

- A. Verify cleanliness according to NADCA ACR 2006, "Verification of HVAC System Cleanliness" Section.
- B. Verify HVAC system cleanliness after mechanical cleaning and before applying any treatment or introducing any treatment-related substance to the HVAC system, including biocidal agents and coatings.
- C. Perform visual inspection for cleanliness. If no contaminants are evident through visual inspection, the HVAC system shall be considered clean. If visible contaminants are evident through visual inspection, those portions of the system where contaminants are visible shall be re-cleaned and subjected to re-inspection for cleanliness.
- D. Additional Verification:
 1. Perform surface comparison testing or NADCA vacuum test.
 2. Conduct NADCA vacuum gravimetric test analysis for nonporous surfaces.
- E. Verification of Coil Cleaning:

1. Measure static-pressure differential across each coil.
 2. Coil will be considered clean if cleaning restored the coil static-pressure differential within 10 percent of <Insert inches wg (Pa)>, the differential measured when the coil was first installed.
 3. Coil will be considered clean if the coil is free of foreign matter and chemical residue, based on a thorough visual inspection.
- F. Prepare a written cleanliness verification report. At a minimum, include the following:
1. Written documentation of the success of the cleaning.
 2. Site inspection reports, initialed by supervisor, including notation on areas of inspection, as verified through visual inspection.
 3. Surface comparison test results if required.
 4. Gravimetric analysis (nonporous surfaces only).
 5. System areas found to be damaged.
- G. Photographic Documentation: Comply with requirements in Section 013233 "Photographic Documentation."

3.5 RESTORATION

- A. Restore and repair HVAC air-distribution equipment, ducts, plenums, and components according to NADCA ACR 2006, "Restoration and Repair of Mechanical Systems" Section.
- B. Restore service openings capable of future reopening. Comply with requirements in Section 233113 "Metal Ducts." Include location of service openings in Project closeout report.
- C. Replace fibrous-glass materials that cannot be restored by cleaning or resurfacing. Comply with requirements in Section 233113 "Metal Ducts" and Section 233116 "Nonmetal Ducts."
- D. Replace damaged insulation according to Section 230713 "Duct Insulation."
- E. Ensure that closures do not hinder or alter airflow.
- F. New closure materials, including insulation, shall match opened materials and shall have removable closure panels fitted with gaskets and fasteners.
- G. Reseal fibrous-glass ducts. Comply with requirements in Section 233116 "Nonmetal Ducts."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230130.51

SECTION 230400 - BASIC HVAC REQUIREMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Basic requirements common to the work in general of Division 23 and other Divisions and Sections of the Specification where referenced.
- B. Provide, unless specified otherwise, all labor, materials, and equipment necessary for completely finished and operational HVAC systems described and specified under other Sections of this Division 23.
- C. Provide all minor incidental items such as offsets, fittings, and accessories required as part of the work even though not specified or indicated.
- D. Inspection: Inspect work preceding or interfacing with work of Division 23 and report any known or observed defects that affect the Work to the General Contractor. Do not proceed with the work until defects are corrected.
- E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 REFERENCES

- A. General:
 - 1. For products or workmanship specified by association, trade, or Federal Standards comply with requirements of the standard, except when more rigid requirements are specified or are required by applicable Codes.
 - 2. The date of the standard is that in effect as the date of the Contract Documents, except when a specific date is specified.
 - 3. When required by individual Specifications Section by means of reference for cleaning or installation requirements, etc., obtain a copy of the standard. Maintain the copy at job site during work until substantial completion. Copy may be in electronic format.
 - 4. Schedule of Referenced Organizations: Reference Section 014200 "References" for a list of the acronyms of organizations referenced in these Specifications.

1.4 DEFINITIONS

- A. Conform to Division 01: These Specifications are of abbreviated, simplified, or streamlined type and include incomplete sentences. Singular words will be interpreted as plural and plural words will be interpreted as singular where applicable and where full context of the Contract Documents so indicates.
- B. The following words are re-defined and/or elaborated on for the context of Division 23 work:
1. Furnish: Except as otherwise defined in greater detail, term "furnish" is used to mean supply and deliver to Project site, ready for unloading, unpacking, assembly, installation, etc., as applicable in each instance.
 2. Install: Except as otherwise defined in greater detail, term "install" is used to describe operations at Project site including unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning and similar operations, as applicable in each instance.
 3. Provide: Except as otherwise defined in greater detail, term "provide" means furnish and install, complete and ready for intended use, as applicable in each instance.
 4. General Contractor: The term "General Contractor" used in Division 23 and elsewhere in the Contract Documents means the party with whom the Owner has executed the Owner-Contractor Agreement.

1.5 QUALITY CONTROL

- A. Conform to Division 01. Materials and apparatus required for the work to be new and of first-class quality; to be furnished, delivered, erected, connected and finished in every detail; and to be so selected and arranged so as to fit properly into the building spaces. Where no specific kind or quality of material is given, a first-class standard article shall be furnished.
- B. Unless otherwise specifically indicated, equipment and materials to be installed in accordance with the recommendations of the Manufacturer. This includes the performance of tests as recommended by the Manufacturer.

1.6 REGULATORY REQUIREMENTS

- A. Comply with latest editions of all applicable Codes, Standards, Ordinances and Regulations in effect as of the date of the Contract Documents adopted by CCD, BD, and FD, including but not necessarily limited to the following:
1. National Electrical Code NFPA-70.
 2. NFPA.
 3. ASHRAE.
 4. SMACNA.
 5. Underwriters Laboratories.

- B. If discrepancies occur between the Contract Documents and any applicable Codes, Guidelines, Ordinances, Acts, or Standards, the most stringent requirements shall apply.
- C. Where hourly fire ratings are indicated or required, provide components and assemblies meeting requirements of the American Insurance Association, Factory Mutual Insurance Association and listed by Underwriters Laboratories, Inc.

1.7 PRODUCT OPTIONS AND SUBSTITUTIONS

- A. Substitutions: Refer to Division 01, General Requirements.
- B. Some materials and equipment are specified by Manufacturer and catalog numbers. The Manufacturer and catalog numbers are used to establish a degree of quality and style for such equipment and material.
- C. When alternate or substitute materials and equipment are used, Contractor shall be responsible for space requirements, configurations, performance, changes in bases, supports, structural members and openings in structure, electrical changes and other apparatus and trades that may be affected by their use.
- D. When providing a product and/or service under the qualification of "acceptable equal," Contractor shall be entirely responsible for additional costs incurred due to modifications to the civil, architectural, structural, mechanical, and electrical design that may be required to accommodate the "acceptable equal."
- E. Substitute materials and equipment are only allowed to be provided from the Manufacturers listed as approved.

1.8 SHOP DRAWINGS, PRODUCT DATA, AND AS-BUILT DRAWINGS

- A. General: Comply with the General Conditions of the Contract and with Division 01 - General Requirements.
 - 1. All documents shall be submitted in electronic format.
 - 2. All submittals to be provided in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.9 CONTRACT RECORD DOCUMENTS

- A. General: Comply with the General Conditions of the Contract and with Division 01 - General Requirements,
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.10 OPERATING AND MAINTENANCE DATA

- A. HVAC Contractor shall submit electronic copy containing a single PDF file of the entire maintenance manual to the DEN Project Manager, General Contractor for their approval.
- B. All submittals to be provided in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- C. The manual shall have:
1. Alphabetical list of all system components including the name, address, and 24-hour phone number of the company responsible for servicing each item during the first year's operation.
 2. Operating instructions for complete system, including emergency procedures for fire or failure of major equipment and procedures for normal starting/operating/shutdown and long-term shutdown.
 3. Maintenance instructions, including valves, valve tag and other identified equipment lists, proper lubricants and lubricating instructions for each piece of equipment and necessary cleaning/replacing/adjusting schedules.
 4. Manufacturer's data on each piece of equipment, including:
 - a. Installation instructions.
 - b. Drawings and specifications (approved shop drawings).
 - c. Parts lists.
 - d. Complete wiring and temperature control diagrams (approved shop drawings).
 5. Each piece identified on any schedule shall be bookmarked in the electronic file by its scheduled tag ID (IE: AHU-1)
- D. In addition to the maintenance manual, and keyed to it, the equipment shall be identified and tagged as specified elsewhere. Insert a copy.
1. Identify all starters, disconnect switches, and manually operated controls, except integral equipment switches with permanently applied, legible markers corresponding to operating instructions in the "Maintenance Manual".
 2. Tag all manual operating valves with 1-1/2" diameter brass tags attached with chains. Tags are to be sequence numbered with legible metal stamps.
 3. Provide a typed tag list or schedule mounted under glass in the room designated by DEN Project Manager stating number, location, and function of each tagged item. Insert a copy of tag list in each "Maintenance Manual".
- E. Division 23 Contractor shall be responsible for scheduling instructional meetings for maintenance personnel on the proper operation and maintenance of all mechanical systems, using the maintenance manual as a guide. These meetings must be scheduled through the DEN Project Manager, and General Contractor far enough in advance so that all personnel can be notified.
- F. Division 23 Contractor shall provide proof of performance certification of all Mechanical

Equipment and Systems to demonstrate that all Mechanical Equipment and Systems are operating to the intent of the design.

1.11 FINAL OBSERVATION

A. Comply with the requirements of Division 01 and the following:

1. Prior to the request for final observation, all Work under the contract shall be completed; all systems shall be in proper working order and placed in operation (System Startup of 48 hours).
2. All HVAC systems shall be properly balanced with quantities shown on the Drawings, and all water circuits shall be adjusted to provide the proper flows.
3. All equipment shall be cleaned, including but not limited to, plumbing fixtures. All debris and construction materials shall be removed from the DEN property to a DEN approved landfill off-airport.
4. The temperature control system shall be complete and in proper working order. All instruments shall be properly and accurately field calibrated.
5. At the request of the DEN Project Manager, a representative of the Contractor who is thoroughly familiar with the Project and operation of the various systems shall be present during the final observation to demonstrate proper operation of the equipment and controls. If requested by the DEN Project Manager, the Contractor shall have representatives from his subcontractors present to assist during final observation.

1.12 PROJECT CONDITIONS

A. Accessibility.

1. Division 23 Contractor shall be responsible for the sufficiency of the size of shafts and chases and the adequate clearance in double partitions and hung ceilings for proper installation of his work. He shall cooperate with Contractors of other Divisions of the Work whose work is in the same space and shall advise the General Contractor of his requirements. Such spaces and clearances shall, however, be kept to the minimum size required.
2. Division 23 Contractor shall locate all equipment, which must be serviced, operated, or maintained in fully accessible positions. Such equipment shall include (but not be limited to) valves, shock absorbers, traps, cleanouts, motors, controllers, switchgear, and drain points. If required for better accessibility, furnish access doors for this purpose. Minor deviations from Drawings may be allowed to provide for better accessibility. Any changes shall be approved by the DEN Project Manager prior to making the change.
3. Division 23 Contractor shall provide the General Contractor with the exact locations of access doors for each concealed valve, shock absorber control, damper, or other device requiring service. Locations of these doors shall be submitted in sufficient time to be installed in the normal course of work.
4. Provide carpentry, masonry, concrete and metal work required for work of this Division where not specifically called for under other Sections.

B. Fabrication.

1. Before any ductwork is fabricated and before running and/or fabricating any lines of piping or ductwork, the Contractor shall assure himself that they can be run as contemplated in cooperation with Contractors of other Divisions of the Work and the physical constraints of existing conditions and new Structural and Architectural Work.

C. Freeze Protection.

1. Do not run lines in outside walls, or locations where freezing may occur. Piping next to outside walls shall be in furred spaces with insulation between the piping and the outside wall. Insulation of piping shall not be considered freeze protection.

D. Scaffolding, Rigging and Hoisting.

1. Provide all scaffolding, rigging, hoisting and services necessary for erection and delivery into the premises of any equipment and apparatus furnished; remove same from premises when no longer required. Conform to OSHA requirements and standards.

1.13 COORDINATION

- A. General: Coordinate and order the progress of mechanical work to conform to the progress of the work of the other trades. Complete the entire installation as soon as the condition of the building will permit.
- B. Coordination with Division 21 Fire Suppression, Division 22 Plumbing, Division 26 Electrical, and Division 33 Utilities and other Divisions as required to perform the Work..
- C. Existing System Interruptions: Comply with Division 01.
- D. Cutting and Patching: Section 024119 "Selective Demolition".
- E. Drawings and Specifications: The Mechanical Drawings indicate the general design and arrangement of lines, equipment, systems, etc. Information shown is diagrammatic in character and does not necessarily indicate every required offset, fitting, etc. Do not scale the Drawings for dimensions. Take dimensions, measurements, locations, levels, etc., from the Architectural and Engineering Drawings and equipment to be furnished.
- F. Discrepancies: Examine Drawings and Specifications for other parts of the work, and if any discrepancies occur between the plans for the work of this Division and the plans for the work of others, report such discrepancies to the DEN Project Manager and obtain written instructions for any changes necessary.
- G. Order of Precedence: The precedence of construction documents are as Specified in the General Conditions.

1.14 START-UP PROCEDURES

- A. Before start-up, each piece of equipment comprising a part of the system shall be checked for proper lubrication, drive rotation, belt tension, proper control sequence, and any other condition, which may cause damage to equipment or endanger personnel.
- B. Ensure that all control systems are fully operational in automatic mode.
- C. If systems are not to continue in use following the start-up procedures, steps should be taken to ensure against accidental operation or operation by unauthorized personnel.
- D. Factory personnel shall be notified as appropriate to start systems requiring their services.
- E. Notify the DEN Project Manager in writing a minimum of 48 hours prior to start-up of all major mechanical equipment and systems.
- F. Should there be any equipment found which had not been properly started up, it will be the responsibility of this Contractor to arrange for the appropriate personnel to start up the equipment at his expense and at a time as scheduled by the DEN Project Manager.

1.15 SCHEDULE OF TESTING

- A. Provide testing in accordance with the General Conditions of the Contract.
- B. A schedule of testing shall be drawn up by the Division 23 Contractor in such a manner that it will show areas tested, test pressure, length of test, date, time and signature of testing personnel.
- C. Notify the DEN Project Manager, DEN Mechanical Inspector, and DEN Mechanical Engineer in writing a minimum of 72 hours prior to testing of any mechanical equipment and systems.
- D. All testing must be performed in the presence DEN Project Manager and or his designated representative; his signature for verification of the test must appear on the schedule.
- E. All testing must be performed in accord with the procedures set forth in Division 23 and other Sections of the Specifications where referenced. At completion of testing, the schedule shall then be submitted in triplicate to the DEN Project Manager.
- F. Make all specified tests on piping, ductwork, and related systems as necessary.
- G. Make sure operational and performance tests are made on seasonal equipment.
- H. Complete all tests required by Code Authorities, such as health codes, building codes, and safety codes.

- I. After test runs have been completed and systems have been demonstrated to be satisfactory and ready for permanent operation, all permanent pipeline strainers and filters shall be cleaned, air filters cleaned or replaced, valve and pump packing properly adjusted, belt tensions adjusted, drive guards secured in place, lubrication checked and replenished if required.

1.16 CLEANING AND FINISHING

- A. Provide cleaning in accordance with the General Requirements of the Contract.
- B. Cleaning shall include but not be limited to removing grease, dirt, dust, stains, labels, fingerprints, and other foreign materials from sight-exposed piping, ductwork, equipment, fixtures and other such items installed under Division 23 of the work. If finishes have been damaged, refinish to original condition and leave everything in proper working order and of intended appearance.
- C. Clean HVAC Systems in accordance with applicable Division 23 Sections.

1.17 WARRANTIES

- A. Conform to Division 1: Provide a written warranty covering the entire mechanical work to be free from defective materials, equipment, and workmanship for a period of two (2) years after date of acceptance. During this period, provide labor and materials as required to repair or provide labor and materials required to repair or replace defects.
- B. Provide special warranties for such items of equipment that have been or are specified to have warranties in excess of two (2) years.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work

described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230400

SECTION 230500 - COMMON WORK RESULTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes the following basic mechanical materials and methods to complement other Division 23 Sections.
 - 1. Piping materials and installation instructions common to most piping systems.
 - 2. Dielectric fittings.
 - 3. Mechanical sleeve seals.
 - 4. Sleeves.
 - 5. Escutcheons.
 - 6. Nonshrink grout for equipment installations.
 - 7. Flowable backfill for underground piping.
 - 8. Field-fabricated metal equipment supports.
 - 9. Concrete bases
 - 10. Installation requirements common to equipment specification Sections.
 - 11. Mechanical demolition.
 - 12. Cutting and patching.
 - 13. Touch up painting and finishing.
 - 14. Pipe and pipe fitting materials are specified in piping system Sections.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 RELATED SECTIONS

- A. Drawings and general provisions of Contract, including General and the Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
- B. Section 230400 "Basic Mechanical Requirements".
- C. Division 31 Earthwork Sections.
- D. Section 059990 "Welding".
- E. Section 230553 "Identification for HVAC Piping and Equipment" for labeling and

identifying mechanical systems and equipment.

1.4 DEFINITIONS

- A. Pipe, pipe fittings, and piping include tube, tube fittings, and tubing.
- B. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below the roof, spaces above ceilings, unexcavated spaces, crawl spaces, and tunnels.
- C. Exposed Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- D. Exposed Exterior Installations: Exposed to view outdoors, or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
- E. Concealed Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.
- F. Concealed Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants, but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

1.5 SUBMITTALS

- A. General: Submit the following according to the Conditions of the Contract and Division 01 Specification Sections:
 - 1. Shop drawings detailing fabrication and installation for metal and wood supports and anchorage for mechanical materials and equipment.
 - 2. Prepare coordination drawings according to Division 01 Section 013300 "Submittals" to a 1/4 inch equals 1 foot scale or larger. Detail major elements, components, and systems of mechanical equipment and materials in relationship with other systems, installations, and building components. Show space requirements for installation and access. Show where sequence and coordination of installations are important to the efficient flow of the Work. Include the following:
 - a. Clearances for servicing and maintaining equipment, including space for equipment disassembly required for periodic maintenance.
 - b. Pump metal support details.
 - 3. Welder certificates signed by Contractor certifying that welders comply with requirements specified under the Quality Assurance Article.
 - 4. Floor x-rays and/or ground penetrating radar reports.
 - 5. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures" .
 - 6. Contractor shall submit fully dimensioned spool drawings for all welded piping

work. Drawings shall indicate all weld types, sizes, and materials to be used. The spool drawing size shall match the full size contract documents of either 24" x 36" or 34" x 44". Spool drawings shall be submitted in accordance with requirements as specified in Section 013300 "Submittal Procedures". . Adobe Acrobat files shall not contain security. Other file formats will not be accepted.

7. Field Test Reports: Written reports of each pressure tests specified in Division 23 Sections. Include the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Failed test results and corrective action taken to achieve requirements.

1.6 QUALITY CONTROL

- A. Equipment Selection: Equipment of greater or larger power, dimensions, capacities, and ratings may be furnished provided such proposed equipment is approved in writing by the DEN Project Manager and connecting mechanical and electrical services, circuit breakers, conduit, motors, bases, and equipment spaces are increased. No additional costs will be approved for these increases, if larger equipment is approved. If minimum energy ratings or efficiencies of the equipment are specified, the equipment must meet the design requirements and commissioning requirements.
- B. Electronic Equipment Compliance:
 1. Contractor warrants that all equipment, devices, items, systems, software, hardware, or firmware provided shall properly, appropriately, and consistently function and accurately process date and time data (including without limitation: calculating, comparing, and sequencing). This warranty supersedes anything in the Specifications or other Contract Documents that might be construed inconsistently. This warranty is applicable whether the equipment, device, item, system, software, hardware, or firmware is specified with or without reference to a manufacturer's name, make, or model number.
- C. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Deliver pipes and tubes with factory-applied end-caps. Maintain end-caps through shipping, storage, and handling to prevent pipe-end damage and prevent entrance of dirt, debris, and moisture.
- B. Protect stored ductwork, pipes, and tubes from moisture and dirt. Elevate above grade. When stored inside, do not exceed structural capacity of the floor.
- C. Store plastic pipes protected from direct sunlight. Support to prevent sagging and bending.

- D. Protect flanges, fittings, and piping specialties from moisture and dirt.
- E. Deliver ductwork and fittings with plastic sheeting to protect it from elements. Inspect duct liner for exposure to dirt and tears.

1.8 SEQUENCING AND SCHEDULING

- A. Coordinate mechanical equipment installation with other building components.
- B. Coordinate the installation of required supporting devices.
- C. Sequence, coordinate, and integrate installations of mechanical materials and equipment for efficient flow of the Work.
- D. Coordinate connection of electrical services.
- E. Coordinate installation of identifying devices after completing covering and painting where devices are applied to surfaces.

PART 2 - PRODUCTS

2.1 PIPE AND PIPE FITTINGS

- A. Refer to individual piping system specification Sections for pipe and fitting materials and joining methods.
- B. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

2.2 JOINING MATERIALS

- A. Refer to individual piping system specification Sections in Division 23 for special joining materials not listed below.
- B. Grooved Mechanical Couplings: Acceptable only for fire protection piping; not acceptable for any other applications.
- C. Pipe Flange Gasket Materials: Suitable for the chemical and thermal conditions of the piping system contents.
 - 1. ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness, except where thickness or specific material is indicated.
 - a. Full-Face Type: For flat-face, Class 125 cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250 cast-iron and steel flanges.
- D. Solder Filler Metal: ASTM B 32.

1. Alloy Sn95 or Alloy Sn94: Tin (approximately 95 percent) and silver (approximately 5 percent) – Not industry standard, usually 5% antimony.

E. Brazing Filler Metals: AWS A5.8.

1. BCuP Series: Copper-phosphorus alloys.
2. BAg1: Silver alloy.

F. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded. All welding rod is to be kept in a operable rod oven at all times.

2.3 PIPING SPECIALTIES

A. Dielectric Fittings: Assembly or fitting having insulating material isolating joined dissimilar metals to prevent galvanic action and stop corrosion.

1. Description: Combination of copper alloy and ferrous; threaded, solder, plain, and weld neck end types and matching piping system materials.
2. Insulating Material: Suitable for system fluid, pressure, and temperature.
3. Dielectric Waterway Fittings: Dielectric fittings designed to effectively separate dissimilar metals exposed to water or other electrolytes, conforming to NSF and ASTM F492 standards for continuous use at temperatures up to 225 degrees F and pressures up to 300 psi. Fittings to have electro-zinc-plated steel casings providing for maintained exterior electrical continuity threaded or flanged ends as applicable, and inert linings.
4. Dielectric Flanges: Factory-fabricated, companion-flange assembly for 150- or 300-psig minimum pressure to suit system pressures.
5. Dielectric-Flange Insulation Kits: Field-assembled, companion-flange assembly, full-face or ring type. Components include neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
 - a. Provide separate companion flanges and steel bolts and nuts for 150- or 300-psig minimum working pressure to suit system pressures.

2.4 MECHANICAL SLEEVE SEALS

A. Reference Section 230517 "Sleeves and Sleeve Seals for HVAC Piping" for sleeve seals.

2.5 SLEEVES

A. Reference Section 230517 "Sleeves and Sleeve Seals for HVAC Piping" for sleeves.

2.6 ESCUTCHEONS

A. Reference Section 230518 "Escutcheons for HVAC Piping" for escutcheons.

2.7 GROUT

- A. Nonshrink, Nonmetallic Grout: ASTM C 1107, Grade B.
 - 1. Characteristics: Post-hardening, volume-adjusting, dry, hydraulic-cement grout, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
 - 2. Design Mix: 5000-psi, 28-day compressive strength.
 - 3. Packaging: Premixed and factory-packaged.

2.8 BACKFILL

- A. Flowable Backfill: Designed in accordance with ASTM C 94 and ASTM D 4832.
 - 1. Refer to Section 312323.33 "Flowable Backfill (Controlled Low-Strength Concrete)" for material and installation requirements.
 - 2. Minimum Requirements:
 - a. Compressive Strength: 50-100 psi
 - b. Slump: 6-8 inches.
 - 3. Required for all piping and ductwork installed below concrete slabs, apron paving and roadways.

PART 3 - EXECUTION

3.1 PIPING SYSTEMS - COMMON REQUIREMENTS

- A. General: Install piping as described below, except where system Sections specify otherwise. Individual piping system specification Sections in Division 23 specify piping installation requirements unique to the piping system.
- B. General Locations and Arrangements: Drawings indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated, except where deviations to layout are approved on coordination drawings.
- C. Install piping at indicated slope.
- D. Install piping free of sags and bends.
- E. Install piping plumb and at right angles and plumb or parallel to building walls. Diagonal runs are prohibited, except where indicated.
- F. Install piping tight to slabs, beams, joists, columns, walls, and other building elements.
- G. Install fittings for changes in direction and branch connections.

- H. Install couplings according to manufacturer's printed instructions.
- I. Piping Joint Construction: Join pipe and fittings as follows and as specifically required in individual piping system Sections.
1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
 2. Remove scale, slag, dirt, rust, and debris from inside and outside of pipe and fittings before assembly.
 3. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full inside diameter. Join pipe fittings and valves as follows:
 - a. Note the internal length of threads in fittings or valve ends, and proximity of internal seat or wall, to determine how far pipe should be threaded into joint.
 - b. Apply appropriate tape or thread compound to external pipe threads (except where dry seal threading is specified).
 - c. Align threads at point of assembly.
 - d. Tighten joint with wrench. Apply wrench to valve end into which pipe is being threaded.
 - e. Damaged Threads: Do not use pipe or pipe fittings having threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- J. Piping Connections: Except as otherwise indicated, make piping connections as specified below.
1. Install unions in piping 2 inches and smaller adjacent to each valve and at final connection to each piece of equipment having a 2-inch or smaller threaded pipe connection.
 2. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.
- K. Piping below apron, concrete slabs or paving shall be encased in flowable backfill. Refer to Section 312323.33 "Flowable Backfill (Controlled Low-Strength Concrete)" for material and installation requirements.

3.2 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

- A. Install equipment to provide the maximum possible headroom where mounting heights are not indicated.
- B. Install equipment according to approved submittal data. Portions of the Work are shown only in diagrammatic form. Refer conflicts to the DEN Project Manager.
- C. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, except where otherwise indicated.

- D. Install mechanical equipment to facilitate servicing, maintenance, and repair or replacement of equipment components. Connect equipment for ease of disconnecting, with minimum of interference with other installations. Extend grease fittings to an accessible location.
- E. Install equipment, giving right-of-way to piping systems installed at a required slope.

3.3 PAINTING AND FINISHING

- A. Refer to Division 09 Sections for Painting for field painting requirements. Paint color schedule shall conform to ASME A13.1-1996, "Scheme for the Identification of Piping Systems."
- B. Damage and Touch Up: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.
- C. All rooftop equipment exposed to public or aircraft view shall be painted flat white or grey in accordance with Division 09.

3.4 CONCRETE PENETRATIONS

- A. Reference Section 017329 "Cutting and Patching" for core drilling and saw cutting requirements.
- B. Reference Section 017329 "Selective Demolition" for demolition and removal of selected portions of a building or structure, and repair procedures for selective demolition operations.
- C. All penetrations required through completed concrete construction shall be core drilled or saw cut at minimum size required. All penetrations in concrete require an x-ray or ground penetrating radar to determine if the location is clear of reinforcing steel and embedded systems. Precautions shall be taken when drilling to prevent damage to structural concrete.
 - 1. The Contractor shall provide an interpretation of the x-rays or radar shot and obtain written acceptance from the DEN Project Manager before proceeding with drilling.

3.5 CONCRETE BASES

- A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to current seismic codes at Project location.
 - 1. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.
 - 2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full

- perimeter of the base.
3. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
 4. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 5. Install anchor bolts to elevations required for proper attachment to supported equipment.
 6. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
 7. Use [**3000-psi**] <Insert other>, 28-day compressive-strength concrete and reinforcement as specified in Division 03.

3.6 WELDING

- A. Qualify welding processes and operators for structural steel according to AWS D1.1 Structural Welding Code - Steel. See Division 5 sections for additional requirements.
- B. All welding shall be inspected in process by a contractor provided, Certified, Independent Testing Agency by an AWS certified welding inspector.
- C. Qualify welding processes and operators for piping according to ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications.
 1. Comply with provisions of ASME B31 Series "Code for Pressure Piping."
 2. Certify that each welder has passed AWS qualification tests for the welding processes involved and that certification is current.

3.7 ERECTION OF METAL SUPPORTS AND ANCHORAGE

- A. Refer to Division 05 for structural steel.
- B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.
- C. Field Welding: Comply with AWS D1.1 Structural Welding Code - Steel, as referenced in Part 1.

3.8 ERECTION OF WOOD SUPPORTS AND ANCHORAGES

- A. Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor mechanical materials and equipment.
- B. Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.
- C. Attach to substrates as required to support applied loads.

3.9 DEMOLITION

- A. Refer to Division 01 and Division 02 Sections for general demolition requirements and procedures.
- B. Where pipe, ductwork, insulation, or equipment to remain is damaged or disturbed, remove damaged portions and install new products of equal capacity and quality.
- C. Temporary Disconnection: Remove, store, clean, reinstall, reconnect, and make operational equipment indicated for relocation.
- D. Disconnect, demolish, and remove mechanical systems, equipment, and components indicated to be removed.
 - 1. Piping to Be Removed: Remove portion of piping and associated supports indicated to be removed, provide a shutoff valve with plug or cap in pressurized systems and cap or plug remaining piping with same or compatible piping material. No piping shall be abandoned in place. Repair insulation.
 - 2. Ducts to Be Removed: Remove portion of ducts and associated supports indicated to be removed and plug remaining ducts with same or compatible ductwork material. No ductwork shall be abandoned in place. Repair insulation.
 - 3. Piping to Be Abandoned in Place: Drain piping and cap or plug piping with same or compatible piping material.
 - 4. Ducts to Be Abandoned in Place: Cap or plug ducts with same or compatible ductwork material.
 - 5. Equipment to Be Removed: Disconnect and cap services and remove equipment.
 - 6. Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, and store equipment; when appropriate, reinstall, reconnect, and make equipment operational.
 - 7. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and deliver to Owner.
 - 8. If pipe, insulation, or equipment to remain is damaged in appearance or is unserviceable, remove damaged or unserviceable portions and replace with new products of equal capacity and quality.
 - 9. Repair structure [**floor, ceilings, roof, slabs**] from removed supports in accordance with [**Division 03**], [**Division 05**], [**and Division 09**]

3.10 GROUTING

- A. Mix and install grout for mechanical equipment base bearing surfaces, pump and other equipment base plates, and anchors.
- B. Clean surfaces that will come into contact with grout.
- C. Provide forms as required for placement of grout.
- D. Avoid air entrapment during placement of grout.

- E. Place grout, completely filling equipment bases.
- F. Place grout on concrete bases and provide smooth bearing surface for equipment.
- G. Place grout around anchors.
- H. Cure placed grout.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the applicable unit price item, work order or lump sum bid item.

END OF SECTION 230500

SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 COORDINATION

- A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:
 - 1. Motor controllers.
 - 2. Torque, speed, and horsepower requirements of the load.
 - 3. Ratings and characteristics of supply circuit and required control sequence.
 - 4. Ambient and environmental conditions of installation location.

1.4 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

- A. Comply with NEMA MG 1 unless otherwise indicated.
- B. Comply with IEEE 841 for severe-duty motors.

2.2 MOTOR CHARACTERISTICS

- A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet (1000 m) above sea level.
- B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.3 POLYPHASE MOTORS

- A. Description: NEMA MG 1, Design B, medium induction motor.
- B. Efficiency: Energy efficient, as defined in NEMA MG 1.
- C. Service Factor: 1.15.
- D. Multispeed Motors: Variable torque.
 - 1. For motors with 2:1 speed ratio, consequent pole, single winding.
 - 2. For motors with other than 2:1 speed ratio, separate winding for each speed.
- E. Multispeed Motors: Separate winding for each speed.
- F. Rotor: Random-wound, squirrel cage.
- G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.
- H. Temperature Rise: Match insulation rating.
- I. Insulation: **[Class F]** <Insert class>.
- J. Code Letter Designation:
 - 1. Motors **[15]** <Insert number> HP and Larger: NEMA starting Code F or Code G.
 - 2. Motors Smaller than **[15]** <Insert number> HP: Manufacturer's standard starting characteristic.
- K. Enclosure Material: Cast iron for motor frame sizes **[324T]** <Insert number> and larger; rolled steel for motor frame sizes smaller than **[324T]** <Insert number>.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

- A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

- B. **Motors Used with Variable Frequency Controllers: [Ratings, characteristics, and features coordinated with and approved by controller manufacturer.]**
1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
 2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
 3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
 4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
- C. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.5 SINGLE-PHASE MOTORS

- A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:
1. Permanent-split capacitor.
 2. Split phase.
 3. Capacitor start, inductor run.
 4. Capacitor start, capacitor run.
- B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.
- C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.
- D. Motors 1/20 HP and Smaller: Shaded-pole type.
- E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION (Not Applicable)

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230513

SECTION 230516 - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Flexible, ball-joint packed expansion joints.
 - 2. Slip-joint, packed expansion joints.
 - 3. Metal, compensator packless expansion joints.
 - 4. Rubber union connector packless expansion joints.
 - 5. Flexible-hose packless expansion joints.
 - 6. Metal-bellows packless expansion joints.
 - 7. Externally pressurized metal-bellows packless expansion joints.
 - 8. Rubber packless expansion joints.
 - 9. Alignment guides and anchors.
 - 10. Pipe loops and swing connections.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. BR: Butyl rubber.
- B. Buna-N: Nitrile rubber.
- C. CR: Chlorosulfonated polyethylene synthetic rubber.
- D. CSM: Chlorosulfonyl-polyethylene rubber.
- E. EPDM: Ethylene-propylene-diene terpolymer rubber.
- F. NR: Natural rubber.
- G. PTFE: Polytetrafluoroethylene plastic.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Flexible Pipe Connectors: Indicate maximum temperature and pressure rating, face-to-face length, live length, hose wall thickness, hose convolutions per foot and per assembly, fundamental frequency of assembly, braid structure, and total number of wires in braid.
2. Expansion Joints: Indicate maximum temperature and pressure rating, and the estimated number of full flexures before joint failure. Provided multi-wall convoluted bellows where possible to reduce joint end force reactions on building structure.
3. Design Data: Indicate selection calculations.
4. For each type of pipe expansion joint and alignment guide indicated.
5. Product Certificates: For each type of pipe expansion joint, signed by product manufacturer.
6. Include data substantiating that materials comply with requirements.

B. Shop Drawings:

1. Expansion Joints: Submit for each assembly shop drawings, along with detailed calculations and procedures applied in making selections as appropriate to lifetime cycles ratings specified. Identify materials of construction and indicate maximum temperature and pressure ratings.

C. Shop Drawings by Delegated-Design Submittal: For each anchor and alignment guide, including analysis data, signed and sealed by the qualified professional engineer responsible for their preparation.

1. Design Calculations: Calculate requirements for thermal expansion of piping systems and for selecting and designing expansion joints, loops, and swing connections.
2. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
3. Alignment Guide Details: Detail field assembly and attachment to building structure.
4. Schedule: Indicate type, manufacturer's number, size, material, pressure rating, end connections, and location for each expansion joint.
5. Design Data: Indicate selection calculations. Calculations shall be based on the following
 - a. Installation Temperature: 50 degrees F.
 - b. Hot Water Heating: 230 degrees F (0% glycol).
 - c. Domestic Hot Water: 140 degrees F.
 - d. PCA glycol: 20 degrees F (min) 230 degrees F(Max) (30 percent Glycol)
 - e. Safety Factor: 30 percent.

1.5 INFORMATIONAL SUBMITTALS

- A. Welding certificates.

1.6 CLOSEOUT SUBMITTALS

- A. Provide final inspection reports prepared by product manufacturers.
- B. Operation and Maintenance Data.
- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the products specified in this Section with minimum of three (3) years experience.
- B. Contractor shall design expansion compensating system under direct supervision of a Professional Engineer experienced in design of this Work and licensed in the State of Colorado.
- C. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- D. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Division 01.
- B. Accept expansion joints on site in factory packing with shipping bars and positioning devices intact. Inspect for damage.
- C. Protect equipment from exposure by leaving factory coverings, pipe end protection, and packaging in place until installation.

1.9 EXTRA MATERIALS

- A. Provide one (1) 12-ounce container of packing lubricant and cartridge style grease gun.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Expansion compensation for us with Steel Piping:
1. Inner Hose: Stainless Steel.
 2. Exterior Sleeve: Double braided stainless steel.
 3. Pressure Rating: 125 psig WSP and 450 degrees F, 200 psig WOG and 250 degrees F at 70 degrees F.
 4. Joint: As specified for pipe joints.
 5. Size: Use pipe sized units.
 6. Maximum offset: 3/4 inch on each side of installed centerline.
- B. Expansion compensation for us with Copper Piping:
1. Inner Hose: Bronze.
 2. Exterior Sleeve: Braided bronze.
 3. Pressure Rating: 125 psig WSP and 450 degrees F.
 4. Joint: As specified for pipe joints.
 5. Size: Use pipe sized units.
 6. Maximum offset: 3/4 inch on each side of installed centerline.

2.2 PERFORMANCE REQUIREMENTS

- A. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.
- B. Capability: Products to absorb 200 percent of maximum axial movement between anchors.
- C. Provide structural work and equipment required to control expansion and contraction of piping. Verify that anchors, guides, and expansion joints provided, adequately protect system.

2.3 PACKED EXPANSION JOINTS

- A. Flexible, Ball-Joint Packed Expansion Joints **[FBJ-01] <Insert drawing designation>**:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Advanced Thermal Systems, Inc.](#)
 - b. [Hyspan Precision Products, Inc.](#)
 - c. [Mason Industries, Inc.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Standards: ASME Boiler and Pressure Vessel Code: Section II, "Materials"; ASME B31.9, "Building Services Piping," for materials and design of pressure-containing parts and bolting.
 3. Material: Carbon-steel assembly with asbestos-free composition packing.
 4. Design: Provide 360-degree rotation and angular deflection.
 5. Minimum Pressure Rating: [250 psig at 400 deg F (1725 kPa at 204 deg C)] **<Insert value>**.
 6. Angular Deflection for NPS 6 (DN 150) and Smaller: 30 degree minimum.
 7. Angular Deflection for NPS 8 (DN 200) and Larger: 15 degree minimum.
 8. Seal Type: Two carbon steel and graphite seals suitable for continuous operation at temperature up to 650 deg F (343 deg C).
 9. Internal Ball: Plated with minimum 1-mil chrome cover.
 10. Ball Socket: One- or two-piece design with integral socket/retainer.
 - a. Stuffing Box: Incorporates containment seals and compression seals for containment of injectable packing.
 - b. Packing Cylinders: Provides packing under full line pressure with check valves to prevent blowback.
 11. End Connections for NPS 2 (DN 50) and Smaller: Threaded.
 12. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.
- B. Slip-Joint Packed Expansion Joints [**SJ-01**] **<Insert drawing designation>**:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Adscos Manufacturing LLC.](#)
 - b. [Advanced Thermal Systems, Inc.](#)
 - c. [Hyspan Precision Products, Inc.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Standard: ASTM F 1007.
 3. Material: Carbon steel with asbestos-free PTFE packing.
 4. Design: With internal guide and injection ports for repacking under full system pressure. Housing shall be furnished with drain ports and lifting ring. Include drip connection if used for steam piping.
 5. Configuration: [**Single joint**] [**Single joint with base**] [**and**] [**double joint with base**] class(es), unless otherwise indicated.
 6. Slip Tube for sizes NPS 1-1/2 (DN 40) through NPS 16 (DN 400): Schedule 80.
 7. Slip Tube for sizes NPS 18 (DN 450) through NPS 24 (DN 600): Schedule 60.
 8. Sliding Surface: 2 mil thick chrome finish.
 9. End Connections: Flanged or welded ends to match piping system.

2.4 PACKLESS EXPANSION JOINTS

A. Metal, Compensator Packless Expansion Joints [MCEJ-01] <Insert drawing designation>:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Flexicraft Industries.](#)
 - b. [Flex-Weld, Inc.](#)
 - c. [Hyspan Precision Products, Inc.](#)
 - d. [Mason Industries, Inc.](#)
 - e. [Metraflex, Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
2. Minimum Pressure Rating: [150 psig (1035 kPa)] [175 psig (1200 kPa)] [200 psig (1380 kPa)] <Insert value>, unless otherwise indicated.
3. Description: Totally enclosed, externally pressurized, multi-ply bellows isolated from fluid flow by an internal pipe sleeve and external housing.
4. Joint Axial Movement: 2 inches (50 mm) of compression and 1/2 inch (12 mm) of extension.
5. Configuration for Copper Tubing: Multi-ply, phosphor-bronze bellows with copper pipe ends.
 - a. End Connections for Copper Tubing NPS 2 (DN 50) and Smaller: [**Solder joint**] [**or**] [**threaded**].
 - b. End Connections for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Threaded.
6. Configuration for Steel Piping: Multi-ply, stainless-steel bellows; steel-pipe end connections; and carbon-steel shroud.
 - a. End Connections for Steel Pipe NPS 2 (DN 50) and Smaller: Threaded.
 - b. End Connections for Steel Pipe NPS 2-1/2 to NPS 4 (DN 65 to DN 100): [**Flanged**] [**Threaded**] [**Welded**].

B. Rubber Union Connector Expansion Joints [RUEJ-01] <Insert drawing designation>. To be used only on chilled water systems:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Amber/Booth Company, Inc.; a VMC Group Company.](#)
 - b. [Flex-Hose Co., Inc.](#)
 - c. [Flexicraft Industries.](#)
 - d. [General Rubber Corporation.](#)
 - e. [Mason Industries, Inc.](#)
 - f. [Proco Products, Inc.](#)
 - g. [Unaflex.](#)

- h. [Unisource Manufacturing, Inc.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
 2. Material: Twin reinforced-rubber spheres[**with external restraining cables**].
 3. Minimum Pressure Rating: [150 psig at 170 deg F (1035 kPa at 77 deg C)] **<Insert value>**, unless otherwise indicated.
 4. End Connections for NPS 2 (DN 50) and Smaller: Threaded.
- C. Flexible-Hose Packless Expansion Joints [**FHEJ-01**] **<Insert drawing designation>**:
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Flex-Hose Co., Inc.](#)
 - b. [Flexicraft Industries.](#)
 - c. [Metraflex, Inc.](#)
 - d. [Mason Industries, Inc.](#)
 - e. [Unisource Manufacturing, Inc.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 2. Description: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose.
 3. Flexible Hose: Corrugated-metal inner hoses and braided outer sheaths.
 4. Expansion Joints for Copper Tubing NPS 2 (DN 50) and Smaller: Copper-alloy fittings with [**solder-joint**] **<Insert type>** end connections.
 - a. Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F (3100 kPa at 21 deg C) and 340 psig at 450 deg F (2340 kPa at 232 deg C) ratings.
 - b. Bronze hoses and double-braid bronze sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 500 psig at 450 deg F (3450 kPa at 232 deg C) ratings.
 5. Expansion Joints for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Copper-alloy fittings with [**threaded**] **<Insert type>** end connections.
 - a. Stainless-steel hoses and single-braid, stainless-steel sheaths with 300 psig at 70 deg F (2070 kPa at 21 deg C) and 225 psig at 450 deg F (1550 kPa at 232 deg C) ratings.
 - b. Stainless-steel hoses and double-braid, stainless-steel sheaths with 420 psig at 70 deg F (2890 kPa at 21 deg C) and 315 psig at 450 deg F (2170 kPa at 232 deg C) ratings.
 6. Expansion Joints for Steel Piping NPS 2 (DN 50) and Smaller: Carbon-steel fittings with threaded end connections.

- a. Stainless-steel hoses and single-braid, stainless-steel sheaths with **450 psig at 70 deg F** (3100 kPa at 21 deg C) and **325 psig at 600 deg F** (2250 kPa at 315 deg C) ratings.
 - b. Stainless-steel hoses and double-braid, stainless-steel sheaths with **700 psig at 70 deg F** (4830 kPa at 21 deg C) and **515 psig at 600 deg F** (3550 kPa at 315 deg C) ratings.
7. Expansion Joints for Steel Piping **NPS 2-1/2 to NPS 6** (DN 65 to DN 150): Carbon-steel fittings with **[flanged] [welded]** end connections.
- a. Stainless-steel hoses and single-braid, stainless-steel sheaths with **200 psig at 70 deg F** (1380 kPa at 21 deg C) and **145 psig at 600 deg F** (1000 kPa at 315 deg C) ratings.
 - b. Stainless-steel hoses and double-braid, stainless-steel sheaths with **275 psig at 70 deg F** (1900 kPa at 21 deg C) and **200 psig at 600 deg F** (1380 kPa at 315 deg C) ratings.
8. Expansion Joints for Steel Piping **NPS 8 to NPS 12** (DN 200 to DN 300): Carbon-steel fittings with **[flanged] [welded]** end connections.
- a. Stainless-steel hoses and single-braid, stainless-steel sheaths with **125 psig at 70 deg F** (860 kPa at 21 deg C) and **90 psig at 600 deg F** (625 kPa at 315 deg C) ratings.
 - b. Stainless-steel hoses and double-braid, stainless-steel sheaths with **165 psig at 70 deg F** (1130 kPa at 21 deg C) and **120 psig at 600 deg F** (830 kPa at 315 deg C) ratings.
9. Expansion Joints for Steel Piping **NPS 14** (DN 350) and Larger: Carbon-steel fittings with **[flanged] [welded]** end connections.
- a. Stainless-steel hoses and double-braid, stainless-steel sheaths with **165 psig at 70 deg F** (1130 kPa at 21 deg C) and **120 psig at 600 deg F** (830 kPa at 315 deg C) ratings.
- D. Metal-Bellows Packless Expansion Joints **[MBEJ-01] <Insert drawing designation>**:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Adesco Manufacturing LLC.](#)
 - b. [American BOA, Inc.](#)
 - c. [Badger Industries, Inc.](#)
 - d. [Expansion Joint Systems, Inc.](#)
 - e. [Flex-Hose Co., Inc.](#)
 - f. [Flexicraft Industries.](#)
 - g. [Flex-Weld, Inc.](#)
 - h. [Hyspan Precision Products, Inc.](#)
 - i. [Mason Industries, Inc.](#)
 - j. [Metraflex, Inc.](#)
 - k. [Tozen Corporation.](#)

- I. [Unaflex](#).
 - m. [Unisource Manufacturing, Inc.](#)
 - n. [Universal Metal Hose; a subsidiary of Hyspan Precision Products, Inc.](#)
 - o. [U.S. Bellows, Inc.](#)
 - p. [WahlcoMetroflex](#).
 - q. <Insert manufacturer's name>.
 - r. or approved equal.
 2. Standards: ASTM F 1120 and EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
 3. Type: Circular, corrugated bellows[**with external tie rods**].
 4. Minimum Pressure Rating: [150 psig (1035 kPa)] [175 psig (1200 kPa)] [200 psig (1379 kPa)] <Insert value>, unless otherwise indicated.
 5. Configuration: [Single joint] [Single joint with base] [and] [double joint with base] class(es), unless otherwise indicated.
 6. Expansion Joints for Copper Tubing: [Single-] [or] [multi-] ply phosphor-bronze bellows, copper pipe ends, and brass shrouds.
 - a. End Connections for Copper Tubing NPS 2 (DN 50) and Smaller: [**Solder joint**] [or] [**threaded**].
 - b. End Connections for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): [**Solder joint**] [or] [**threaded**].
 - c. End Connections for Copper Tubing NPS 5 (DN 125) and Larger: Flanged.
 7. Expansion Joints for Steel Piping: [Single-] [or] [multi-] ply stainless-steel bellows, steel pipe ends, and carbon-steel shroud.
 - a. End Connections for Steel Pipe NPS 2 (DN 50) and Smaller: Threaded.
 - b. End Connections for Steel Pipe NPS 2-1/2 (DN 65) and Larger: [**Flanged**] [**Welded**].
- E. Externally Pressurized Metal-Bellows Packless Expansion Joints [**EPEJ-01**] <Insert drawing designation>:
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Adesco Manufacturing LLC](#).
 - b. [Hyspan Precision Products, Inc.](#)
 - c. [Mason Industries, Inc.](#)
 - d. [Metraflex, Inc.](#)
 - e. [U.S. Bellows, Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
 2. Minimum Pressure Rating: [150 psig (1035 kPa)] [200 psig (1379 kPa)] [300 psig (2068 kPa)] <Insert value>, unless otherwise indicated.
 3. Description:

- a. Totally enclosed, externally pressurized, multi-ply, stainless-steel bellows isolated from fluid flow by an internal pipe sleeve.
 - b. Carbon-steel housing.
 - c. Drain plugs and lifting lug for the **NPS 3 (DN 80)** and larger.
 - d. Bellows shall have operating clearance between the internal pipe sleeves and the external shrouds.
 - e. Joints shall be supplied with a built-in scale to confirm the starting position and operating movement.
 - f. Joint Axial Movement: [4 inches (100 mm)] [6 inches (150 mm)] [8 inches (200 mm)] **<Insert compression limit>** of compression and [0.75 inch (19 mm)] [1 inch (25 mm)] [2 inches (50 mm)] **<Insert extension limit>** of extension.
4. Permanent Locking Bolts: Set locking bolts to maintain joint lengths during installation. Temporary welding tabs that are removed after installation in lieu of locking bolts are not acceptable.
 5. End Connection Configuration: Flanged; one raised, fixed and one floating flange.
- F. Rubber Packless Expansion Joints [**REJ-01**] **<Insert drawing designation>**:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Amber/Booth Company, Inc.: a VMC Group Company.](#)
 - b. [Flex-Hose Co., Inc.](#)
 - c. [Flexicraft Industries.](#)
 - d. [Flex-Weld, Inc.](#)
 - e. [Garlock Sealing Technologies.](#)
 - f. [General Rubber Corporation.](#)
 - g. [Mason Industries, Inc.](#)
 - h. [Metraflex, Inc.](#)
 - i. [Proco Products, Inc.](#)
 - j. [Red Valve Company, Inc.](#)
 - k. [Tozen Corporation.](#)
 - l. [Unaflex.](#)
 - m. [Unisource Manufacturing, Inc.](#)
 - n. **<Insert manufacturer's name>**.
 - o. or approved equal.
 2. Standards: ASTM F 1123 and FSA's "Technical Handbook: Non-Metallic Expansion Joints and Flexible Pipe Connectors."
 3. Material: Fabric-reinforced rubber complying with FSA-PSJ-703.
 4. Arch Type: [**Single**] [**or**] [**multiple**] arches[**with external control rods**].
 5. Spherical Type: [**Single**] [**or**] [**multiple**] spheres[**with external control rods**].
 6. Minimum Pressure Rating for **NPS 1-1/2 to NPS 4 (DN 40 to DN 100)**: [150 psig (1035 kPa) **at 220 deg F (104 deg C)**] **<Insert value>**.
 7. Minimum Pressure Rating for **NPS 5 and NPS 6 (DN 125 and DN 150)**: [140 psig (966 kPa) **at 200 deg F (93 deg C)**] **<Insert value>**.

8. Minimum Pressure Rating for **NPS 8 to NPS 12** (DN 200 to DN 300): [140 psig (966 kPa) at 180 deg F (82 deg C)] <Insert value>.
9. Material for Fluids Containing Acids, Alkalis, or Chemicals: [Butyl rubber] [Chlorosulfonyl-polyethylene rubber] [Ethylene-propylene-diene terpolymer rubber] <Insert material>.
10. Material for Fluids Containing Gas, Hydrocarbons, or Oil: [Buna-N] [Chlorosulfonated polyethylene synthetic rubber] <Insert material>.
11. Material for Water: [Butyl rubber] [Buna-N] [Chlorosulfonated polyethylene synthetic rubber] [Chlorosulfonyl-polyethylene rubber] [Ethylene-propylene-diene terpolymer rubber] [Natural rubber].
12. End Connections: Full-faced, integral steel flanges with steel retaining rings.

2.5 ALIGNMENT GUIDES AND ANCHORS

A. Alignment Guides [AG-01] <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Adscos Manufacturing LLC.](#)
 - b. [Advanced Thermal Systems, Inc.](#)
 - c. [Flex-Hose Co., Inc.](#)
 - d. [Flexicraft Industries.](#)
 - e. [Flex-Weld, Inc.](#)
 - f. [Hyspan Precision Products, Inc.](#)
 - g. [Mason Industries, Inc.](#)
 - h. [Metraflex, Inc.](#)
 - i. [Senior Flexonics Pathway.](#)
 - j. [Unisource Manufacturing, Inc.](#)
 - k. [U.S. Bellows, Inc.](#)
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
2. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding slider for bolting to pipe.

B. Anchor Materials:

1. Steel Shapes and Plates: ASTM A 36/A 36M.
2. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel hex head.
3. Washers: ASTM F 844, steel, plain, flat washers.
4. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, with tension and shear capacities appropriate for application.
 - a. Stud: Threaded, zinc-coated carbon steel.
 - b. Expansion Plug: Zinc-coated steel.
 - c. Washer and Nut: Zinc-coated steel.

5. Chemical Fasteners: Insert-type stud, bonding-system anchor for use with hardened Portland cement concrete, with tension and shear capacities appropriate for application.
 - a. Bonding Material: ASTM C 881/C 881M, Type IV, Grade 3, two-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed.
 - b. Stud: ASTM A 307, zinc-coated carbon steel with continuous thread on stud, unless otherwise indicated.
 - c. Washer and Nut: Zinc-coated steel.
6. Concrete: Portland cement mix, **[3000 psi]** minimum. Refer to Division 3 for formwork, reinforcement, and concrete.
7. Grout: ASTM C1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink, nonmetallic grout; suitable for interior and exterior applications.
 - a. Properties: Nonstaining, noncorrosive, and nongaseous.
 - b. Design Mix: **[5000-psi]**, 28-day compressive strength.
8. Swivel Joints: **[Fabricated steel] [Bronze] [Ductile Iron] [Cast steel] [Insert type]** body, double ball bearing race, field lubricated, with **[rubber (Buna-N)] [Insert type]** o-ring seals.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine piping layout and notify DEN Project Manager of additional anchors or expansion joints required to adequately protect system.
- B. Provide inspection services by flexible pipe manufacturer's representative for final installing and certify installation is in accordance with manufacturer's recommendations and connectors are performing satisfactorily.

3.2 INSTALLATION - GENERAL

- A. Install flexible pipe connectors on pipes connected to equipment supported by vibration isolation. Axial and lateral offsets shall not exceed manufacturers' recommendations.
- B. Accomplish structural work and provide equipment required to control expansion and contraction of piping, loops, pipe offsets, and swing joints, and provide corrugated bellows type expansion joints where required.
- C. Install flexible connectors at right angles to displacement. Install one end immediately adjacent to isolated equipment and anchor other end.

- D. Rigidly anchor pipe to building structure where necessary. Provide pipe guides so movement is directed along axis of pipe only. Erect piping such that strain and weight is not on cast connections or apparatus.
- E. Provide support and equipment required to control expansion and contraction of piping. Provide loops, pipe offsets, and swing joints, or expansion joints where **[required]** **[indicated]**.
- F. Provide expansion loops as indicated on drawings.

3.3 EXPANSION JOINT INSTALLATION

- A. Install expansion joints of sizes matching sizes of piping in which they are installed.
- B. Install packed-type expansion joints with packing suitable for fluid service.
- C. Install metal-bellows expansion joints according to EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
- D. Install rubber packless expansion joints according to FSA-PSJ-703.
- E. Install alignment guides to allow expansion and to avoid end-loading and torsional stress.

3.4 PIPE LOOP AND SWING CONNECTION INSTALLATION

- A. Install pipe loops cold-sprung in tension or compression as required to partly absorb tension or compression produced during anticipated change in temperature.
- B. Connect risers and branch connections to mains with at least **[five (5)] <Insert number>** pipe fittings, including tee in main.
- C. Connect risers and branch connections to terminal units with at least **[four (4)] <Insert number>** pipe fittings, including tee in riser.
- D. Connect mains and branch connections to terminal units with at least **[four (4)] <Insert number>** pipe fittings, including tee in main.
- E. Attach pipe bends and loops to anchors.
 - 1. Steel Anchors: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
 - 2. Concrete Anchors: Attach by fasteners. Follow fastener manufacturer's written instructions.

3.5 ALIGNMENT-GUIDE AND ANCHOR INSTALLATION

- A. Install alignment guides to guide expansion and to avoid end-loading and torsional stress.
- B. Install [**one (1)**] [**two (2)**] guide(s) on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than [**four (4)**] **<Insert number>** pipe diameters from expansion joint.
- C. Attach guides to pipe, and secure guides to building structure.
- D. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.
- E. Anchor Attachments:
 - 1. Anchor Attachment to Steel Pipe: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
 - 2. Anchor Attachment to Copper Tubing: Attach with pipe hangers. Use MSS SP-69, Type 24; U bolts bolted to anchor.
- F. Fabricate and install steel anchors by welding steel shapes, plates, and bars. Comply with ASME B31.9 and AWS D1.1/D1.1M.
 - 1. Anchor Attachment to Steel Structural Members: Attach by welding.
 - 2. Anchor Attachment to Concrete Structural Members: Attach by fasteners. Follow fastener manufacturer's written instructions.
- G. Construct concrete anchors of poured-in-place concrete of dimensions indicated and include embedded fasteners.
- H. Install pipe anchors according to expansion-joint manufacturer's written instructions if expansion joints or compensators are indicated.
- I. Use grout to form flat bearing surfaces for guides and anchors attached to concrete.

3.6 MANUFACTURER'S FIELD SERVICES

- A. Provide services under provisions of Division 01 requirements.
- B. Provide inspection services by flexible pipe manufacturer's representative to assist Contractor for final installing and certify installation is in accordance with manufacturer's recommendations and connectors are performing satisfactorily.
 - 1. Provide inspection report to DEN Project Manager.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230516

SECTION 230517 - SLEEVES AND SLEEVE SEALS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Sleeves.
 - 2. Stack-sleeve fittings.
 - 3. Sleeve-seal systems.
 - 4. Sleeve-seal fittings.
 - 5. Grout.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.

1.4 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SLEEVES

- A. Cast-Iron Wall Pipes: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

- B. Galvanized-Steel Wall Pipes: ASTM A 53/A 53M, Schedule 40, with plain ends and welded steel collar; zinc coated.
- C. Galvanized-Steel-Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.
- D. PVC-Pipe Sleeves: ASTM D 1785, Schedule 40.
- E. Galvanized-Steel-Sheet Sleeves: 0.0239-inch (0.6-mm) minimum thickness; round tube closed with welded longitudinal joint.
- F. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.
- G. Molded-PVC Sleeves: With nailing flange for attaching to wooden forms.

2.2 STACK-SLEEVE FITTINGS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. Smith, Jay R. Mfg. Co.
 - 2. Zurn Specification Drainage Operation; Zurn Plumbing Products Group.
 - 3. **<Insert manufacturer's name>**.
 - 4. or approved equal.
- B. Description: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing.
 - 1. Underdeck Clamp: Clamping ring with setscrews.

2.3 SLEEVE-SEAL SYSTEMS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. Advance Products & Systems, Inc.
 - 2. CALPICO, Inc.
 - 3. Metraflex Company (The).
 - 4. Pipeline Seal and Insulator, Inc.
 - 5. Proco Products, Inc.
 - 6. **<Insert manufacturer's name>**.
 - 7. or approved equal.
- B. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
 - 1. Sealing Elements: **[EPDM-rubber] [NBR]** interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

2. Pressure Plates: **[Carbon steel] [Plastic] [Stainless steel]**.
3. Connecting Bolts and Nuts: **[Carbon steel, with corrosion-resistant coating,] [Stainless steel]** of length required to secure pressure plates to sealing elements.

2.4 SLEEVE-SEAL FITTINGS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. Presealed Systems.
2. **<Insert manufacturer's name>**.
3. or approved equal.

B. Description: Manufactured plastic, sleeve-type, waterstop assembly made for imbedding in concrete slab or wall. Unit has plastic or rubber waterstop collar with center opening to match piping OD.

2.5 GROUT

- A. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- B. Characteristics: Nonshrink; recommended for interior and exterior applications.
- C. Design Mix: **5000-psi (34.5-MPa)**, 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION

- A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.
- B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide **[1-inch (25-mm)] <Insert dimension>** annular clear space between piping and concrete slabs and walls.
 1. Sleeves are not required for core-drilled holes.
- C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
 1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.

2. Cut sleeves to length for mounting flush with both surfaces.
 - a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas [2 inches (50 mm)] <Insert dimension> above finished floor level.
 3. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.
- D. Install sleeves for pipes passing through interior partitions.
1. Cut sleeves to length for mounting flush with both surfaces.
 2. Install sleeves that are large enough to provide 1/4-inch (6.4-mm) annular clear space between sleeve and pipe or pipe insulation.
 3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with requirements for sealants specified in Section 079200 "Joint Sealants."
- E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Section 078413 "Penetration Firestopping."

3.2 STACK-SLEEVE-FITTING INSTALLATION

- A. Install stack-sleeve fittings in new slabs as slabs are constructed.
1. Install fittings that are large enough to provide 1/4-inch (6.4-mm) annular clear space between sleeve and pipe or pipe insulation.
 2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with requirements for flashing specified in Section 076200 "Sheet Metal Flashing and Trim."
 3. Install section of cast-iron soil pipe to extend sleeve to 2 inches (50 mm) above finished floor level.
 4. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
 5. Using grout, seal the space around outside of stack-sleeve fittings.
- B. Fire-Barrier Penetrations: Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Section 078413 "Penetration Firestopping."

3.3 SLEEVE-SEAL-SYSTEM INSTALLATION

- A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at service piping entries into building.
- B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal system components, and install in annular space

between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.

3.4 SLEEVE-SEAL-FITTING INSTALLATION

- A. Install sleeve-seal fittings in new walls and slabs as they are constructed.
- B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.
- C. Secure nailing flanges to concrete forms.
- D. Using grout, seal the space around outside of sleeve-seal fittings.

3.5 SLEEVE AND SLEEVE-SEAL SCHEDULE

- A. Use sleeves and sleeve seals for the following piping-penetration applications:
 - 1. Exterior Concrete Walls above Grade:
 - a. Piping Smaller Than [NPS 6 (DN 150)] <Insert pipe size>: [Cast-iron wall sleeves] [Galvanized-steel wall sleeves] [Galvanized-steel-pipe sleeves] [Sleeve-seal fittings] <Insert material>.
 - b. Piping [NPS 6 (DN 150)] <Insert pipe size> and Larger: [Cast-iron wall sleeves] [Galvanized-steel wall sleeves] [Galvanized-steel-pipe sleeves] <Insert material>.
 - 2. Exterior Concrete Walls below Grade:
 - a. Piping Smaller Than [NPS 6 (DN 150)] <Insert pipe size>: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Sleeve-seal fittings] <Insert material>.
 - 1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.
 - b. Piping [NPS 6 (DN 150)] <Insert pipe size> and Larger: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] <Insert material>.
 - 1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.
 - 3. Concrete Slabs-on-Grade:
 - a. Piping Smaller Than [NPS 6 (DN 150)] <Insert pipe size>: [Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with

sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Sleeve-seal fittings] <Insert material>.

- 1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.
 - b. Piping [NPS 6 (DN 150)] <Insert pipe size> and Larger: **[Cast-iron wall sleeves with sleeve-seal system] [Galvanized-steel wall sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves with sleeve-seal system] [Galvanized-steel-pipe sleeves] <Insert material>.**
 - 1) Select sleeve size to allow for 1-inch (25-mm) annular clear space between piping and sleeve for installing sleeve-seal system.
4. Concrete Slabs above Grade:
- a. Piping Smaller Than [NPS 6 (DN 150)] <Insert pipe size>: **[Galvanized-steel-pipe sleeves] [PVC-pipe sleeves] [Stack-sleeve fittings] [Sleeve-seal fittings] [Molded-PE or -PP sleeves] [Molded-PVC sleeves] <Insert material>.**
 - b. Piping [NPS 6 (DN 150)] <Insert pipe size> and Larger: **[Galvanized-steel-pipe sleeves] [PVC-pipe sleeves] [Stack-sleeve fittings] <Insert material>.**
5. Interior Partitions:
- a. Piping Smaller Than [NPS 6 (DN 150)] <Insert pipe size>: **[Galvanized-steel-pipe sleeves] [PVC-pipe sleeves] <Insert material>.**
 - b. Piping [NPS 6 (DN 150)] <Insert pipe size> and Larger: **[Galvanized-steel-sheet sleeves] <Insert material>.**

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230517

SECTION 230518 - ESCUTCHEONS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Escutcheons.
 - 2. Floor plates.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.

1.4 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 ESCUTCHEONS

- A. One-Piece, Cast-Brass Type: With **[polished, chrome-plated]** **[and]** **[rough-brass]** finish and setscrew fastener.
- B. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with chrome-plated finish and spring-clip fasteners.
- C. One-Piece, Stamped-Steel Type: With chrome-plated finish and spring-clip fasteners.

- D. Split-Casting Brass Type: With **[polished, chrome-plated]** **[and]** **[rough-brass]** finish and with concealed hinge and setscrew.
- E. Split-Plate, Stamped-Steel Type: With chrome-plated finish, **[concealed]** **[and]** **[exposed-rivet]** hinge, and spring-clip fasteners.

2.2 FLOOR PLATES

- A. One-Piece Floor Plates: Cast-iron flange[**with holes for fasteners**].
- B. Split-Casting Floor Plates: Cast brass with concealed hinge.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install escutcheons for piping penetrations of walls, ceilings, and finished floors.
- B. Install escutcheons with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.
 - 1. Escutcheons for New Piping:
 - a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
 - b. Chrome-Plated Piping: One-piece, cast-brass[**or split-casting brass**] type with polished, chrome-plated finish.
 - c. Insulated Piping: One-piece, stamped-steel type[**or split-plate, stamped-steel type with concealed hinge**] [**or split-plate, stamped-steel type with exposed-rivet hinge**].
 - d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass[**or split-casting brass**] type with polished, chrome-plated finish.
 - e. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, stamped-steel type[**or split-plate, stamped-steel type with concealed hinge**] [**or split-plate, stamped-steel type with exposed-rivet hinge**].
 - f. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, cast-brass[**or split-casting brass**] type with polished, chrome-plated finish.
 - g. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type[**or split-plate, stamped-steel type with concealed hinge**] [**or split-plate, stamped-steel type with exposed-rivet hinge**].
 - h. Bare Piping in Unfinished Service Spaces: One-piece, cast-brass[**or split-casting brass**] type with **[polished, chrome-plated]** **[rough-brass]** finish.
 - i. Bare Piping in Unfinished Service Spaces: One-piece, stamped-steel type[**or split-plate, stamped-steel type with concealed hinge**] [**or split-plate, stamped-steel type with exposed-rivet hinge**].

- j. Bare Piping in Equipment Rooms: One-piece, cast-brass[**or split-casting brass**] type with [**polished, chrome-plated**] [**rough-brass**] finish.
 - k. Bare Piping in Equipment Rooms: One-piece, stamped-steel type[**or split-plate, stamped-steel type with concealed hinge**] [**or split-plate, stamped-steel type with exposed-rivet hinge**].
2. Escutcheons for Existing Piping:
- a. Chrome-Plated Piping: Split-casting brass type with polished, chrome-plated finish.
 - b. Insulated Piping: Split-plate, stamped-steel type with [**concealed**] [**or**] [**exposed-rivet**] hinge.
 - c. Bare Piping at Wall and Floor Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
 - d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: Split-plate, stamped-steel type with [**concealed**] [**or**] [**exposed-rivet**] hinge.
 - e. Bare Piping at Ceiling Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
 - f. Bare Piping at Ceiling Penetrations in Finished Spaces: Split-plate, stamped-steel type with [**concealed**] [**or**] [**exposed-rivet**] hinge.
 - g. Bare Piping in Unfinished Service Spaces: Split-casting brass type with [**polished, chrome-plated**] [**rough-brass**] finish.
 - h. Bare Piping in Unfinished Service Spaces: Split-plate, stamped-steel type with [**concealed**] [**or**] [**exposed-rivet**] hinge.
 - i. Bare Piping in Equipment Rooms: Split-casting brass type with [**polished, chrome-plated**] [**rough-brass**] finish.
 - j. Bare Piping in Equipment Rooms: Split-plate, stamped-steel type with [**concealed**] [**or**] [**exposed-rivet**] hinge.
- C. Install floor plates for piping penetrations of equipment-room floors.
- D. Install floor plates with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.
- 1. New Piping: One-piece, floor-plate type.
 - 2. Existing Piping: Split-casting, floor-plate type.

3.2 FIELD QUALITY CONTROL

- A. Replace broken and damaged escutcheons and floor plates using new materials.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230518

SECTION 230519 - METERS AND GAUGES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Bimetallic-actuated thermometers.
2. Filled-system thermometers.
3. Liquid-in-glass thermometers.
4. Light-activated thermometers.
5. Thermowells.
6. Dial-type pressure gauges.
7. Gauge attachments.
8. Test plugs.
9. Test-plug kits.
10. Sight flow indicators.
11. Orifice flowmeters.
12. Pitot-tube flowmeters.
13. Turbine flowmeters.
14. Venturi flowmeters.
15. Vortex-shedding flowmeters.
16. Impeller-turbine, thermal-energy meters.
17. Ultrasonic, thermal-energy meters.

- B. Related Sections:

1. Section 231123 "Facility Natural-Gas Piping" for gas meters.
2. Section 232216 "Steam and Condensate Piping Specialties" for steam and condensate meters.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.

1. Provide list, which indicates use, operating range, total range, and location for

- manufactured components.
 - 2. Include data substantiating that materials comply with requirements.
 - B. Wiring Diagrams: For power, signal, and control wiring.
- 1.4 INFORMATIONAL SUBMITTALS
- A. Product Certificates: For each type of meter and gauge, from manufacturer.
- 1.5 CLOSEOUT SUBMITTALS
- A. Operation and Maintenance Data: For meters and gauges to include in operation and maintenance manuals.
 - B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of components and instrumentation.
- 1.6 ENVIRONMENTAL REQUIREMENTS
- A. Do not install instrumentation when areas are under construction, except for required rough-in, taps, supports and test plugs.
- 1.7 EXTRA MATERIALS
- A. Provide [**two (2)**] <Insert number> bottles of red gauge oil for static pressure gauges.
 - B. Provide [**two (2)**] <Insert number> [**pressure gauges with pulsation damper**] [**dial thermometers**].
- 1.8 CONSTRUCTION WASTE MANAGEMENT
- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 BIMETALLIC-ACTUATED THERMOMETERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Ashcroft Inc.](#)
 2. [Ernst Flow Industries.](#)
 3. [Marsh Bellofram.](#)
 4. [Miljoco Corporation.](#)
 5. [Nanmac Corporation.](#)
 6. [Noshok.](#)
 7. [Palmer Wahl Instrumentation Group.](#)
 8. [REOTEMP Instrument Corporation.](#)
 9. [Tel-Tru Manufacturing Company.](#)
 10. [Trerice, H. O. Co.](#)
 11. [Watts Regulator Co.: a div. of Watts Water Technologies, Inc.](#)
 12. [Weiss Instruments, Inc.](#)
 13. [WIKA Instrument Corporation - USA.](#)
 14. [Winters Instruments - U.S.](#)
 15. <Insert manufacturer's name>.
 16. or approved equal.
- B. Standard: ASME B40.200.
- C. Case: Liquid-filled type(s); stainless steel with [3-inch (76-mm)] [5-inch (127-mm)] <Insert dimension> nominal diameter.
- D. Dial: [**Nonreflective aluminum**] <Insert material> with permanently etched scale markings and scales in [deg F (deg C)] [**deg F and deg C**].
- E. Connector Type(s): Union joint, [**adjustable angle**] [**rigid, back**] [**and**] [**rigid, bottom**] <Insert type>, with unified-inch screw threads.
- F. Connector Size: [1/2 inch (13 mm)] <Insert dimension>, with ASME B1.1 screw threads.
- G. Stem: 0.25 or 0.375 inch (6.4 or 9.4 mm) in diameter; stainless steel.
- H. Window: Plain glass <Insert material>.
- I. Ring: Stainless steel.
- J. Element: Bimetal coil.
- K. Pointer: Dark-colored metal.
- L. Accuracy: Plus or minus [1] [1.5] <Insert number> percent of scale range.
- 2.2 FILLED-SYSTEM THERMOMETERS
- A. Direct-Mounted, Metal-Case, Vapor-Actuated Thermometers:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Ashcroft Inc.](#)
 - b. [Marsh Bellofram.](#)
 - c. [Miljoco Corporation.](#)
 - d. [Palmer Wahl Instrumentation Group.](#)
 - e. [REOTEMP Instrument Corporation.](#)
 - f. [Trerice, H. O. Co.](#)
 - g. [Weiss Instruments, Inc.](#)
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Standard: ASME B40.200.
 3. Case: Sealed type, **[cast aluminum or drawn steel]** **<Insert material>**;
[4-1/2-inch (114-mm)] [5-inch (127-mm)] [6-inch (152-mm)] <Insert dimension>
nominal diameter.
 4. Element: Bourdon tube or other type of pressure element.
 5. Movement: Mechanical, **[dampening type,]** with link to pressure element and
connection to pointer.
 6. Dial: Nonreflective aluminum with permanently etched scale markings graduated
in **[deg F (deg C)] [deg F and deg C]**.
 7. Pointer: Dark-colored metal.
 8. Window: **[Glass] [or] [plastic]** **<Insert material>**.
 9. Ring: **[Metal] [Stainless steel]** **<Insert material>**.
 10. Connector Type(s): Union joint, **[adjustable, 180 degrees in vertical plane, 360
degrees in horizontal plane, with locking device] [rigid, back] [and] [rigid,
bottom]**; with ASME B1.1 screw threads.
 11. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass
stem and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
 12. Accuracy: Plus or minus **[1]** **<Insert number>** percent of scale range.
- B. Direct-Mounted, Plastic-Case, Vapor-Actuated Thermometers:
1. **Manufacturers: Subject to compliance with requirements, provide products by
one of the following:**
 - a. [Ashcroft Inc.](#)
 - b. [Miljoco Corporation.](#)
 - c. [REOTEMP Instrument Corporation.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Standard: ASME B40.200.
 3. Case: Sealed type, **[plastic]** **<Insert material>**; **[4-1/2-inch (114-mm)] [5-inch
(127-mm)] [6-inch (152-mm)] <Insert dimension>** nominal diameter.
 4. Element: Bourdon tube or other type of pressure element.
 5. Movement: Mechanical, with link to pressure element and connection to pointer.
 6. Dial: Nonreflective aluminum with permanently etched scale markings graduated

- in [deg F (deg C)] [deg F and deg C].
7. Pointer: Dark-colored metal.
 8. Window: [Glass] [or] [plastic] <Insert material>.
 9. Ring: [Metal] [or] [plastic] <Insert material>.
 10. Connector Type(s): Union joint, [adjustable, 180 degrees in vertical plane, 360 degrees in horizontal plane, with locking device] [rigid, back] [and] [rigid, bottom]; with ASME B1.1 screw threads.
 11. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
 12. Accuracy: Plus or minus [1] <Insert number> percent of scale range.
- C. Remote-Mounted, Metal-Case, Vapor-Actuated Thermometers:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [AMETEK, Inc.; U.S. Gauge.](#)
 - b. [Ashcroft Inc.](#)
 - c. [Marsh Bellofram.](#)
 - d. [Miljoco Corporation.](#)
 - e. [Palmer Wahl Instrumentation Group.](#)
 - f. [REOTEMP Instrument Corporation.](#)
 - g. [Trerice, H. O. Co.](#)
 - h. [Weiss Instruments, Inc.](#)
 - i. [WIKA Instrument Corporation - USA.](#)
 - j. <Insert manufacturer's name>.
 - k. or approved equal.
 2. Standard: ASME B40.200.
 3. Case: Sealed type, [cast aluminum or drawn steel] <Insert material>; [4-1/2-inch (114-mm)] [6-inch (152-mm)] <Insert dimension> nominal diameter with [back] [front] flange and holes for panel mounting.
 4. Element: Bourdon tube or other type of pressure element.
 5. Movement: Mechanical, with link to pressure element and connection to pointer.
 6. Dial: Nonreflective aluminum with permanently etched scale markings graduated in [deg F (deg C)] [deg F and deg C].
 7. Pointer: Dark-colored metal.
 8. Window: [Glass] [or] [plastic] <Insert material>.
 9. Ring: [Metal] [Stainless steel] <Insert material>.
 10. Connector Type(s): Union joint, [back] [bottom]; with ASME B1.1 screw threads.
 11. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.

12. Accuracy: Plus or minus [1] <Insert number> percent of scale range.

D. Remote-Mounted, Plastic-Case, Vapor-Actuated Thermometers:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [AMETEK, Inc.; U.S. Gauge.](#)
- b. [Ashcroft Inc.](#)
- c. [Miljoco Corporation.](#)
- d. [REOTEMP Instrument Corporation.](#)
- e. [Trerice, H. O. Co.](#)
- f. <Insert manufacturer's name>.
- g. or approved equal.

2. Standard: ASME B40.200.

3. Case: Sealed type, [plastic] <Insert material>; [4-1/2-inch (114-mm)] [6-inch (152-mm)] <Insert dimension> nominal diameter with [back] [front] flange and holes for panel mounting.

4. Element: Bourdon tube or other type of pressure element.

5. Movement: Mechanical, with link to pressure element and connection to pointer.

6. Dial: Nonreflective aluminum with permanently etched scale markings graduated in [deg F (deg C)] [deg F and deg C].

7. Pointer: Dark-colored metal.

8. Window: [Glass] [or] [plastic] <Insert material>.

9. Ring: [Metal] [or] [plastic] <Insert material>.

10. Connector Type(s): Union joint, threaded, [back] [bottom]; with ASME B1.1 screw threads.

11. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.

- a. Design for Air-Duct Installation: With ventilated shroud.
- b. Design for Thermowell Installation: Bare stem.

12. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.3 LIQUID-IN-GLASS THERMOMETERS

A. Metal-Case, Compact-Style, Liquid-in-Glass Thermometers:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Trerice, H. O. Co.](#)
- b. <Insert manufacturer's name>.
- c. or approved equal.

2. Standard: ASME B40.200.

3. Case: [**Cast aluminum**] <Insert material>; 6-inch (152-mm) nominal size.
4. Case Form: [**Back angle**] [**Straight**] unless otherwise indicated.
5. Tube: Glass with magnifying lens and blue[**or red**] organic liquid.
6. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in [deg F (deg C)] [**deg F and deg C**].
7. Window: Glass or plastic.
8. Stem: Aluminum or brass and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
9. Connector: 3/4 inch (19 mm), with ASME B1.1 screw threads.
10. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

B. Plastic-Case, Compact-Style, Liquid-in-Glass Thermometers:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Flo Fab Inc.](#)
 - b. [Miljoco Corporation.](#)
 - c. [Tel-Tru Manufacturing Company.](#)
 - d. [Watts Regulator Co.; a div. of Watts Water Technologies, Inc.](#)
 - e. [Weiss Instruments, Inc.](#)
 - f. [WIKA Instrument Corporation - USA.](#)
 - g. <Insert manufacturer's name>.
 - h. or approved equal.
2. Standard: ASME B40.200.
3. Case: [**Plastic**] <Insert material>; 6-inch (152-mm) nominal size.
4. Case Form: [**Back angle**] [**Straight**] unless otherwise indicated.
5. Tube: Glass with magnifying lens and blue[**or red**] organic liquid.
6. Tube Background: Nonreflective with permanently etched scale markings graduated in [deg F (deg C)] [**deg F and deg C**].
7. Window: Glass or plastic.
8. Stem: Aluminum or brass and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
9. Connector: 3/4 inch (19 mm), with ASME B1.1 screw threads.
10. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

C. Metal-Case, Industrial-Style, Liquid-in-Glass Thermometers:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Flo Fab Inc.](#)
 - b. [Miljoco Corporation.](#)
 - c. [Palmer Wahl Instrumentation Group.](#)
 - d. [Tel-Tru Manufacturing Company.](#)
 - e. [Trerice, H. O. Co.](#)
 - f. [Weiss Instruments, Inc.](#)
 - g. [Winters Instruments - U.S.](#)
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Standard: ASME B40.200.
 3. Case: [**Cast aluminum**] **<Insert material>**; [7-inch (178-mm)] [9-inch (229-mm)] nominal size unless otherwise indicated.
 4. Case Form: [**Adjustable angle**] [**Back angle**] [**Straight**] **<Insert form>** unless otherwise indicated.
 5. Tube: Glass with magnifying lens and blue[**or red**] organic liquid.
 6. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in [deg F (deg C)] [**deg F and deg C**].
 7. Window: [**Glass**] [**or**] [**plastic**] **<Insert material>**.
 8. Stem: [**Aluminum**] **<Insert material>** and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
 9. Connector: 1-1/4 inches (32 mm), with ASME B1.1 screw threads.
 10. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.4 LIGHT-ACTIVATED THERMOMETERS

A. Direct-Mounted, Light-Activated Thermometers:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Flo Fab Inc.](#)
 - b. [REOTEMP Instrument Corporation.](#)
 - c. [Trerice, H. O. Co.](#)
 - d. [Weiss Instruments, Inc.](#)
 - e. [WIKA Instrument Corporation - USA.](#)
 - f. [Winters Instruments - U.S.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
2. Case: [**Plastic**] [**Metal**] **<Insert material>**; [7-inch (178-mm)] [9-inch (229-mm)] nominal size unless otherwise indicated.
3. Scale(s): [Deg F (Deg C)] [**Deg F and deg C**].
4. Case Form: [**Adjustable angle**] **<Insert form>**.
5. Connector: [1-1/4 inches (32 mm)] **<Insert dimension>**, with ASME B1.1 screw

- threads.
6. Stem: [**Aluminum**] <Insert material> and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
 7. Display: Digital.
 8. Accuracy: Plus or minus 2 deg F (1 deg C).

B. Remote-Mounted, Light-Activated Thermometers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Miljoco Corporation](#).
 - b. [Weiss Instruments, Inc.](#)
 - c. [Winters Instruments - U.S.](#)
 - d. <Insert manufacturer's name>.
 - e. or approved equal.
2. Case: Plastic, for wall mounting.
3. Scale(s): [Deg F (Deg C)] [**Deg F and deg C**].
4. Sensor: Bulb and thermister wire.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
5. Display: Digital.
6. Accuracy: Plus or minus 2 deg F (1 deg C).

2.5 DUCT-THERMOMETER MOUNTING BRACKETS

- A. Socket: Brass separable sockets for thermometer stems with extensions where necessary to clear insulation, and with cap and chain.
- B. Description: Flanged bracket with screw holes, for attachment to air duct and made to hold thermometer stem.
 1. Flange: 3-inch outside diameter reversible flange, designed to fasten to sheet metal air ducts, with brass perforated stem.

2.6 THERMOWELLS

- A. Thermowells:
 1. Standard: ASME B40.200.
 2. Description: Pressure-tight, socket-type fitting made for insertion into piping tee fitting.
 3. Material for Use with Copper Tubing: [**CNR**] [or] [**CUNI**] <Insert material>.

4. Material for Use with Steel Piping: **[CRES] [CSA] <Insert material>**.
5. Type: Stepped shank unless straight or tapered shank is indicated.
6. External Threads: **NPS 1/2, NPS 3/4, or NPS 1**, (DN 15, DN 20, or NPS 25,) ASME B1.20.1 pipe threads.
7. Internal Threads: **1/2, 3/4, and 1 inch** (13, 19, and 25 mm), with ASME B1.1 screw threads.
8. Bore: Diameter required to match thermometer bulb or stem.
9. Insertion Length: Length required to match thermometer bulb or stem.
10. Lagging Extension: Include on thermowells for insulated piping and tubing.
11. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

B. Heat-Transfer Medium: **[Mixture of graphite and glycerin] <Insert material>**.

2.7 PRESSURE GAUGES

A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gauges:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [AMETEK, Inc.; U.S. Gauge.](#)
 - b. [Ashcroft Inc.](#)
 - c. [Ernst Flow Industries.](#)
 - d. [Flo Fab Inc.](#)
 - e. [Marsh Bellofram.](#)
 - f. [Miljoco Corporation.](#)
 - g. [Noshok.](#)
 - h. [Palmer Wahl Instrumentation Group.](#)
 - i. [REOTEMP Instrument Corporation.](#)
 - j. [Tel-Tru Manufacturing Company.](#)
 - k. [Trerice, H. O. Co.](#)
 - l. [Watts Regulator Co.; a div. of Watts Water Technologies, Inc.](#)
 - m. [Weiss Instruments, Inc.](#)
 - n. [WIKA Instrument Corporation - USA.](#)
 - o. [Winters Instruments - U.S.](#)
 - p. **<Insert manufacturer's name>**.
 - q. or approved equal.
2. Standard: ASME B40.100.
3. Case: **[Liquid-filled] [Open-front, pressure relief] [Solid-front, pressure relief] <Insert type>** type(s); **[cast aluminum or drawn steel] <Insert material>**; **[4-1/2-inch (114-mm)] [6-inch (152-mm)] <Insert dimension>** nominal diameter.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with **[NPS 1/4 (DN 8)] [NPS 1/4 or NPS 1/2 (DN 8 or DN 15)] [NPS 1/2 (DN 15)]**, ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Nonreflective aluminum with permanently etched scale markings graduated

- in [psi (kPa)] [psi and kPa].
8. Pointer: Dark-colored metal.
 9. Window: [Glass] <Insert material>.
 10. Ring: [Metal] [Brass] [Stainless steel].
 11. Accuracy: [Grade A, plus or minus 1 percent of middle half of] scale range.

B. Remote-Mounted, Metal-Case, Dial-Type Pressure Gauges:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [AMETEK, Inc.: U.S. Gauge.](#)
 - b. [Ashcroft Inc.](#)
 - c. [Ernst Flow Industries.](#)
 - d. [Flo Fab Inc.](#)
 - e. [Marsh Bellofram.](#)
 - f. [Miljoco Corporation.](#)
 - g. [Noshok.](#)
 - h. [Palmer Wahl Instrumentation Group.](#)
 - i. [REOTEMP Instrument Corporation.](#)
 - j. [Tel-Tru Manufacturing Company.](#)
 - k. [Trerice, H. O. Co.](#)
 - l. [Watts Regulator Co.: a div. of Watts Water Technologies, Inc.](#)
 - m. [Weiss Instruments, Inc.](#)
 - n. [WIKA Instrument Corporation - USA.](#)
 - o. [Winters Instruments - U.S.](#)
 - p. <Insert manufacturer's name>.
 - q. or approved equal.
2. Standard: ASME B40.100.
3. Case: [Liquid-filled] <Insert type> type; [cast aluminum or drawn steel] [metal] <Insert material>; [4-1/2-inch (114-mm)] [6-inch (152-mm)] <Insert dimension> nominal diameter with [back] [front] flange and holes for panel mounting.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with [NPS 1/4 (DN 8)] [NPS 1/4 or NPS 1/2 (DN 8 or DN 15)] [NPS 1/2 (DN 15)], ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Nonreflective aluminum with permanently etched scale markings graduated in [psi (kPa)] [psi and kPa].
8. Pointer: Dark-colored metal.
9. Window: [Glass] <Insert material>.
10. Ring: [Metal] [Stainless steel] <Insert material>.
11. Accuracy: [Grade A, plus or minus 1 percent of middle half of] [Grade B, plus or minus 2 percent of middle half of] [Grade C, plus or minus 3 percent of middle half of] [Grade D, plus or minus 5 percent of whole] scale range.

2.8 GAUGE ATTACHMENTS

- A. Snubbers: ASME B40.100, brass; with [NPS 1/4 (DN 8)] [NPS 1/4 or NPS 1/2 (DN 8 or DN 15)] [NPS 1/2 (DN 15)], ASME B1.20.1 pipe threads and [piston] [porous-metal]-type surge-dampening device. Include extension for use on insulated piping.
- B. Siphons: Loop-shaped section of [brass] [stainless-steel] [steel] pipe with [NPS 1/4 (DN 8)] [NPS 1/4 or NPS 1/2 (DN 8 or DN 15)] [NPS 1/2 (DN 15)] pipe threads.
- C. Valves: Stainless-steel needle, with [NPS 1/4 (DN 8)] [NPS 1/4 or NPS 1/2 (DN 8 or DN 15)] [NPS 1/2 (DN 15)], ASME B1.20.1 pipe threads.

2.9 TEST PLUGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Flow Design, Inc.](#)
 - 2. [Miljoco Corporation.](#)
 - 3. [National Meter, Inc.](#)
 - 4. [Peterson Equipment Co., Inc.](#)
 - 5. [Sisco Manufacturing Company, Inc.](#)
 - 6. [Trerice, H. O. Co.](#)
 - 7. [Watts Regulator Co.; a div. of Watts Water Technologies, Inc.](#)
 - 8. [Weiss Instruments, Inc.](#)
 - 9. <Insert manufacturer's name>.
 - 10. or approved equal.
- B. Description: Test-station fitting made for insertion into piping tee fitting.
- C. Body: Brass or stainless steel with core inserts and gasketed and threaded cap. Include extended stem on units to be installed in insulated piping.
- D. Thread Size: [NPS 1/4 (DN 8)] [or] [NPS 1/2 (DN 15)], ASME B1.20.1 pipe thread.
- E. Minimum Pressure and Temperature Rating: [500 psig at 200 deg F (3450 kPa at 93 deg C)] <Insert ratings>.
- F. Core Inserts: [Chlorosulfonated polyethylene synthetic] [and] [EPDM] self-sealing rubber.

2.10 TEST-PLUG KITS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Flow Design, Inc.](#)
 - 2. [Miljoco Corporation.](#)

3. [National Meter, Inc.](#)
 4. [Peterson Equipment Co., Inc.](#)
 5. [Sisco Manufacturing Company, Inc.](#)
 6. [Trerice, H. O. Co.](#)
 7. [Watts Regulator Co.; a div. of Watts Water Technologies, Inc.](#)
 8. [Weiss Instruments, Inc.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Furnish **[one]** **<Insert number>** test-plug kit(s) containing **[one]** **[two]** thermometer(s), one pressure gauge and adapter, and carrying case. Thermometer sensing elements, pressure gauge, and adapter probes shall be of diameter to fit test plugs and of length to project into piping.
- C. Low-Range Thermometer: Small, bimetallic insertion type with **[1- to 2-inch- (25- to 51-mm-)]** **<Insert dimension>** diameter dial and tapered-end sensing element. Dial range shall be at least **[25 to 125 deg F (minus 4 to plus 52 deg C)]** **<Insert temperature range>**.
- D. High-Range Thermometer: Small, bimetallic insertion type with **[1- to 2-inch- (25- to 51-mm-)]** **<Insert dimension>** diameter dial and tapered-end sensing element. Dial range shall be at least **[0 to 300 deg F (minus 18 to plus 149 deg C)]** **<Insert temperature range>**.
- E. Pressure Gauge: Small, Bourdon-tube insertion type with **[2- to 3-inch- (51- to 76-mm-)]** **<Insert dimension>** diameter dial and probe. Dial range shall be at least **[0 to 200 psig (0 to 1380 kPa)]** **<Insert range>**.
- F. Carrying Case: Metal or plastic, with formed instrument padding.

2.11 SIGHT FLOW INDICATORS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. [Archon Industries, Inc.](#)
 2. [Dwyer Instruments, Inc.](#)
 3. [Emerson Process Management; Brooks Instrument.](#)
 4. [Ernst Co., John C., Inc.](#)
 5. [Ernst Flow Industries.](#)
 6. [KOBOLD Instruments, Inc. - USA; KOBOLD Messring GmbH.](#)
 7. [OPW Engineered Systems; a Dover company.](#)
 8. [Penberthy; A Brand of Tyco Valves & Controls - Prophetstown.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Description: Piping inline-installation device for visual verification of flow.
- C. Construction: Bronze or stainless-steel body, with sight glass and **[ball, flapper, or**

paddle wheel] <Insert device> indicator, and threaded or flanged ends.

- D. Minimum Pressure Rating: [125 psig (860 kPa)] [150 psig (1034 kPa)] <Insert value>.
- E. Minimum Temperature Rating: [200 deg F (93 deg C)] <Insert temperature>.
- F. End Connections for NPS 2 (DN 50) and Smaller: Threaded.
- G. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.

2.12 FLOWMETERS

A. Turbine Flowmeters:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [ABB; Instrumentation and Analytical.](#)
 - b. [Data Industrial Corp.](#)
 - c. [EMCO Flow Systems; a division of Spirax Sarco, Inc.](#)
 - d. [ERDCO Engineering Corp.](#)
 - e. [Hoffer Flow Controls, Inc.](#)
 - f. [Liquid Controls; a unit of IDEX Corporation.](#)
 - g. [McCrometer, Inc.](#)
 - h. [Midwest Instruments & Controls Corp.](#)
 - i. [ONICON Incorporated.](#)
 - j. [SeaMetrics, Inc.](#)
 - k. [Sponsler, Inc.; a unit of IDEX Corporation.](#)
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
2. Description: Flowmeter with sensor and indicator.
3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.
4. Sensor: Impeller turbine; for inserting into pipefitting or for installing in piping and measuring flow directly in **gallons per minute** (liters per second).
 - a. Design: Device or pipe fitting with inline turbine and integral direct-reading scale for **[gas] [oil] [steam] [water]** <Insert fluid>.
 - b. Construction: Bronze or stainless-steel body, with plastic turbine or impeller.
 - c. Minimum Pressure Rating: [150 psig (1035 kPa)] <Insert value>.
 - d. Minimum Temperature Rating: [180 deg F (82 deg C)] <Insert temperature>.
5. Indicator: Hand-held meter; either an integral part of sensor or a separate meter.
6. Accuracy: Plus or minus [1-1/2] <Insert number> percent.
7. Display: Shows rate of flow[, **with register to indicate total volume in gallons** (liters)].

8. Operating Instructions: Include complete instructions with each flowmeter.

2.13 THERMAL-ENERGY METERS

A. Impeller-Turbine, Thermal-Energy Meters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Data Industrial Corp.](#)
- b. [Hoffer Flow Controls, Inc.](#)
- c. [ISTEC Corporation.](#)
- d. [ONICON Incorporated.](#)
- e. **<Insert manufacturer's name>.**
- f. or approved equal.

2. Description: System with[**strainer**,] flow sensor, temperature sensors, transmitter, indicator, and connecting wiring.
3. Flow Sensor: Impeller turbine with corrosion-resistant-metal body and transmitter; for installing in piping.
 - a. Design: Total thermal-energy measurement.
 - b. Minimum Pressure Rating: [150 psig (1035 kPa)] **<Insert value>.**
 - c. Minimum Temperature Range: [40 to 250 deg F (5 to 121 deg C)] **<Insert temperature range>.**
4. Temperature Sensors: Insertion-type transducer.
5. Indicator: Solid-state, integrating-type meter[**with integral battery pack**]; for wall mounting.
 - a. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or **British thermal units** (joules).
 - b. Battery Pack: Five-year lithium battery.
6. Accuracy: Plus or minus [1] **<Insert number>** percent.
7. Display: Visually indicates total fluid volume in **gallons** (liters) and thermal-energy flow in kilowatts per hour or **British thermal units** (joules).
8. Strainer: Full size of main line piping.
9. Operating Instructions: Include complete instructions with each thermal-energy meter system.

B. Ultrasonic, Thermal-Energy Meters:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [EMCO Flow Systems; a division of Spirax Sarco, Inc.](#)
- b. [Siemens Energy & Automation, Inc.](#)
- c. **<Insert manufacturer's name>.**
- d. or approved equal.

2. Description: Meter with flow sensor, temperature sensors, transmitter, indicator, and connecting wiring.
3. Flow Sensor: Transit-time ultrasonic type with transmitter.
4. Temperature Sensors: Insertion-type or strap-on transducer.
5. Indicator: Solid-state, integrating-type meter[**with integral battery pack**].
 - a. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or **British thermal units (joules)**.
 - b. Battery Pack: Five-year lithium battery.
6. Accuracy: Plus or minus [1] **<Insert number>** percent.
7. Display: Visually indicates total fluid volume in **gallons (liters)** and thermal-energy flow in kilowatts per hour or **British thermal units (joules)**.
8. Operating Instructions: Include complete instructions with each thermal-energy meter system.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install positive displacement meters with isolating valves on inlet and outlet. Provide full line size valved bypass with globe valve for liquid service meters.
- C. Provide one pressure gauge per pump. Install taps before strainers and on suction and discharge of pumps and manifold to a single pressure gauge with an isolation valve for each leg of the manifold.
- D. Install pressure gauges with pulsation dampers. Provide needle valve to isolate each gauge. Extend nipples to allow clearance from insulation.
- E. Install thermometers in piping systems in sockets in short couplings. Enlarge pipes smaller than 2-1/2 inch for installation of thermometer sockets. Ensure sockets allow clearance from insulation.
- F. Install thermometer sockets adjacent to controls systems thermostat, transmitter, or sensor sockets. Where thermometers are provided on local panels, duct or pipe mounted thermometers are not required.
- G. Locate duct mounted thermometers minimum 10 feet downstream of mixing dampers, coils, or other devices causing air turbulence.
- H. Coil and conceal excess capillary on remote element instruments.
- I. Provide instruments with scale ranges selected according to service with largest appropriate scale.
- J. Install gauges, thermometers and test plug in locations where there is an unobstructed

field of view from a normal operating level. All portions of gauges and thermometers shall be easily read from a normal operating level. Locations of test plugs shall be treated as a gauges or thermometers for installation and field of view verification.

- K. Install thermowells with socket extending [**a minimum of 2 inches (51 mm) into fluid**] [**one-third of pipe diameter**] [**to center of pipe**] and in vertical position in piping tees.
- L. Install thermowells of sizes required to match thermometer connectors. Include bushings if required to match sizes.
- M. Install thermowells with extension on insulated piping.
- N. Fill thermowells with heat-transfer medium.
- O. Install direct-mounted thermometers in thermowells and adjust vertical and tilted positions.
- P. Install remote-mounted thermometer bulbs in thermowells and install cases on panels; connect cases with tubing and support tubing to prevent kinks. Use minimum tubing length.
- Q. Install direct-mounted pressure gauges in piping tees with pressure gauge located on pipe in vertical to 45 degrees off vertical at the most readable position.
- R. Install remote-mounted pressure gauges on panel.
- S. Install valve and snubber in piping for each pressure gauge for fluids (except steam).
- T. Install valve and syphon fitting in piping for each pressure gauge for steam.
- U. Install test plugs in piping tees.
- V. Locate test plugs [adjacent to thermometers and thermometer sockets] [**adjacent to pressure gauges and pressure gauge taps**] [**adjacent to pressure gauges and pressure gauge taps**] [**adjacent to control device sockets**] [**where indicated**].
- W. Install flow indicators in piping systems in accessible positions for easy viewing.
- X. Assemble and install connections, tubing, and accessories between flow-measuring elements and flowmeters according to manufacturer's written instructions.
- Y. Install flowmeter elements in accessible positions in piping systems.
- Z. Install differential-pressure-type flowmeter elements, with at least minimum straight lengths of pipe, upstream and downstream from element according to manufacturer's written instructions.
- AA. Install permanent indicators on walls or brackets in accessible and readable positions.
- BB. Install connection fittings in accessible locations for attachment to portable indicators.

CC. Mount thermal-energy meters on wall if accessible; if not, provide brackets to support meters.

DD. Install thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic boiler.
3. Two inlets and two outlets of each chiller.
4. Inlet and outlet of each hydronic coil in air-handling units.
5. Two inlets and two outlets of each hydronic heat exchanger.
6. Inlet and outlet of each thermal-storage tank.
7. **<Insert location>**.

EE. Install pressure gauges in the following locations:

1. Inlet and outlet of each pressure-reducing valve.
2. Inlet and outlet of each chiller, cooling tower, boiler, and heat exchanger downstream of any balancing valve.
3. Suction and discharge of each pump.
4. Inlet and outlet of any strainer or filter.
5. Inlet of expansion tanks.
6. **<Insert location>**.

FF. Pressure and Temperature plugs:

1. Inlet and outlet of all coils.
2. **<Insert location>**

3.2 CONNECTIONS

- A. Install meters and gauges adjacent to machines and equipment to allow service and maintenance of meters, gauges, machines, and equipment.
- B. Connect flowmeter-system elements to meters.
- C. Connect flowmeter transmitters to meters.
- D. Connect thermal-energy meter transmitters to meters.

3.3 ADJUSTING

- A. After installation, calibrate meters according to manufacturer's written instructions.
- B. Adjust faces of meters and gauges to proper angle for best visibility, clean windows and lenses, and calibrate to zero.

3.4 THERMOMETER SCHEDULE

- A. Thermometers at inlet and outlet of each hydronic zone shall be[**one of**] the following:
1. Liquid-filled, bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.
- B. Thermometers at inlet and outlet of each hydronic boiler shall be[**one of**] the following:
1. Liquid-filled bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.
- C. Thermometers at inlets and outlets of each chiller shall be[**one of**] the following:
1. Liquid-filled, bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.
- D. Thermometers at inlet and outlet of each hydronic coil in air-handling units and built-up central systems shall be[**one of**] the following:
1. Liquid-filled, bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.
- E. Thermometers at inlets and outlets of each hydronic heat exchanger shall be[**one of**] the following:
1. Liquid-filled, bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.

- F. Thermometers at inlet and outlet of each hydronic heat-recovery unit shall be **[one of]** the following:
1. Liquid-filled, bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.
- G. Thermometers at inlet and outlet of each thermal-storage tank shall be **[one of]** the following:
1. Liquid-filled, bimetallic-actuated type.
 2. **[Direct] [Remote]**-mounted, metal-case, vapor-actuated type.
 3. **[Compact] [Industrial]**-style, liquid-in-glass type.
 4. **[Direct] [Remote]**-mounted, light-activated type.
 5. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.

3.5 THERMOMETER SCALE-RANGE SCHEDULE

- A. Scale Range for Chilled-Water Piping: **[0 to 100 deg F (Minus 20 to plus 50 deg C)] [0 to 100 deg F and minus 20 to plus 50 deg C]**.
- B. Scale Range for Condenser-Water Piping: **[0 to 150 deg F (Minus 20 to plus 70 deg C)] [0 to 150 deg F and minus 20 to plus 70 deg C]**.
- C. Scale Range for Heating, Hot-Water Piping: **[50 to 400 deg F (0 to 200 deg C)] [50 to 400 deg F and 0 to 200 deg C]**.

3.6 PRESSURE-GAUGE SCHEDULE

- A. Pressure gauges at discharge of each pressure-reducing valve shall be **[one of]** the following:
1. **[Liquid-filled] [Open-front, pressure-relief] [Solid-front, pressure-relief] <Insert type>**, **[direct] [remote]**-mounted, metal case.
 2. **[Sealed] <Insert type>**, **[direct] [remote]**-mounted, plastic case.
 3. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.
- B. Pressure gauges at inlet and outlet of each chiller chilled-water and condenser-water connection shall be **[one of]** the following:
1. **[Liquid-filled] [Open-front, pressure-relief] [Solid-front, pressure-relief] <Insert type>**, **[direct] [remote]**-mounted, metal case.
 2. **[Sealed] <Insert type>**, **[direct] [remote]**-mounted, plastic case.
 3. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing

rubber inserts.

- C. Pressure gauges at suction and discharge of each pump shall be **[one of]** the following:
1. **[Liquid-filled] [Open-front, pressure-relief] [Solid-front, pressure-relief] <Insert type>**, **[direct] [remote]**-mounted, metal case.
 2. **[Sealed] <Insert type>**, **[direct] [remote]**-mounted, plastic case.
 3. Test plug with **[chlorosulfonated polyethylene synthetic] [EPDM]** self-sealing rubber inserts.

3.7 PRESSURE-GAUGE SCALE-RANGE SCHEDULE

- A. Scale Range for Chilled-Water Piping: **[0 to 160 psi (0 to 1100 kPa)] [0 to 160 psi and 0 to 1100 kPa]**.
- B. Scale Range for Condenser-Water Piping: **[0 to 160 psi (0 to 1100 kPa)] [0 to 160 psi and 0 to 1100 kPa]**.
- C. Scale Range for Heating, Hot-Water Piping: **[0 to 160 psi (0 to 1100 kPa)] [0 to 160 psi and 0 to 1100 kPa]**.

3.8 FLOWMETER SCHEDULE

- A. Flowmeters for Chilled-Water Piping: Turbine type.
- B. Flowmeters for Condenser-Water Piping: Turbine type.
- C. Flowmeters for Heating, Hot-Water Piping: Turbine type.
- D. Flowmeters for Steam and Steam-Condensate Piping: Turbine type.

3.9 THERMAL-ENERGY METER SCHEDULE

- A. Thermal-Energy Meters for Chilled-Water Piping: Impeller-turbine type.
- B. Thermal-Energy Meters for Condenser-Water Piping: Impeller-turbine type.
- C. Thermal-Energy Meters for Heating, Hot-Water Piping: Impeller-turbine type.
- D. Thermal-Energy Meters for Steam and Steam-Condensate Piping: Impeller-turbine type.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230519

SECTION 230523.11 - GLOBE VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Bronze angle valves.
 - 2. Bronze globe valves.
 - 3. Iron globe valves.
 - 4. Chainwheels.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and accessory. Provide manufacturers catalog information. Indicate valve data and ratings.
 - 1. Include data substantiating that materials comply with requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of valves.

C. EXTRA MATERIALS

1. Provide two (2) repacking kits for each type and size valve.

1.6 QUALITY ASSURANCE

- A. Valves: Manufacturer's name and pressure rating marked on valve body.
- B. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 1. Protect internal parts against rust and corrosion.
 2. Protect threads, flange faces, grooves, and weld ends.
 3. Set angle and globe valves closed to prevent rattling.
- B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- C. Use the following precautions during storage:
 1. Maintain valve end protection.
 2. Store valves indoors and maintain at higher-than-ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
 3. Provide temporary protective coating on cast iron and steel valves.
 4. Provide temporary end caps and closures on fittings. Maintain in place until installation.
 5. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.
- D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.1 for flanges on iron valves.
 - 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 4. ASME B16.18 for solder joint.
 - 5. ASME B31.1 for power piping valves.
 - 6. ASME B31.9 for building services piping valves.
- C. Refer to HVAC valve schedule articles for applications of valves.
- D. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- E. Valve Sizes: Same as upstream piping unless otherwise indicated.
- F. Valves in Insulated Piping: With **2-inch (50-mm)** stem extensions.

2.2 BRONZE ANGLE VALVES

- A. Class 125 Bronze Angle Valves:
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [American Valve, Inc.](#)
 - b. [Hammond Valve.](#)
 - c. [Milwaukee Valve Company.](#)
 - d. [NIBCO INC.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
 - 2. Description:
 - a. Standard: MSS SP-80, Type 1.
 - b. CWP Rating: **200 psig (1380 kPa)**.
 - c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
 - d. Ends: Threaded.
 - e. Stem and Disc: **[Bronze] [PTFE]**.
 - f. Packing: Asbestos free.
 - g. Handwheel: Malleable iron[, **bronze, or aluminum**].

B. Class 150 Bronze Angle Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Crane Co.; Crane Valve Group; Stockham Division.](#)
 - b. [Kitz Corporation.](#)
 - c. **<Insert manufacturer's name>.**
 - d. or approved equal.
2. Description:
 - a. Standard: MSS SP-80, Type 1.
 - b. CWP Rating: **300 psig** (2070 kPa).
 - c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.
 - d. Ends: Threaded.
 - e. Stem and Disc: [**Bronze**] [**PTFE**].
 - f. Packing: Asbestos free.
 - g. Handwheel: Malleable iron[, **bronze, or aluminum**].

2.3 BRONZE GLOBE VALVES

A. Class 125 Bronze Globe Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
 - b. [Crane Co.; Crane Valve Group; Stockham Division.](#)
 - c. [Hammond Valve.](#)
 - d. [Kitz Corporation.](#)
 - e. [Milwaukee Valve Company.](#)
 - f. [NIBCO INC.](#)
 - g. [Powell Valves.](#)
 - h. [Red-White Valve Corporation.](#)
 - i. [Valve Solutions.](#)
 - j. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
 - k. **<Insert manufacturer's name>.**
 - l. or approved equal.
2. Description:
 - a. Standard: MSS SP-80, Type 1.
 - b. CWP Rating: **200 psig** (1380 kPa).
 - c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
 - d. Ends: Threaded[**or solder joint**].
 - e. Stem and Disc: [**Bronze**] [**PTFE**].
 - f. Packing: Asbestos free.
 - g. Handwheel: Malleable iron[, **bronze, or aluminum**].

B. Class 150 Bronze Globe Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Hammond Valve.](#)
- c. [Kitz Corporation.](#)
- d. [Milwaukee Valve Company.](#)
- e. [NIBCO INC.](#)
- f. [Powell Valves.](#)
- g. [Red-White Valve Corporation.](#)
- h. [Valve Solutions.](#)
- i. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- j. **<Insert manufacturer's name>.**
- k. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 2.
- b. CWP Rating: **300 psig** (2070 kPa).
- c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.
- d. Ends: Threaded.
- e. Stem: Bronze.
- f. Disc: **[Bronze] [PTFE]**.
- g. Packing: Asbestos free.
- h. Handwheel: Malleable iron[, **bronze, or aluminum**].

2.4 IRON GLOBE VALVES

A. Class 125 Iron Globe Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- d. [Hammond Valve.](#)
- e. [Kitz Corporation.](#)
- f. [Milwaukee Valve Company.](#)
- g. [NIBCO INC.](#)
- h. [Powell Valves.](#)
- i. [Red-White Valve Corporation.](#)
- j. [Valve Solutions.](#)
- k. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- l. **<Insert manufacturer's name>.**
- m. or approved equal.

2. Description:

- a. Standard: MSS SP-85, Type I.
- b. CWP Rating: 200 psig (1380 kPa).
- c. Body Material: ASTM A 126, gray iron with bolted bonnet.
- d. Ends: Flanged.
- e. Trim: Bronze.
- f. Packing and Gasket: Asbestos free.
- g. Operator: Handwheel or chainwheel.

B. Class 250 Iron Globe Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- d. [Hammond Valve.](#)
- e. [Milwaukee Valve Company.](#)
- f. [NIBCO INC.](#)
- g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- h. **<Insert manufacturer's name>**.
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-85, Type I.
- b. CWP Rating: 500 psig (3450 kPa).
- c. Body Material: ASTM A 126, gray iron with bolted bonnet.
- d. Ends: Flanged.
- e. Trim: Bronze.
- f. Packing and Gasket: Asbestos free.
- g. Operator: Handwheel or chainwheel.

2.5 CHAINWHEELS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Babbitt Steam Specialty Co.](#)
2. [Roto Hammer Industries.](#)
3. [Trumbull Industries.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

B. Description: Valve actuation assembly with sprocket rim, chain guides, chain[, and attachment brackets for mounting chainwheels directly to handwheels].

1. Sprocket Rim with Chain Guides: [**Ductile iron**] [**Ductile or cast iron**] [**Cast iron**] [**Aluminum**] [**Bronze**], of type and size required for valve.[**Include zinc or epoxy coating.**]
2. Chain: [**Hot-dip-galvanized steel**] [**Brass**] [**Stainless steel**], of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside, before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide dielectric fittings wherever jointing dissimilar metals.
- C. Locate valves for easy access and provide separate support where necessary.
- D. Provide clearance for installation of insulation and access to valves and fittings.
- E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

- F. Install valves with stems upright or horizontal, not inverted.
- G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.
- H. Install valves in horizontal piping with stem at or above center of pipe.
- I. Install valves in position to allow full stem movement.
- J. Install chainwheels on operators for globe valves [NPS 4 (DN 100)] <Insert pipe size> and larger and more than [96 inches (2400 mm)] <Insert dimension> above floor. Extend chains to [60 inches (1520 mm)] <Insert dimension> above finished floor.
- K. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.4 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.5 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
 - 1. Throttling Service except Steam: [Globe] [Globe or angle] valves.
 - 2. Throttling Service, Steam: [Globe] [Globe or angle] valves.
- B. If valves with specified CWP ratings are unavailable, the same types of valves with higher CWP ratings may be substituted.
- C. Select valves with the following end connections:
 - 1. For Copper Tubing, NPS 2 (DN 50) and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules.
 - 2. For Copper Tubing, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 3. For Copper Tubing, NPS 5 (DN 125) and Larger: Flanged ends.
 - 4. For Steel Piping, NPS 2 (DN 50) and Smaller: Threaded ends.
 - 5. For Steel Piping, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 6. For Steel Piping, NPS 5 (DN 125) and Larger: Flanged ends.
- D. Provide and install brass male adapters each side of valves in copper piped system. Sweat solder adapters to pipe.

3.6 CHILLED-WATER VALVE SCHEDULE

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze angle or globe valves, [**Class 125**] [**Class 150**], [**bronze**] [**nonmetallic**] disc, with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron globe valves, [**Class 125**] [**Class 250**] with flanged ends.

3.7 CONDENSER-WATER VALVE SCHEDULE

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze angle or globe valves, [**Class 125**] [**Class 150**], [**bronze**] [**nonmetallic**] disc, with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron globe valves, [**Class 125**] [**Class 250**] with flanged ends.

3.8 HEATING-WATER VALVE SCHEDULE

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze angle or globe valves, [**Class 125**] [**Class 150**], [**bronze**] [**nonmetallic**] disc, with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron globe valves, [**Class 125**] [**Class 250**] with flanged ends.

3.9 LOW-PRESSURE STEAM VALVE SCHEDULE (**15 PSIG** ([104 kPa]) OR LESS)

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze angle or globe valves, [**Class 125**] [**Class 150**], [**bronze**] [**nonmetallic**] disc, with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron globe valves, [**Class 125**] [**Class 250**] with flanged ends.

3.10 HIGH-PRESSURE STEAM VALVE SCHEDULE (MORE THAN **15 PSIG** ([104 kPa]))

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze angle or globe valves, [**Class 125**] [**Class 150**], [**bronze**] [**nonmetallic**] disc, with [**soldered**] [**threaded**] ends.
- B. Pipe Sizes **NPS 2-1/2** (DN 65) and Larger: Iron globe valves, [**Class 125**] [**Class 250**].

3.11 STEAM-CONDENSATE VALVE SCHEDULE

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze angle or globe valves, [**Class 125**] [**Class 150**], [**bronze**] [**nonmetallic**] disc, with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron globe valves, [**Class 125**] [**Class 250**].

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230523.11

SECTION 230523.12 - BALL VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Brass ball valves.
 - 2. Bronze ball valves.
 - 3. Steel ball valves.
 - 4. Iron ball valves.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and accessory. Provide manufacturers catalog information. Indicate valve data and ratings.
 - 1. Include data substantiating that materials comply with requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual locations of valves.

C. EXTRA MATERIALS

1. Provide two (2) repacking kits for each type and size valve.

1.6 QUALITY ASSURANCE

- A. Valves: Manufacturer's name and pressure rating marked on valve body.
- B. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 1. Protect internal parts against rust and corrosion.
 2. Protect threads, flange faces, and weld ends.
 3. Set ball valves open to minimize exposure of functional surfaces.
- B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- C. Use the following precautions during storage:
 1. Maintain valve end protection.
 2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
 3. Provide temporary protective coating on cast iron and steel valves.
 4. Provide temporary end caps and closures on fittings. Maintain in place until installation.
 5. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.
- D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use operating handles or stems as lifting or rigging points.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.1 for flanges on iron valves.
 - 3. ASME B16.5 for flanges on steel valves.
 - 4. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 5. ASME B16.18 for solder-joint connections.
 - 6. ASME B31.1 for power piping valves.
 - 7. ASME B31.9 for building services piping valves.
- C. Bronze valves shall be made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are not permitted.
- D. Refer to HVAC valve schedule articles for applications of valves.
- E. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- F. Valve Sizes: Same as upstream piping unless otherwise indicated.
- G. Valve Actuator Types:
 - 1. Gear Actuator: For quarter-turn valves [NPS 4 (DN 100)] <Insert size> and larger.
 - 2. Handlever: For quarter-turn valves smaller than [NPS 4 (DN 100)] <Insert size>.
- H. Valves in Insulated Piping:
 - 1. Include 2-inch (50-mm) stem extensions.
 - 2. Extended operating handle of nonthermal-conductive material, and protective sleeves that allow operation of valves without breaking the vapor seals or disturbing insulation.
 - 3. Memory stops that are fully adjustable after insulation is applied.
- I. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRASS BALL VALVES

- A. One-Piece Brass Ball Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Kitz Corporation](#).
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.

2. Description:
 - a. Standard: MSS SP-110.
 - b. CWP Rating: **400 psig** (2760 kPa).
 - c. Body Design: One piece.
 - d. Body Material: Forged brass.
 - e. Ends: Threaded.
 - f. Seats: PTFE.
 - g. Stem: Brass.
 - h. Ball: Chrome-plated brass.
 - i. Port: Reduced.

B. Two-Piece Brass Ball Valves with Full Port and Brass Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [American Valve, Inc.](#)
 - b. [Conbraco Industries, Inc.; Apollo Valves](#).
 - c. [Crane Co.; Crane Valve Group; Crane Valves](#).
 - d. [Crane Co.; Crane Valve Group; Stockham Valves](#).
 - e. [DynaQuip Controls](#).
 - f. [Hammond Valve](#).
 - g. [Jomar International, LTD.](#)
 - h. [Kitz Corporation](#).
 - i. [Legend Valve](#).
 - j. [Marwin Valve; a division of Richards Industries](#).
 - k. [Milwaukee Valve Company](#).
 - l. [NIBCO INC.](#)
 - m. [Red-White Valve Corporation](#).
 - n. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
 - o. **<Insert manufacturer's name>**.
 - p. or approved equal.

2. Description:
 - a. Standard: MSS SP-110.
 - b. SWP Rating: **150 psig** (1035 kPa).
 - c. CWP Rating: **600 psig** (4140 kPa).
 - d. Body Design: Two piece.
 - e. Body Material: Forged brass.
 - f. Ends: Threaded.
 - g. Seats: PTFE.

- h. Stem: Brass.
- i. Ball: Chrome-plated brass.
- j. Port: Full.

C. Two-Piece Brass Ball Valves with Full Port and Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Flow-Tek, Inc.; a subsidiary of Bray International, Inc.](#)
- d. [Hammond Valve.](#)
- e. [Jamesbury; a subsidiary of Metso Automation.](#)
- f. [Kitz Corporation.](#)
- g. [Marwin Valve; a division of Richards Industries.](#)
- h. [Milwaukee Valve Company.](#)
- i. [RuB Inc.](#)
- j. **<Insert manufacturer's name>.**
- k. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Forged brass.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.
- j. Port: Full.

D. Two-Piece Brass Ball Valves with Regular Port and Brass Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Hammond Valve.](#)
- b. [Jamesbury; a subsidiary of Metso Automation.](#)
- c. [Legend Valve.](#)
- d. [Marwin Valve; a division of Richards Industries.](#)
- e. [Milwaukee Valve Company.](#)
- f. [NIBCO INC.](#)
- g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- h. **<Insert manufacturer's name>.**
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Forged brass.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Brass.
- i. Ball: Chrome-plated brass.
- j. Port: Regular.

E. Two-Piece Brass Ball Valves with Regular Port and Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Jamesbury; a subsidiary of Metso Automation.
- b. Marwin Valve; a division of Richards Industries.
- c. **<Insert manufacturer's name>.**
- d. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Brass or bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.
- j. Port: Regular.

F. Three-Piece Brass Ball Valves with Full Port and Brass Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Jomar International, LTD.
- b. Kitz Corporation.
- c. Red-White Valve Corporation.
- d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- e. **<Insert manufacturer's name>.**
- f. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).

- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Three piece.
- e. Body Material: Forged brass.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Brass.
- i. Ball: Chrome-plated brass.
- j. Port: Full.

G. Three-Piece Brass Ball Valves with Full Port and Stainless-Steel Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Jomar International, LTD.
- b. Kitz Corporation.
- c. Marwin Valve; a division of Richards Industries.
- d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- e. **<Insert manufacturer's name>**.
- f. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Three piece.
- e. Body Material: Forged brass.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.
- j. Port: Full.

2.3 BRONZE BALL VALVES

A. One-Piece Bronze Ball Valves with Bronze Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Conbraco Industries, Inc.; Apollo Valves.
- b. NIBCO INC.
- c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- d. **<Insert manufacturer's name>**.
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. CWP Rating: 400 psig (2760 kPa).
- c. Body Design: One piece.
- d. Body Material: Bronze.
- e. Ends: Threaded.
- f. Seats: PTFE.
- g. Stem: Bronze.
- h. Ball: Chrome-plated brass.
- i. Port: Reduced.

B. One-Piece Bronze Ball Valves with Stainless-Steel Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Conbraco Industries, Inc.; Apollo Valves.
- b. NIBCO INC.
- c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- d. **<Insert manufacturer's name>.**
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. CWP Rating: 600 psig (4140 kPa).
- c. Body Design: One piece.
- d. Body Material: Bronze.
- e. Ends: Threaded.
- f. Seats: PTFE.
- g. Stem: Stainless steel.
- h. Ball: Stainless steel, vented.
- i. Port: Reduced.

C. Two-Piece Bronze Ball Valves with Full Port and Bronze or Brass Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. American Valve, Inc.
- b. Conbraco Industries, Inc.; Apollo Valves.
- c. Crane Co.; Crane Valve Group; Crane Valves.
- d. Hammond Valve.
- e. Lance Valves; a division of Advanced Thermal Systems, Inc.
- f. Legend Valve.
- g. Milwaukee Valve Company.
- h. NIBCO INC.
- i. Red-White Valve Corporation.
- j. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- k. **<Insert manufacturer's name>.**
- l. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Bronze.
- i. Ball: Chrome-plated brass.
- j. Port: Full.

D. Two-Piece Bronze Ball Valves with Full Port and Stainless-Steel Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Conbraco Industries, Inc.; Apollo Valves.
- b. Crane Co.; Crane Valve Group; Crane Valves.
- c. Hammond Valve.
- d. Lance Valves; a division of Advanced Thermal Systems, Inc.
- e. Milwaukee Valve Company.
- f. NIBCO INC.
- g. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- h. **<Insert manufacturer's name>.**
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.
- j. Port: Full.

E. Two-Piece Bronze Ball Valves with Regular Port and Bronze or Brass Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. American Valve, Inc.
- b. Conbraco Industries; Apollo Valves.
- c. Crane Co.; Crane Valves Group; Jenkins Valves.
- d. Crane Co.; Crane Valves Group; Stockham Valves.

- e. [DynaQuip Controls](#).
- f. [Hammond Valve](#).
- g. [Lance Valves; a division of Advanced Thermal Systems, Inc.](#)
- h. [Milwaukee Valve Company](#).
- i. [NIBCO INC.](#)
- j. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- k. **<Insert manufacturer's name>**.
- l. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: **150 psig** (1035 kPa).
- c. CWP Rating: **600 psig** (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Bronze.
- i. Ball: Chrome-plated brass.
- j. Port: Regular.

F. Two-Piece Bronze Ball Valves with Regular Port and Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Conbraco Industries; Apollo Valves](#).
- b. [Crane Co.; Crane Valves Group; Jenkins Valves](#).
- c. [Hammond Valve](#).
- d. [Milwaukee Valve Company](#).
- e. [NIBCO INC.](#)
- f. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- g. **<Insert manufacturer's name>**.
- h. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: **150 psig** (1035 kPa).
- c. CWP Rating: **600 psig** (4140 kPa).
- d. Body Design: Two piece.
- e. Body Material: Bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.
- j. Port: Regular.

G. Three-Piece Bronze Ball Valves with Full Port and Bronze or Brass Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Conbraco Industries, Inc.; Apollo Valves.](#)
- b. [DynaQuip Controls.](#)
- c. [Hammond Valve.](#)
- d. [Milwaukee Valve Company.](#)
- e. [NIBCO INC.](#)
- f. [Red-White Valve Corporation.](#)
- g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- h. **<Insert manufacturer's name>.**
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Three piece.
- e. Body Material: Bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Bronze.
- i. Ball: Chrome-plated brass.
- j. Port: Full.

H. Three-Piece Bronze Ball Valves with Full Port Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Conbraco Industries, Inc.; Apollo Valves.](#)
- b. [Hammond Valve.](#)
- c. [Milwaukee Valve Company.](#)
- d. [NIBCO INC.](#)
- e. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- f. **<Insert manufacturer's name>.**
- g. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Three piece.
- e. Body Material: Bronze.
- f. Ends: Threaded.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.

j. Port: Full.

I. Three-Piece Bronze Ball Valves with Regular Port, and Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Conbraco Industries, Inc.; Apollo Valves.](#)
- b. [Jamesbury; a subsidiary of Metso Automation.](#)
- c. [NIBCO INC.](#)
- d. **<Insert manufacturer's name>.**
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-110.
- b. SWP Rating: 150 psig (1035 kPa).
- c. CWP Rating: 600 psig (4140 kPa).
- d. Body Design: Three piece.
- e. Body Material: Bronze.
- f. Ends: Threaded and solder.
- g. Seats: PTFE.
- h. Stem: Stainless steel.
- i. Ball: Stainless steel, vented.
- j. Port: Regular.

2.4 STEEL BALL VALVES

A. Class 150 Steel Ball Valves with Full Port and Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Conbraco Industries, Inc.; Apollo Valves.](#)
- b. [Jamesbury; a subsidiary of Metso Automation.](#)
- c. [NIBCO INC.](#)
- d. **<Insert manufacturer's name>.**
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-72.
- b. CWP Rating: 285 psig (1964 kPa).
- c. Body Design: Split body.
- d. Body Material: Carbon steel, ASTM A 216, Type WCB.
- e. Ends: Flanged.
- f. Seats: PTFE.
- g. Stem: Stainless steel.
- h. Ball: Stainless steel, vented.

i. Port: Full.

B. Class 300 Steel Ball Valves with Full Port and Stainless-Steel Trim:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Conbraco Industries, Inc.; Apollo Valves.](#)
- b. [Jamesbury; a subsidiary of Metso Automation.](#)
- c. [NIBCO INC.](#)
- d. **<Insert manufacturer's name>.**
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-72.
- b. CWP Rating: **720 psig** (4960 kPa).
- c. Body Design: Split body.
- d. Body Material: Carbon steel, ASTM A 216, Type WCB.
- e. Ends: Flanged.
- f. Seats: PTFE.
- g. Stem: Stainless steel.
- h. Ball: Stainless steel, vented.
- i. Port: Full.

2.5 IRON BALL VALVES

A. Class 125 Iron Ball Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [American Valve, Inc.](#)
- b. [Conbraco Industries; Apollo Valves.](#)
- c. [Kitz Corporation.](#)
- d. [Sure Flow Equipment Inc.](#)
- e. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- f. **<Insert manufacturer's name>.**
- g. or approved equal.

2. Description:

- a. Standard: MSS SP-72.
- b. CWP Rating: **200 psig** (1380 kPa).
- c. Body Design: Split body.
- d. Body Material: ASTM A 126, gray iron.
- e. Ends: Flanged.
- f. Seats: PTFE.
- g. Stem: Stainless steel.

- h. Ball: Stainless steel.
- i. Port: Full.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside, before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide dielectric fittings wherever jointing dissimilar metals.
- C. Locate valves for easy access and provide separate support where necessary.
- D. Provide clearance for installation of insulation and access to valves and fittings.
- E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.
- F. Install valves with stems upright or horizontal, not inverted.

- G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.
- H. Install valves in horizontal piping with stem at or above center of pipe.
- I. Install valves in position to allow full stem movement.
- J. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- B. Select valves with the following end connections:
 - 1. For Copper Tubing, **NPS 2 (DN 50)** and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules below.
 - 2. For Copper Tubing, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends except where threaded valve-end option is indicated in valve schedules below.
 - 3. For Copper Tubing, **NPS 5 (DN 125)** and Larger: Flanged ends.
 - 4. For Steel Piping, **NPS 2 (DN 50)** and Smaller: Threaded ends.
 - 5. For Steel Piping, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends except where threaded valve-end option is indicated in valve schedules below.
 - 6. For Steel Piping, **NPS 5 (DN 125)** and Larger: Flanged ends.

3.5 CHILLED-WATER VALVE SCHEDULE

- A. Pipe **NPS 2 (DN 50)** and Smaller: **[One] [Two] [Three]** piece, **[full] [regular] [reduced]** port, **[brass] [or] [bronze]** with **[brass] [bronze] [stainless-steel]** trim.
 - 1. Valves may be provided with solder-joint ends instead of threaded ends.
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron ball valves.
 - 1. Iron Valves, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: May be provided with threaded ends instead of flanged ends.
 - 2. Steel Ball Valves: Class 150.
- C. Pipe **NPS 2-1/2 (DN 65)** and Larger:
 - 1. Iron ball valves.
 - a. Iron Valves, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: May be provided with threaded ends instead of flanged ends.
 - 2. Class 150 steel ball valves.

3.6 CONDENSER-WATER VALVE SCHEDULE

A. Pipe **NPS 2 (DN 50)** and Smaller: **[One] [Two] [Three]** piece, **[full] [regular] [reduced]** port, **[brass] [or] [bronze]** with **[brass] [bronze] [stainless-steel]** trim.

1. Valves may be provided with solder-joint ends instead of threaded ends.

B. Pipe **NPS 2-1/2 (DN 65)** and Larger:

1. Iron ball valves.

a. Iron Valves, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: May be provided with threaded ends instead of flanged ends.

2. Class 150 steel ball valves.

3.7 HEATING-WATER VALVE SCHEDULE

A. Pipe **NPS 2 (DN 50)** and Smaller: **[One] [Two] [Three]** piece, **[full] [regular] [reduced]** port, **[brass] [or] [bronze]** with **[brass] [bronze] [stainless-steel]** trim.

1. Valves may be provided with solder-joint ends instead of threaded ends.

B. Pipe **NPS 2-1/2 (DN 65)** and Larger:

1. Iron ball valves.

a. Iron Valves, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: May be provided with threaded ends instead of flanged ends.

2. Class 150 steel ball valves.

3.8 LOW-PRESSURE STEAM VALVE SCHEDULE (**15 PSIG ([104 kPa])** OR LESS)

A. Pipe **NPS 2 (DN 50)** and Smaller: **[One] [Two] [Three]** piece, **[full] [regular] [reduced]** port, **[brass] [or] [bronze]** with **[brass] [bronze] [stainless-steel]** trim.

B. Pipe **NPS 2-1/2 (DN 65)** and Larger:

1. Iron ball valves.

a. Iron Valves, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: May be provided with threaded ends instead of flanged ends.

2. Class 150 steel ball valves.

- 3.9 HIGH-PRESSURE STEAM VALVE SCHEDULE (MORE THAN 15 PSIG ([104 kPa]))
- A. Pipe NPS 2 (DN 50) and Smaller: [One] [Two] [Three] piece, [full] [regular] [reduced] port, [brass] [or] [bronze] with [brass] [bronze] [stainless-steel] trim.
 - B. Pipe NPS 2-1/2 (DN 65) and Larger:
 - 1. Iron ball valves.
 - a. Iron Valves, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
 - 2. Class 300 steel ball valves.
- 3.10 STEAM-CONDENSATE VALVE SCHEDULE
- A. Pipe NPS 2 (DN 50) and Smaller: [One] [Two] [Three] piece, [full] [regular] [reduced] port, [brass] [or] [bronze] with [brass] [bronze] [stainless-steel] trim.
 - B. Pipe NPS 2-1/2 (DN 65) and Larger:
 - 1. Iron ball valves.
 - a. Iron Valves, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
 - 2. Class 300 steel ball valves.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230523.12

SECTION 230523.13 - BUTTERFLY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Iron, single-flange butterfly valves.
 - 2. Iron, grooved-end butterfly valves.
 - 3. High-performance butterfly valves.
 - 4. Chainwheels.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.
- C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.
- D. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and accessory. Provide manufacturers catalog information. Indicate valve data and ratings.
 - 1. Include data substantiating that materials comply with requirements.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual locations of valves.

B. EXTRA MATERIALS

1. Provide two (2) repacking kits for each type and size valve.

1.6 QUALITY ASSURANCE

- A. Valves: Manufacturer's name and pressure rating marked on valve body.
- B. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 1. Protect internal parts against rust and corrosion.
 2. Protect threads, flange faces, grooves, and weld ends.
 3. Set butterfly valves closed or slightly open.
- B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- C. Use the following precautions during storage:
 1. Maintain valve end protection.
 2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

- B. ASME Compliance:
1. ASME B16.1 for flanges on iron valves.
 2. ASME B16.5 for pipe flanges and flanged fittings, NPS 1/2 through NPS 24.
 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 4. ASME B31.1 for power piping valves.
 5. ASME B31.9 for building services piping valves.
- C. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- D. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- E. Valve Sizes: Same as upstream piping unless otherwise indicated.
- F. Valve Actuator Types:
1. Gear Actuator: For valves **NPS 8 (DN 200)** and larger.
 2. Handlever: For valves **NPS 6 (DN 150)** and smaller.
 3. Chainwheel: Device for attachment to gear, stem, or other actuator of size and with chain for mounting height, according to "Valve Installation" Article.
- G. Valves in Insulated Piping: With **2-inch (50-mm)** stem extensions with extended necks.

2.2 IRON, SINGLE-FLANGE BUTTERFLY VALVES

- A. Iron, Single-Flange Butterfly Valves with Aluminum-Bronze Disc:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. ABZ Valve and Controls; a division of ABZ Manufacturing, Inc.
 - b. Bray Controls; a division of Bray International.
 - c. Cooper Cameron Valves; a division of Cooper Cameron Corporation.
 - d. Conbraco Industries, Inc.; Apollo Valves.
 - e. Crane Co.; Crane Valve Group; Jenkins Valves.
 - f. Crane Co.; Crane Valve group; Stockham Valves.
 - g. DeZurik Water Controls.
 - h. Hammond Valve.
 - i. Kitz Corporation.
 - j. Milwaukee Valve Company.
 - k. NIBCO INC.
 - l. Norriseal; a Dover Corporation company.
 - m. Red-White Valve Corporation.
 - n. Spence Engineering Company; a division of CICOR International, Inc.
 - o. Tyco Valves & Controls; a unit of Tyco Flow Control.
 - p. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
 - q. **<Insert manufacturer's name>.**

r. or approved equal.

2. Description:

- a. Standard: MSS SP-67, Type I.
- b. CWP Rating: [150 psig (1035 kPa)] [200 psig (1380 kPa)].
- c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
- d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
- e. Seat: [EPDM] [NBR].
- f. Stem: One- or two-piece stainless steel.
- g. Disc: Aluminum bronze.

B. Iron, Single-Flange Butterfly Valves with Ductile-Iron Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [ABZ Valve and Controls; a division of ABZ Manufacturing, Inc.](#)
- b. [Bray Controls; a division of Bray International.](#)
- c. [Cooper Cameron Valves; a division of Cooper Cameron Corporation.](#)
- d. [Conbraco Industries, Inc.; Apollo Valves.](#)
- e. [Crane Co.; Crane Valve Group; Center Line Valves.](#)
- f. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- g. [DeZurik Water Controls.](#)
- h. [Hammond Valve.](#)
- i. [Kitz Corporation.](#)
- j. [Milwaukee Valve Company.](#)
- k. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- l. [NIBCO INC.](#)
- m. [Norriseal; a Dover company.](#)
- n. [Spence Engineering Company; a division of CICOR International, Inc.](#)
- o. [Sure Flow Equipment Inc.](#)
- p. [Tyco Valves & Controls; a unit of Tyco Flow Control.](#)
- q. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- r. <Insert manufacturer's name>.
- s. or approved equal.

2. Description:

- a. Standard: MSS SP-67, Type I.
- b. CWP Rating: [150 psig (1035 kPa)] [200 psig (1380 kPa)].
- c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
- d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
- e. Seat: [EPDM] [NBR].
- f. Stem: One- or two-piece stainless steel.
- g. Disc: Nickel-plated[or -coated] ductile iron.

C. Iron, Single-Flange Butterfly Valves with Stainless-Steel Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [ABZ Valve and Controls; a division of ABZ Manufacturing, Inc.](#)
- b. [Bray Controls; a division of Bray International.](#)
- c. [Cooper Cameron Valves; a division of Cooper Cameron Corporation.](#)
- d. [Conbraco Industries, Inc.; Apollo Valves.](#)
- e. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- f. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- g. [DeZurik Water Controls.](#)
- h. [Hammond Valve.](#)
- i. [Kitz Corporation.](#)
- j. [Milwaukee Valve Company.](#)
- k. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- l. [NIBCO INC.](#)
- m. [Norriseal; a Dover company.](#)
- n. [Red-White Valve Corporation.](#)
- o. [Spence Engineering Company; a division of CICOR International, Inc.](#)
- p. [Sure Flow Equipment Inc.](#)
- q. [Tyco Valves & Controls; a unit of Tyco Flow Control.](#)
- r. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- s. **<Insert manufacturer's name>.**
- t. or approved equal.

2. Description:

- a. Standard: MSS SP-67, Type I.
- b. CWP Rating: [150 psig (1035 kPa)] [200 psig (1380 kPa)].
- c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
- d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
- e. Seat: [EPDM] [NBR].
- f. Stem: One- or two-piece stainless steel.
- g. Disc: Stainless steel.

2.3 DUCTILE-IRON, GROOVED-END BUTTERFLY VALVES

A. 175 CWP, Iron, Grooved-End Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Kennedy Valve; a division of McWane, Inc.](#)
- b. [Shurjoint Piping Products.](#)
- c. [Tyco Fire Products LP; Grinnell Mechanical Products.](#)
- d. [Victaulic Company.](#)
- e. **<Insert manufacturer's name>.**
- f. or approved equal.

2. Description:

- a. Standard: MSS SP-67, Type I.
- b. CWP Rating: 175 psig (1200 kPa).
- c. Body Material: Coated, ductile iron.
- d. Stem: Two-piece stainless steel.
- e. Disc: Coated, ductile iron.
- f. Seal: EPDM.

B. 300 CWP, Iron, Grooved-End Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Anvil International, Inc.](#)
- b. [Kennedy Valve Company; a division of McWane, Inc.](#)
- c. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- d. [NIBCO INC.](#)
- e. [Shurjoint Piping Products.](#)
- f. [Tyco Fire Products LP; Grinnell Mechanical Products.](#)
- g. [Victaulic Company.](#)
- h. **<Insert manufacturer's name>**.
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-67, Type I.
- b. NPS 8 (DN 50) and Smaller CWP Rating: 300 psig (2070 kPa).
- c. NPS 10 (DN 250) and Larger CWP Rating: 200 psig (1380 kPa).
- d. Body Material: Coated, ductile iron.
- e. Stem: Two-piece stainless steel.
- f. Disc: Coated, ductile iron.
- g. Seal: EPDM.

2.4 HIGH-PERFORMANCE BUTTERFLY VALVES

A. Class 150, Single-Flange, High-Performance Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [ABZ Valve and Controls; a division of ABZ Manufacturing, Inc.](#)
- b. [Bray Controls; a division of Bray International.](#)
- c. [Cooper Cameron Valves; a division of Cooper Cameron Corporation.](#)
- d. [Crane Co.; Crane Valve Group; Flowseal Brand.](#)
- e. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- f. [DeZurik Water Controls.](#)
- g. [Hammond Valve.](#)
- h. [Jamesbury; a subsidiary of Metso Automation.](#)

- i. [Milwaukee Valve Company.](#)
- j. [NIBCO INC.](#)
- k. [Process Development & Control, Inc.](#)
- l. [Tyco Valves & Controls; a unit of Tyco Flow Control.](#)
- m. [Xomox; a brand of Crane Co.](#)
- n. **<Insert manufacturer's name>.**
- o. or approved equal.

2. Description:

- a. Standard: MSS SP-68.
- b. CWP Rating: **285 psig** (1965 kPa) at **100 deg F** (38 deg C).
- c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
- d. Body Material: Carbon steel, cast iron, ductile iron, or stainless steel.
- e. Seat: Reinforced PTFE or metal.
- f. Stem: Stainless steel; offset from seat plane.
- g. Disc: Carbon steel.
- h. Service: Bidirectional.

B. Class 300, Single-Flange, High-Performance Butterfly Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [ABZ Valve and Controls; a division of ABZ Manufacturing, Inc.](#)
- b. [Bray Controls; a division of Bray International.](#)
- c. [Cooper Cameron Valves; a division of Cooper Cameron Corporation.](#)
- d. [Crane Co.; Crane Valve Group; Flowseal Valves.](#)
- e. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- f. [DeZurik Water Controls.](#)
- g. [Hammond Valve.](#)
- h. [Jamesbury; a subsidiary of Metso Automation.](#)
- i. [Milwaukee Valve Company.](#)
- j. [NIBCO INC.](#)
- k. [Process Development & Control, Inc.](#)
- l. [Tyco Valves & Controls; a unit of Tyco Flow Control.](#)
- m. [Xomox; a brand of Crane Co.](#)
- n. **<Insert manufacturer's name>.**

2. Description:

- a. Standard: MSS SP-68.
- b. CWP Rating: **720 psig** (4965 kPa) at **100 deg F** (38 deg C).
- c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
- d. Body Material: Carbon steel, cast iron, or ductile iron.
- e. Seat: Reinforced PTFE or metal.
- f. Stem: Stainless steel; offset from seat plane.
- g. Disc: Carbon steel.

h. Service: Bidirectional.

2.5 CHAINWHEELS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Babbitt Steam Specialty Co.](#)
2. [Roto Hammer Industries.](#)
3. [Trumbull Industries.](#)
4. **<Insert manufacturer's name>.**
5. or approved equal.

B. **Description: Valve actuation assembly with sprocket rim, chain guides, chain[, and attachment brackets for mounting chainwheels directly to hand wheels].**

1. Sprocket Rim with Chain Guides: [**Ductile iron**] [**Ductile or cast iron**] [**Cast iron**] [**Aluminum**] [**Bronze**], of type and size required for valve. [**Include zinc or epoxy coating.**]
2. Chain: [**Hot-dip, galvanized steel**] [**Brass**] [**Stainless steel**], of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine mating flange faces for damage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- D. Do not attempt to repair defective valves; replace with new valves.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside, before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide dielectric fittings wherever jointing dissimilar metals.
- C. Locate valves for easy access and provide separate support where necessary.
- D. Provide clearance for installation of insulation and access to valves and fittings.
- E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.
- F. Install valves with stems upright or horizontal, not inverted.
- G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.
- H. Install valves in horizontal piping with stem at or above center of pipe.
- I. Install valves in position to allow full stem movement.
- J. Install chainwheels on operators for butterfly valves [NPS 4 (DN 100)] <Insert size> and larger and more than [96 inches (2400 mm)] <Insert dimension> above floor. Extend chains to [60 inches (1520 mm)] <Insert dimension> above finished floor.
- K. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.4 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.5 CHILLED-WATER VALVE SCHEDULE

- A. Pipe NPS 2-1/2 (DN 65) and Larger:
 - 1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 200 CWP, [EPDM] [NBR] seat, [aluminum-bronze] [ductile-iron] [stainless-steel] disc.
 - 2. Iron, Single-Flange Butterfly Valves, NPS 14 to NPS 24 (DN 350 to DN 600): 150 CWP, [EPDM] [NBR] seat, [aluminum-bronze] [ductile-iron] [stainless-steel] disc.
 - 3. Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [175] [300] CWP.
 - 4. High-Performance Butterfly Valves: [Class 150] [Class 300], single flange.

3.6 CONDENSER-WATER VALVE SCHEDULE

A. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 200 CWP, [EPDM] [NBR] seat, [aluminum-bronze] [ductile-iron] [stainless-steel] disc.
2. Iron, Single-Flange Butterfly Valves, NPS 14 to NPS 24 (DN 350 to DN 600): 150 CWP, [EPDM] [NBR] seat, [aluminum-bronze] [ductile-iron] [stainless-steel] disc.
3. Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [175] [300] CWP.
4. High-Performance Butterfly Valves: [Class 150] [Class 300], single flange.

3.7 HEATING-WATER VALVE SCHEDULE

A. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 200 CWP, [EPDM] [NBR] seat, [aluminum-bronze] [ductile-iron] [stainless-steel] disc.
2. Iron, Single-Flange Butterfly Valves, NPS 14 to NPS 24 (DN 350 to DN 600): 150 CWP, [EPDM] [NBR] seat, [aluminum-bronze] [ductile-iron] [stainless-steel] disc.
3. Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [175] [300] CWP.
4. High-Performance Butterfly Valves: [Class 150] [Class 300], single flange.

3.8 LOW-PRESSURE STEAM VALVE SCHEDULE (15 PSIG ([104 kPa]) OR LESS)

- #### A. Pipe NPS 2-1/2 (DN 65) and Larger: [Class 150] [Class 300], high-performance butterfly valves, single flange.

3.9 HIGH-PRESSURE STEAM VALVE SCHEDULE (MORE THAN 15 PSIG ([104 kPa]))

- #### A. Pipe NPS 2-1/2 (DN 65) and Larger: [Class 150] [Class 300], high-performance butterfly valves, single flange.

3.10 STEAM-CONDENSATE VALVE SCHEDULE

- #### A. Pipe NPS 2-1/2 (DN 65) and Larger: [Class 150] [Class 300], high-performance butterfly valves, single flange.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230523.13

SECTION 230523.14 - CHECK VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Bronze lift check valves.
 - 2. Bronze swing check valves.
 - 3. Iron swing check valves.
 - 4. Iron swing check valves with closure control.
 - 5. Iron, grooved-end swing check valves.
 - 6. Iron, center-guided check valves.
 - 7. Iron, plate-type check valves.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.
- C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.
- D. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and accessory. Provide manufacturers catalog information. Indicate valve data and ratings.
 - 1. Include data substantiating that materials comply with requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures"
 - 1. Record actual locations of valves.

C. EXTRA MATERIALS

- 1. Provide two (2) repacking kits for each type and size valve.

1.6 QUALITY ASSURANCE

- A. Valves: Manufacturer's name and pressure rating marked on valve body.
- B. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 - 1. Protect internal parts against rust and corrosion.
 - 2. Protect threads, flange faces, grooves, and weld ends.
 - 3. Block check valves in either closed or open position.
- B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- C. Use the following precautions during storage:
 - 1. Maintain valve end protection.
 - 2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
 - 3. Provide temporary protective coating on cast iron and steel valves.
 - 4. Provide temporary end caps and closures on fittings. Maintain in place until installation.
 - 5. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.
- D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
1. ASME B1.20.1 for threads for threaded-end valves.
 2. ASME B16.1 for flanges on iron valves.
 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 4. ASME B16.18 for solder joint.
 5. ASME B31.1 for power piping valves.
 6. ASME B31.9 for building services piping valves.
- C. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- D. Bronze valves shall be made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are not permitted.
- E. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- F. Valve Sizes: Same as upstream piping unless otherwise indicated.
- G. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE LIFT CHECK VALVES

- A. Class 125 Lift Check Valves with Bronze Disc:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Jenkins Valves.
 - c. Crane Co.; Crane Valve Group; Stockham Division.
 - d. **<Insert manufacturer's name>.**
 - e. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 1.
- b. CWP Rating: 200 psig (1380 kPa).
- c. Body Design: Vertical flow.
- d. Body Material: ASTM B 61 or ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: Bronze.

B. Class 125 Lift Check Valves with Nonmetallic Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Flo Fab Inc.](#)
- b. [Hammond Valve.](#)
- c. [Kitz Corporation.](#)
- d. [Milwaukee Valve Company.](#)
- e. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- f. [NIBCO INC.](#)
- g. [Red-White Valve Corporation.](#)
- h. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- i. **<Insert manufacturer's name>**.
- j. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 2.
- b. CWP Rating: 200 psig (1380 kPa).
- c. Body Design: Vertical flow.
- d. Body Material: ASTM B 61 or ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: NBR or PTFE.

2.3 BRONZE SWING CHECK VALVES

A. Class 125, Bronze Swing Check Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [American Valve, Inc.](#)
- b. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- c. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- d. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- e. [Hammond Valve.](#)
- f. [Kitz Corporation.](#)
- g. [Macomb Groups \(The\).](#)
- h. [Milwaukee Valve Company.](#)

- i. [NIBCO INC.](#)
- j. [Powell Valves.](#)
- k. [Red-White Valve Corporation.](#)
- l. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- m. **<Insert manufacturer's name>.**
- n. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 3.
- b. CWP Rating: **200 psig** (1380 kPa).
- c. Body Design: Horizontal flow.
- d. Body Material: ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: Bronze.

B. Class 125, Bronze Swing Check Valves with Nonmetallic Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- d. [Hammond Valve.](#)
- e. [Kitz Corporation.](#)
- f. [Milwaukee Valve Company.](#)
- g. [NIBCO INC.](#)
- h. [Red-White Valve Corporation.](#)
- i. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- j. **<Insert manufacturer's name>.**
- k. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 4.
- b. CWP Rating: **200 psig** (1380 kPa).
- c. Body Design: Horizontal flow.
- d. Body Material: ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: PTFE.

C. Class 150, Bronze Swing Check Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [American Valve, Inc.](#)
- b. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- c. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)

- d. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- e. [Kitz Corporation.](#)
- f. [Macomb Groups \(The\).](#)
- g. [Milwaukee Valve Company.](#)
- h. [NIBCO INC.](#)
- i. [Red-White Valve Corporation.](#)
- j. **<Insert manufacturer's name>.**
- k. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 3.
- b. CWP Rating: 300 psig (2070 kPa).
- c. Body Design: Horizontal flow.
- d. Body Material: ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: Bronze.

D. Class 150, Bronze Swing Check Valves with Nonmetallic Disc:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Hammond Valve.](#)
- d. [Milwaukee Valve Company.](#)
- e. [NIBCO INC.](#)
- f. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- g. **<Insert manufacturer's name>.**
- h. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 4.
- b. CWP Rating: 300 psig (2070 kPa).
- c. Body Design: Horizontal flow.
- d. Body Material: ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: PTFE.

2.4 IRON SWING CHECK VALVES

A. Class 125, Iron Swing Check Valves with Metal Seats:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)

- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- d. [Hammond Valve.](#)
- e. [Kitz Corporation.](#)
- f. [Legend Valve.](#)
- g. [Macomb Groups \(The\).](#)
- h. [Milwaukee Valve Company.](#)
- i. [NIBCO INC.](#)
- j. [Powell Valves.](#)
- k. [Red-White Valve Corporation.](#)
- l. [Sure Flow Equipment Inc.](#)
- m. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- n. **<Insert manufacturer's name>.**
- o. or approved equal.

2. Description:

- a. Standard: MSS SP-71, Type I.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).**
- d. Body Design: Clear or full waterway.
- e. Body Material: ASTM A 126, gray iron with bolted bonnet.
- f. Ends: Flanged.
- g. Trim: Bronze.
- h. Gasket: Asbestos free.

B. Class 125, Iron Swing Check Valves with Nonmetallic-to-Metal Seats:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- c. **<Insert manufacturer's name>.**
- d. or approved equal.

2. Description:

- a. Standard: MSS SP-71, Type I.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).**
- d. Body Design: Clear or full waterway.
- e. Body Material: ASTM A 126, gray iron with bolted bonnet.
- f. Ends: Flanged.
- g. Trim: Composition.
- h. Seat Ring: Bronze.
- i. Disc Holder: Bronze.
- j. Disc: PTFE.
- k. Gasket: Asbestos free.

C. Class 250, Iron Swing Check Valves with Metal Seats:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- d. [Hammond Valve.](#)
- e. [Milwaukee Valve Company.](#)
- f. [NIBCO INC.](#)
- g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- h. **<Insert manufacturer's name>.**
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-71, Type I.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).**
- d. Body Design: Clear or full waterway.
- e. Body Material: ASTM A 126, gray iron with bolted bonnet.
- f. Ends: Flanged.
- g. Trim: Bronze.
- h. Gasket: Asbestos free.

2.5 IRON SWING CHECK VALVES WITH CLOSURE CONTROL

A. Class 125, Iron Swing Check Valves with Lever- and Spring-Closure Control:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [NIBCO INC.](#)
- b. **<Insert manufacturer's name>.**
- c. or approved equal.

2. Description:

- a. Standard: MSS SP-71, Type I.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).**
- d. Body Design: Clear or full waterway.
- e. Body Material: ASTM A 126, gray iron with bolted bonnet.
- f. Ends: Flanged.
- g. Trim: Bronze.
- h. Gasket: Asbestos free.
- i. Closure Control: Factory-installed, exterior lever and spring.

- B. Class 125, Iron Swing Check Valves with Lever and Weight-Closure Control:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
 - b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
 - c. [Crane Co.; Crane Valve Group; Stockham Division.](#)
 - d. [Hammond Valve.](#)
 - e. [Milwaukee Valve Company.](#)
 - f. [NIBCO INC.](#)
 - g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
 - h. **<Insert manufacturer's name>.**
 - i. or approved equal.
 2. Description:
 - a. Standard: MSS SP-71, Type I.
 - b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).**
 - c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).**
 - d. Body Design: Clear or full waterway.
 - e. Body Material: ASTM A 126, gray iron with bolted bonnet.
 - f. Ends: Flanged.
 - g. Trim: Bronze.
 - h. Gasket: Asbestos free.
 - i. Closure Control: Factory-installed, exterior lever and weight.

2.6 IRON, GROOVED-END SWING CHECK VALVES

- A. 300 CWP, Iron, Grooved-End Swing Check Valves:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Anvil International, Inc.](#)
 - b. [Shurjoint Piping Products.](#)
 - c. [Tyco Valves & Controls; a unit of Tyco Flow Control.](#)
 - d. [Victaulic Company.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
 2. Description:
 - a. CWP Rating: **300 psig (2070 kPa).**
 - b. Body Material: ASTM A 536, ductile iron.
 - c. Seal: EPDM.
 - d. Disc: Spring operated, ductile iron or stainless steel.

2.7 IRON, CENTER-GUIDED CHECK VALVES

A. Class 125, Iron, Compact-Wafer, Center-Guided Check Valves with Metal Seat:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Anvil International, Inc.](#)
- b. [APCO Willamette Valve and Primer Corporation.](#)
- c. [Crispin Valve.](#)
- d. [DFT Inc.](#)
- e. [Flo Fab Inc.](#)
- f. [GA Industries, Inc.](#)
- g. [Hammond Valve.](#)
- h. [Metraflex, Inc.](#)
- i. [Milwaukee Valve Company.](#)
- j. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- k. [NIBCO INC.](#)
- l. [Spence Engineering Company, Inc.; a division of CIRCOR International, Inc.](#)
- m. [Sure Flow Equipment Inc.](#)
- n. [Val-Matic Valve & Manufacturing Corp.](#)
- o. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- p. **<Insert manufacturer's name>.**
- q. or approved equal.

2. **Description:**

- a. Standard: MSS SP-125.
- b. [NPS 2-1/2 to NPS 12 \(DN 65 to DN 300\), CWP Rating: 200 psig \(1380 kPa\).](#)
- c. [NPS 14 to NPS 24 \(DN 350 to DN 600\), CWP Rating: 150 psig \(1035 kPa\).](#)
- d. Body Material: ASTM A 126, gray iron.
- e. Style: Compact wafer.
- f. Seat: Bronze.

B. Class 125, Iron, Globe, Center-Guided Check Valves with Metal Seat:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [DFT Inc.](#)
- d. [Flomatic Corporation.](#)
- e. [Hammond Valve.](#)
- f. [Metraflex, Inc.](#)
- g. [Milwaukee Valve Company.](#)
- h. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- i. [NIBCO INC.](#)
- j. [Spence Engineering Company, Inc.; a division of CIRCOR International.](#)

- a. Standard: MSS SP-125.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 300 psig (2070 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 250 psig (1725 kPa).
- d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- e. Style: Globe, spring loaded.
- f. Ends: Flanged.
- g. Seat: Bronze.

E. Class 250, Iron, Compact-Wafer, Center-Guided Check Valves with Metal Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. APCO Willamette Valve and Primer Corporation.
- b. Crispin Valve.
- c. DFT Inc.
- d. Flo Fab Inc.
- e. Hammond Valve.
- f. Metraflex, Inc.
- g. Milwaukee Valve Company.
- h. NIBCO INC.
- i. Sure Flow Equipment Inc.
- j. Val-Matic Valve & Manufacturing Corp.
- k. **<Insert manufacturer's name>.**
- l. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 400 psig (2760 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).
- d. Body Material: ASTM A 126, gray iron.
- e. Style: Compact wafer, spring loaded.
- f. Seat: Bronze.

F. Class 250, Iron, Globe, Center-Guided Check Valves with Metal Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. APCO Willamette Valve and Primer Corporation.
- b. Crispin Valve.
- c. DFT Inc.
- d. Flomatic Corporation.
- e. Hammond Valve.
- f. Metraflex, Inc.
- g. Milwaukee Valve Company.
- h. Mueller Steam Specialty; a division of SPX Corporation.
- i. NIBCO INC.
- j. Val-Matic Valve & Manufacturing Corp.

- k. **<Insert manufacturer's name>**.
 - l. or approved equal.
 2. Description:
 - a. Standard: MSS SP-125.
 - b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 400 psig (2760 kPa).**
 - c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).**
 - d. Body Material: ASTM A 126, gray iron.
 - e. Style: Globe, spring loaded.
 - f. Ends: Flanged.
 - g. Seat: Bronze.
- G. Class 300, Iron, Compact-Wafer, Center-Guided Check Valves with Metal Seat:
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [APCO Willamette Valve and Primer Corporation.](#)
 - b. [Crispin Valve.](#)
 - c. [Val-Matic Valve & Manufacturing Corp.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Description:
 - a. Standard: MSS SP-125.
 - b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).**
 - c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 400 psig (2760 kPa).**
 - d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
 - e. Style: Compact wafer, spring loaded.
 - f. Seat: Bronze.
- H. Class 300, Iron, Globe, Center-Guided Check Valves with Metal Seat:
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [APCO Willamette Valve and Primer Corporation.](#)
 - b. [Crispin Valve.](#)
 - c. [Val-Matic Valve & Manufacturing Corp.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Description:
 - a. Standard: MSS SP-125.
 - b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).**
 - c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 400 psig (2760 kPa).**
 - d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.

- e. Style: Globe, spring loaded.
- f. Ends: Flanged.
- g. Seat: Bronze.

I. Class 125, Iron, Compact-Wafer, Center-Guided Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [DFT Inc.](#)
- d. [Flo Fab Inc.](#)
- e. [Hammond Valve.](#)
- f. [Milwaukee Valve Company.](#)
- g. [NIBCO INC.](#)
- h. [Spence Engineering Company, Inc.; a division of CIRCOR International, Inc.](#)
- i. [Sure Flow Equipment Inc.](#)
- j. [Val-Matic Valve & Manufacturing Corp.](#)
- k. **<Insert manufacturer's name>.**
- l. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).**
- d. Body Material: ASTM A 126, gray iron.
- e. Style: Compact wafer.
- f. Seat: **[EPDM] [or] [NBR] <Insert material>.**

J. Class 125, Iron, Globe, Center-Guided Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Anvil International, Inc.](#)
- b. [APCO Willamette Valve and Primer Corporation.](#)
- c. [Crispin Valve.](#)
- d. [DFT Inc.](#)
- e. [GA Industries, Inc.](#)
- f. [Hammond Valve.](#)
- g. [Milwaukee Valve Company.](#)
- h. [NIBCO INC.](#)
- i. [Sure Flow Equipment Inc.](#)
- j. [Val-Matic Valve & Manufacturing Corp.](#)
- k. **<Insert manufacturer's name>.**
- l. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **200 psig** (1380 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **150 psig** (1035 kPa).
- d. Body Material: ASTM A 126, gray iron.
- e. Style: Globe, spring loaded.
- f. Ends: Flanged.
- g. Seat: **[EPDM] [or] [NBR] <Insert material>**.

K. Class 150, Iron, Compact-Wafer, Center-Guided Check Valves with Resilient Seat:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [Val-Matic Valve & Manufacturing Corp.](#)
- d. **<Insert manufacturer's name>**.
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **300 psig** (2070 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **250 psig** (1725 kPa).
- d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- e. Style: Compact wafer.
- f. Seat: **[EPDM] [or] [NBR] <Insert material>**.

L. Class 150, Iron, Globe, Center-Guided Check Valves with Resilient Seat:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [DFT Inc.](#)
- d. [Val-Matic Valve & Manufacturing Corp.](#)
- e. **<Insert manufacturer's name>**.
- f. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **300 psig** (2070 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **250 psig** (1725 kPa).
- d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- e. Style: Globe, spring loaded.
- f. Ends: Flanged.

g. Seat: **[EPDM] [or] [NBR] <Insert material>**.

M. Class 250, Iron, Compact-Wafer, Center-Guided Check Valves with Resilient Seat:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [DFT Inc.](#)
- d. [Flo Fab Inc.](#)
- e. [Hammond Valve.](#)
- f. [Milwaukee Valve Company.](#)
- g. [NIBCO INC.](#)
- h. [Sure Flow Equipment Inc.](#)
- i. [Val-Matic Valve & Manufacturing Corp.](#)
- j. **<Insert manufacturer's name>**.
- k. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 400 psig (2760 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).**
- d. Body Material: ASTM A 126, gray iron.
- e. Style: Compact wafer, spring loaded.
- f. Seat: **[EPDM] [or] [NBR] <Insert material>**.

N. Class 250, Iron, Globe, Center-Guided Check Valves with Resilient Seat:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [DFT Inc.](#)
- d. [Hammond Valve.](#)
- e. [Milwaukee Valve Company.](#)
- f. [NIBCO INC.](#)
- g. [Val-Matic Valve & Manufacturing Corp.](#)
- h. **<Insert manufacturer's name>**.
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 400 psig (2760 kPa).**
- c. **NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).**
- d. Body Material: ASTM A 126, gray iron.
- e. Style: Globe, spring loaded.

- f. Ends: Flanged.
- g. Seat: [EPDM] [or] [NBR] <Insert material>.

O. Class 300, Iron, Compact-Wafer, Center-Guided Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [Val-Matic Valve & Manufacturing Corp.](#)
- d. <Insert manufacturer's name>.
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 400 psig (2760 kPa).
- d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- e. Style: Compact wafer, spring loaded.
- f. Seat: [EPDM] [or] [NBR] <Insert material>.

P. Class 300, Iron, Globe, Center-Guided Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crispin Valve.](#)
- c. [Val-Matic Valve & Manufacturing Corp.](#)
- d. <Insert manufacturer's name>.
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-125.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 400 psig (2760 kPa).
- d. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- e. Style: Globe, spring loaded.
- f. Ends: Flanged.
- g. Seat: [EPDM] [or] [NBR] <Insert material>.

2.8 IRON, PLATE-TYPE CHECK VALVES

A. Class 125, Iron, Dual-Plate Check Valves with Metal Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

2. **Basis-of-Design Product:** Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. APCO Willamette Valve and Primer Corporation.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. Flomatic Corporation.
 - d. Mueller Steam Specialty; a division of SPX Corporation.
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.

3. Description:

- a. Standard: API 594.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **200 psig** (1380 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **150 psig** (1035 kPa).
- d. Body Design: Wafer, spring-loaded plates.
- e. Body Material: ASTM A 126, gray iron.
- f. Seat: Bronze.

B. Class 150, Iron, Dual-Plate Check Valves with Metal Seat:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. APCO Willamette Valve and Primer Corporation.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. Mueller Steam Specialty; a division of SPX Corporation.
 - d. Val-Matic Valve & Manufacturing Corp.
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.

2. Description:

- a. Standard: API 594.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **300 psig** (2070 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **250 psig** (1725 kPa).
- d. Body Design: Wafer, spring-loaded plates.
- e. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- f. Seat: Bronze.

C. Class 250, Iron, Dual-Plate Check Valves with Metal Seat:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. APCO Willamette Valve and Primer Corporation.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. **<Insert manufacturer's name>.**
 - d. or approved equal.

2. Description:

- a. Standard: API 594.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 400 psig (2760 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).
- d. Body Design: Wafer, spring-loaded plates.
- e. Body Material: ASTM A 126, gray iron.
- f. Seat: Bronze.

D. Class 300, Iron, Dual-Plate Check Valves with Metal Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- c. [Mueller Steam Specialty; a division of SPX Corporation.](#)
- d. [Val-Matic Valve & Manufacturing Corp.](#)
- e. <Insert manufacturer's name>.
- f. or approved equal.

2. Description:

- a. Standard: API 594.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 400 psig (2760 kPa).
- d. Body Design: Wafer, spring-loaded plates.
- e. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- f. Seat: Bronze.

E. Class 125, Iron, Single-Plate Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Flo Fab Inc.](#)
- b. [Sure Flow Equipment Inc.](#)
- c. <Insert manufacturer's name>.
- d. or approved equal.

2. Description:

- a. Standard: API 594.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).
- d. Body Design: Wafer, spring-loaded plate.
- e. Body Material: ASTM A 126, gray iron.
- f. Seat: [EPDM] [or] [NBR] <Insert material>.

F. Class 125, Iron, Dual-Plate Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Cameron; Valves & Measurement Group.](#)
- c. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- d. [Crane Co.; Crane Valve Group; Stockham Division.](#)
- e. [NIBCO INC.](#)
- f. [Spence Engineering Company, Inc.; a division of CIRCOR International, Inc.](#)
- g. [Sure Flow Equipment Inc.](#)
- h. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- i. **<Insert manufacturer's name>.**
- j. or approved equal.

2. Description:

- a. Standard: API 594.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **200 psig** (1380 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **150 psig** (1035 kPa).
- d. Body Design: Wafer, spring-loaded plates.
- e. Body Material: ASTM A 126, gray iron.
- f. Seat: **[EPDM] [or] [NBR] <Insert material>.**

G. Class 150, Iron, Dual-Plate Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [APCO Willamette Valve and Primer Corporation.](#)
- b. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- c. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- d. [Val-Matic Valve & Manufacturing Corp.](#)
- e. **<Insert manufacturer's name>.**
- f. or approved equal.

2. Description:

- a. Standard: API 594.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **300 psig** (2070 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **250 psig** (1725 kPa).
- d. Body Design: Wafer, spring-loaded plates.
- e. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.
- f. Seat: **[EPDM] [or] [NBR] <Insert material>.**

H. Class 250, Iron, Wafer, Single-Plate Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Sure Flow Equipment Inc.](#)
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
2. Description:
- a. Standard: API 594.
 - b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **400 psig** (2760 kPa).
 - c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **300 psig** (2070 kPa).
 - d. Body Design: Wafer, spring-loaded plate.
 - e. Body Material: ASTM A 126, gray iron.
 - f. Seat: **[EPDM] [or] [NBR] <Insert material>**.
- I. Class 250, Iron, Dual-Plate Check Valves with Resilient Seat:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [APCO Willamette Valve and Primer Corporation.](#)
 - b. [Crane Co.; Crane Valve Group; Crane Valves.](#)
 - c. [Sure Flow Equipment Inc.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Description:
 - a. Standard: API 594.
 - b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **400 psig** (2760 kPa).
 - c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **300 psig** (2070 kPa).
 - d. Body Design: Wafer, spring-loaded plates.
 - e. Body Material: ASTM A 126, gray iron.
 - f. Seat: **[EPDM] [or] [NBR] <Insert material>**.
- J. Class 300, Iron, Dual-Plate Check Valves with Resilient Seat:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [APCO Willamette Valve and Primer Corporation.](#)
 - b. [Val-Matic Valve & Manufacturing Corp.](#)
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Description:
 - a. Standard: API 594.
 - b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **500 psig** (3450 kPa).
 - c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **400 psig** (2760 kPa).
 - d. Body Design: Wafer, spring-loaded plates.
 - e. Body Material: ASTM A 395/A 395M or ASTM A 536, ductile iron.

- f. Seat: [EPDM] [or] [NBR] <Insert material>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside, before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide dielectric fittings wherever jointing dissimilar metals.
- C. Locate valves for easy access and provide separate support where necessary.
- D. Provide clearance for installation of insulation and access to valves and fittings.
- E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.
- F. Install valves with stems upright or horizontal, not inverted.
- G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of

fluid flow.

- H. Install valves in horizontal piping with stem at or above center of pipe.
- I. Install valves in position to allow full stem movement.
- J. Install check valves for proper direction of flow and as follows:
 - 1. Swing Check Valves: In horizontal position with hinge pin level.
 - 2. **[Center-Guided]** **[and]** **[Plate-Type]** Check Valves: In horizontal or vertical position, between flanges.
 - 3. Lift Check Valves: With stem upright and plumb.
- K. Install valve tags. Comply with requirements for valve tags and schedules in Section 230553 "Identification for HVAC Piping and Equipment."

3.4 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.5 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
 - 1. Pump-Discharge Check Valves:
 - a. **NPS 2 (DN 50)** and Smaller: Bronze swing check valves with **[bronze]** **[or]** **[nonmetallic]** disc.
 - b. **NPS 2-1/2 (DN 65)** and Larger: Iron swing check valves with lever and weight or with spring or iron, center-guided, **[metal]** **[or]** **[resilient]**-seat check valves.
- B. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- C. Select valves, except wafer types, with the following end connections:
 - 1. For Copper Tubing, **NPS 2 (DN 50)** and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules.
 - 2. For Copper Tubing, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 3. For Copper Tubing, **NPS 5 (DN 125)** and Larger: Flanged ends.
 - 4. For Steel Piping, **NPS 2 (DN 50)** and Smaller: Threaded ends.
 - 5. For Steel Piping, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 6. For Steel Piping, **NPS 5 (DN 125)** and Larger: Flanged ends.
 - 7. For Grooved-End **[Copper Tubing]** **[and]** **[Steel Piping]** except Steam and

Steam Condensate Piping: Valve ends may be grooved.

3.6 CHILLED-WATER VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Bronze Swing Check Valves: **[Class 125] [Class 150]**, **[bronze] [nonmetallic]** disc.

B. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron Valves, **NPS 2-1/2 to NPS 4** (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
2. Iron Swing Check Valves: **[Class 125] [Class 250]**, **[metal] [nonmetallic-to-metal]** seats.
3. Iron Swing Check Valves with Closure Control, **NPS 2-1/2 to NPS 12** (DN 65 to DN 300): **Class 125**, lever and **[spring] [weight]**.
4. Iron, Grooved-End Check Valves, **NPS 3 to NPS 12** (DN 80 to DN 300): 300 CWP.
5. Iron, Center-Guided Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]**, **[compact-wafer] [globe]**, **[metal] [resilient]** seat.
6. Iron, Plate-Type Check Valves: **[Class 125] [Class 250]** single plate; resilient seat.
7. Iron, Plate-Type Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]** dual plate; metal seat.
8. Iron, Plate-Type Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]** dual plate; resilient seat.

3.7 CONDENSER-WATER VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Bronze Swing Check Valves: **[Class 125] [Class 150]**, **[bronze] [nonmetallic]** disc.

B. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron Valves, **NPS 2-1/2 to NPS 4** (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
2. Iron Swing Check Valves: **[Class 125] [Class 250]**, **[metal] [nonmetallic-to-metal]** seats.
3. Iron Swing Check Valves with Closure Control, **NPS 2-1/2 to NPS 12** (DN 65 to DN 300): **Class 125**, lever and **[spring] [weight]**.
4. Iron, Grooved-End Check Valves, **NPS 3 to NPS 12** (DN 80 to DN 300): 300 CWP.
5. Iron, Center-Guided Check Valves, **NPS 2-1/2 to NPS 24** (DN 65 to DN 600): **[Class 125] [Class 150] [Class 250] [Class 300]**, **[metal] [resilient]** seat.
6. Iron, Plate-Type Check Valves: **[Class 125] [Class 250]** single plate; resilient

- seat.
- 7. Iron, Plate-Type Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]** dual plate; metal seat.
- 8. Iron, Plate-Type Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]** dual plate; resilient seat.

3.8 HEATING-WATER VALVE SCHEDULE

A. Pipe **NPS 2** (DN 50) and Smaller:

- 1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
- 2. Bronze Swing Check Valves: **[Class 125] [Class 150]**, **[bronze] [nonmetallic]** disc.

B. Pipe **NPS 2-1/2** (DN 65) and Larger:

- 1. Iron Valves, **NPS 2-1/2 to NPS 4** (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
- 2. Iron Swing Check Valves: **[Class 125] [Class 250]**, **[metal] [nonmetallic-to-metal]** seats.
- 3. Iron Swing Check Valves with Closure Control, **NPS 2-1/2 to NPS 12** (DN 65 to DN 300): Class 125, lever and **[spring] [weight]**.
- 4. Iron, Grooved-End Check Valves, **NPS 3 to NPS 12** (DN 80 to DN 300): 300 CWP.
- 5. Iron, Center-Guided Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]**, **[compact-wafer] [globe]**, **[metal] [resilient]** seat.
- 6. Iron, Plate-Type Check Valves: **[Class 125] [Class 250]** single plate; resilient seat.
- 7. Iron, Plate-Type Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]** dual plate; metal seat.
- 8. Iron, Plate-Type Check Valves: **[Class 125] [Class 150] [Class 250] [Class 300]** dual plate; resilient seat.

3.9 LOW-PRESSURE STEAM VALVE SCHEDULE (**15 PSIG** ([104 kPa]) OR LESS)

A. Pipe **NPS 2** (DN 50) and Smaller:

- 1. Bronze Swing Check Valves: **[Class 125] [Class 150]**, **[bronze] [nonmetallic]** disc.

B. Pipe **NPS 2-1/2** (DN 65) and Larger:

- 1. Iron Valves, **NPS 2-1/2 to NPS 4** (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
- 2. Iron Swing Check Valves: **[Class 125] [Class 250]**, **[metal] [nonmetallic-to-metal]** seats.
- 3. Iron Swing Check Valves with Closure Control, **NPS 2-1/2 to NPS 12** (DN 65 to DN 300): Class 125, lever and **[spring] [weight]**.

3.10 HIGH-PRESSURE STEAM VALVE SCHEDULE (MORE THAN 15 PSIG ([104 kPa]))

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze Swing Check Valves: [Class 125] [Class 150], [bronze] [nonmetallic] disc.

B. Pipe Sizes NPS 2-1/2 (DN 65) and Larger:

1. Iron Valves, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
2. Iron Swing Check Valves: [Class 125] [Class 250], [metal] [nonmetallic-to-metal] seats.
3. Iron Swing Check Valves with Closure Control, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): Class 125, lever and [spring] [weight].

3.11 STEAM-CONDENSATE VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze Swing Check Valves: [Class 125] [Class 150], [bronze] [nonmetallic] disc.

B. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron Valves, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
2. Iron Swing Check Valves: [Class 125] [Class 250], [metal] [nonmetallic-to-metal] seats.
3. Iron Swing Check Valves with Closure Control: Class 125, lever and [spring] [weight].

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230523.14

SECTION 230523.15 - GATE VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Bronze gate valves.
 - 2. Iron gate valves.
 - 3. Chainwheels.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. NRS: Nonrising stem.
- C. OS&Y: Outside screw and yoke.
- D. RS: Rising stem.
- E. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and accessory. Provide manufacturers catalog information. Indicate valve data and ratings.
 - 1. Include data substantiating that materials comply with requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual locations of valves.

C. EXTRA MATERIALS

1. Provide two repacking kits for each type and size valve.

1.6 QUALITY ASSURANCE

A. Valves: Manufacturer's name and pressure rating marked on valve body.

B. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, and weld ends.
3. Set gate valves closed to prevent rattling.

B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.

C. Use the following precautions during storage:

1. Maintain valve end protection.
2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
3. Provide temporary protective coating on cast iron and steel valves.
4. Provide temporary end caps and closures on fittings. Maintain in place until installation.
5. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

E. Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
1. ASME B1.20.1 for threads for threaded-end valves.
 2. ASME B16.1 for flanges on iron valves.
 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 4. ASME B16.18 for solder joint.
 5. ASME B31.1 for power piping valves.
 6. ASME B31.9 for building services piping valves.
- C. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- D. Bronze valves shall be made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are not permitted.
- E. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- F. Valve Sizes: Same as upstream piping unless otherwise indicated.
- G. RS Valves in Insulated Piping: With 2-inch (50-mm) stem extensions.
- H. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE GATE VALVES

- A. Class 125, NRS, Bronze Gate Valves:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. American Valve, Inc.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. Crane Co.; Crane Valve Group; Jenkins Valves.
 - d. Crane Co.; Crane Valve Group; Stockham Valves.

- e. [Hammond Valve.](#)
- f. [Kitz Corporation.](#)
- g. [The Macomb Groups.](#)
- h. [Milwaukee Valve Company.](#)
- i. [NIBCO INC.](#)
- j. [Powell Valves.](#)
- k. [Red-White Valve Corporation.](#)
- l. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- m. **<Insert manufacturer's name>.**
- n. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 1.
- b. CWP Rating: 200 psig (1380 kPa).
- c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
- d. Ends: Threaded[**or solder joint**].
- e. Stem: Bronze.
- f. Disc: Solid wedge; bronze.
- g. Packing: Asbestos free.
- h. Handwheel: Malleable iron[, **bronze, or aluminum**].

B. Class 125, RS, Bronze Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [American Valve, Inc.](#)
- b. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- c. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- d. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- e. [Hammond Valve.](#)
- f. [Kitz Corporation.](#)
- g. [The Macomb Groups.](#)
- h. [Milwaukee Valve Company.](#)
- i. [NIBCO INC.](#)
- j. [Powell Valves.](#)
- k. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- l. **<Insert manufacturer's name>.**
- m. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 2.
- b. CWP Rating: 200 psig (1380 kPa).
- c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
- d. Ends: Threaded[**or solder joint**].
- e. Stem: Bronze.
- f. Disc: Solid wedge; bronze.
- g. Packing: Asbestos free.

h. Handwheel: Malleable iron, bronze, or aluminum.

C. Class 150, NRS, Bronze Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Hammond Valve.](#)
- b. [Kitz Corporation.](#)
- c. [Milwaukee Valve Company.](#)
- d. [NIBCO INC.](#)
- e. [Powell Valves.](#)
- f. [Red-White Valve Corporation.](#)
- g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- h. **<Insert manufacturer's name>.**
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 1.
- b. CWP Rating: **300 psig** (2070 kPa).
- c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.
- d. Ends: Threaded.
- e. Stem: Bronze.
- f. Disc: Solid wedge; bronze.
- g. Packing: Asbestos free.
- h. Handwheel: Malleable iron, bronze, or aluminum.

D. Class 150, RS, Bronze Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- c. [Hammond Valve.](#)
- d. [Kitz Corporation.](#)
- e. [The Macomb Groups.](#)
- f. [Milwaukee Valve Company.](#)
- g. [NIBCO INC.](#)
- h. [Powell Valves.](#)
- i. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- j. **<Insert manufacturer's name>.**
- k. or approved equal.

2. Description:

- a. Standard: MSS SP-80, Type 2.
- b. CWP Rating: **300 psig** (2070 kPa).
- c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.

- d. Ends: Threaded.
- e. Stem: Bronze.
- f. Disc: Solid wedge; bronze.
- g. Packing: Asbestos free.
- h. Handwheel: Malleable iron[, **bronze, or aluminum**].

2.3 IRON GATE VALVES

A. Class 125, NRS, Iron Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- d. [Flo Fab Inc.](#)
- e. [Hammond Valve.](#)
- f. [Kitz Corporation.](#)
- g. [Legend Valve.](#)
- h. [The Macomb Groups.](#)
- i. [Milwaukee Valve Company.](#)
- j. [NIBCO INC.](#)
- k. [Powell Valves.](#)
- l. [Red-White Valve Corporation.](#)
- m. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- n. **<Insert manufacturer's name>.**
- o. or approved equal.

2. Description:

- a. Standard: MSS SP-70, Type I.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **200 psig** (1380 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **150 psig** (1035 kPa).
- d. Body Material: ASTM A 126, gray iron with bolted bonnet.
- e. Ends: Flanged.
- f. Trim: Bronze.
- g. Disc: Solid wedge.
- h. Packing and Gasket: Asbestos free.

B. Class 125, OS&Y, Iron Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Jenkins Valves.](#)
- c. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- d. [Flo Fab Inc.](#)

- e. [Hammond Valve.](#)
- f. [Kitz Corporation.](#)
- g. [Legend Valve.](#)
- h. [The Macomb Groups.](#)
- i. [Milwaukee Valve Company.](#)
- j. [NIBCO INC.](#)
- k. [Powell Valves.](#)
- l. [Red-White Valve Corporation.](#)
- m. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- n. **<Insert manufacturer's name>.**
- o. or approved equal.

2. Description:

- a. Standard: MSS SP-70, Type I.
- b. [NPS 2-1/2 to NPS 12 \(DN 65 to DN 300\)](#), CWP Rating: [200 psig \(1380 kPa\)](#).
- c. [NPS 14 to NPS 24 \(DN 350 to DN 600\)](#), CWP Rating: [150 psig \(1035 kPa\)](#).
- d. Body Material: ASTM A 126, gray iron with bolted bonnet.
- e. Ends: Flanged.
- f. Trim: Bronze.
- g. Disc: Solid wedge.
- h. Packing and Gasket: Asbestos free.

C. Class 250, NRS, Iron Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- c. [NIBCO INC.](#)
- d. **<Insert manufacturer's name>.**
- e. or approved equal.

2. Description:

- a. Standard: MSS SP-70, Type I.
- b. [NPS 2-1/2 to NPS 12 \(DN 65 to DN 300\)](#), CWP Rating: [500 psig \(3450 kPa\)](#).
- c. [NPS 14 to NPS 24 \(DN 350 to DN 600\)](#), CWP Rating: [300 psig \(2070 kPa\)](#).
- d. Body Material: ASTM A 126, gray iron with bolted bonnet.
- e. Ends: Flanged.
- f. Trim: Bronze.
- g. Disc: Solid wedge.
- h. Packing and Gasket: Asbestos free.

D. Class 250, OS&Y, Iron Gate Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Crane Co.; Crane Valve Group; Crane Valves.](#)
- b. [Crane Co.; Crane Valve Group; Stockham Valves.](#)
- c. [Hammond Valve.](#)
- d. [Milwaukee Valve Company.](#)
- e. [NIBCO INC.](#)
- f. [Powell Valves.](#)
- g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- h. **<Insert manufacturer's name>.**
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-70, Type I.
- b. [NPS 2-1/2 to NPS 12 \(DN 65 to DN 300\)](#), CWP Rating: [500 psig \(3450 kPa\)](#).
- c. [NPS 14 to NPS 24 \(DN 350 to DN 600\)](#), CWP Rating: [300 psig \(2070 kPa\)](#).
- d. Body Material: ASTM A 126, gray iron with bolted bonnet.
- e. Ends: Flanged.
- f. Trim: Bronze.
- g. Disc: Solid wedge.
- h. Packing and Gasket: Asbestos free.

2.4 CHAINWHEELS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Babbitt Steam Specialty Co.](#)
2. [Roto Hammer Industries.](#)
3. [Trumbull Industries.](#)
4. **<Insert manufacturer's name>.**
5. or approved equal.

B. Description: Valve actuation assembly with sprocket rim, chain guides, chain[, and **attachment brackets for mounting chainwheels directly to hand wheels**].

1. Sprocket Rim with Chain Guides: [**Ductile iron**] [**Ductile or cast iron**] [**Cast iron**] [**Aluminum**] [**Bronze**], of type and size required for valve.[**Include zinc or epoxy coating.**]
2. Chain: [**Hot-dip-galvanized steel**] [**Brass**] [**Stainless steel**], of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.

- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside, before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide dielectric fittings wherever jointing dissimilar metals.
- C. Locate valves for easy access and provide separate support where necessary.
- D. Provide clearance for installation of insulation and access to valves and fittings.
- E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.
- F. Install valves with stems upright or horizontal, not inverted.
- G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.
- H. Install valves in horizontal piping with stem at or above center of pipe.
- I. Install valves in position to allow full stem movement.
- J. Install chainwheels on operators for gate valves [NPS 4 (DN 100)] <Insert size> and larger and more than [96 inches (2400 mm)] <Insert dimension> above floor. Extend chains to [60 inches (1520 mm)] <Insert dimension> above finished floor.
- K. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.4 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.5 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
 - 1. Shutoff Service: Gate valves.
- B. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- C. Select valves, except wafer types, with the following end connections:
 - 1. For Copper Tubing, **NPS 2 (DN 50)** and Smaller: Threaded ends, except where solder-joint valve-end option is indicated in valve schedules below.
 - 2. For Copper Tubing, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends, except where threaded valve-end option is indicated in valve schedules below.
 - 3. For Copper Tubing, **NPS 5 (DN 125)** and Larger: Flanged ends.
 - 4. For Steel Piping, **NPS 2 (DN 50)** and Smaller: Threaded ends.
 - 5. For Steel Piping, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends, except where threaded valve-end option is indicated in valve schedules below.
 - 6. For Steel Piping, **NPS 5 (DN 125)** and Larger: Flanged ends.
 - 7. For Grooved-End [**Copper Tubing**] [**and**] [**Steel Piping**], except for Steam and Steam Condensate Piping: Valve ends may be grooved.

3.6 CHILLED-WATER VALVE SCHEDULE

- A. Pipe **NPS 2 (DN 50)** and Smaller: Bronze Valves, [**Class 125**] [**Class 150**], [**NRS**] [**RS**] with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron Gate Valves, [**Class 125**] [**Class 250**], [**NRS**] [**OS&Y**].

3.7 CONDENSER-WATER VALVE SCHEDULE

- A. Pipe **NPS 2 (DN 50)** and Smaller: Bronze Valves, [**Class 125**] [**Class 150**], [**NRS**] [**RS**] with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron Gate Valves, [**Class 125**] [**Class 250**], [**NRS**] [**OS&Y**].

3.8 HEATING-WATER VALVE SCHEDULE

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze Valves, [**Class 125**] [**Class 150**], [**NRS**] [**RS**] with [**soldered**] [**threaded**] ends.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron Gate Valves, [**Class 125**] [**Class 250**], [**NRS**] [**OS&Y**].

3.9 LOW-PRESSURE STEAM VALVE SCHEDULE (**15 PSIG** ([104 kPa])) OR LESS)

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze Gate Valves, [**Class 125**] [**Class 150**], [**NRS**] [**RS**].
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron Gate Valves, [**Class 125**] [**Class 250**], [**NRS**] [**OS&Y**].

3.10 HIGH-PRESSURE STEAM VALVE SCHEDULE (MORE THAN **15 PSIG** ([104 kPa]))

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze Gate Valves, [**Class 125**] [**Class 150**], [**NRS**] [**RS**], bronze.
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron Gate Valves, [**Class 125**] [**Class 250**], [**NRS**] [**OS&Y**].

3.11 STEAM-CONDENSATE VALVE SCHEDULE

- A. Pipe **NPS 2** (DN 50) and Smaller: Bronze Gate Valves, [**Class 125**] [**Class 150**], [**NRS**] [**RS**].
- B. Pipe **NPS 2-1/2** (DN 65) and Larger: Iron Gate Valves, [**Class 125**] [**Class 250**], [**NRS**] [**OS&Y**].
- C. MEASUREMENT

PART 4 - METHOD OF MEASUREMENT

- 4.1 No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230523.15

SECTION 230523.16 - PLUG VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Lubricated plug valves.
 - 2. Eccentric plug valves.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and accessory. Provide manufacturers catalog information. Indicate valve data and ratings.
 - 1. Include data substantiating that materials comply with requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of valves.

C. EXTRA MATERIALS

1. Provide two (2) repacking kits for each type and size valve.

1.6 QUALITY ASSURANCE

- A. Valves: Manufacturer's name and pressure rating marked on valve body.
- B. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 1. Protect internal parts against rust and corrosion.
 2. Protect threads, flange faces, grooves, and weld ends.
 3. Set plug valves open to minimize exposure of functional surfaces.
- B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- C. Use the following precautions during storage:
 1. Maintain valve end protection.
 2. Store valves indoors and maintain at higher-than-ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
 3. Provide temporary protective coating on cast iron and steel valves.
 4. Provide temporary end caps and closures on fittings. Maintain in place until installation.
 5. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.
- D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.1 for flanges on iron valves.
 - 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 4. ASME B31.1 for power piping valves.
 - 5. ASME B31.9 for building services piping valves.
- C. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- D. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- E. Valve Sizes: Same as upstream piping unless otherwise indicated.
- F. Valve Actuator Types: Wrench. Furnish Owner with one wrench for every **[five] [10]** **<Insert number>** plug valves, for each size square plug-valve head.

2.2 LUBRICATED PLUG VALVES

- A. Class 125, Lubricated Plug Valves with Threaded Ends:
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Nordstrom Valves, Inc.](#)
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
 - 2. Description:
 - a. Standard: MSS SP-78, Type I single gland.
 - b. **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**, CWP Rating: **200 psig (1380 kPa)**.
 - c. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
 - d. Pattern: **[Regular] [or] [short] [venturi]**.
 - e. Plug: Cast iron or bronze with sealant groove.
- B. Class 125, Lubricated Plug Valves with Flanged Ends:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Nordstrom Valves, Inc.](#)
 - b. **<Insert manufacturer's name>.**
 - c. or approved equal.
 2. Description:
 - a. Standard: MSS SP-78, **[Type I single gland] [or] [Type II regular gland]**.
 - b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **200 psig** (1380 kPa).
 - c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **150 psig** (1035 kPa).
 - d. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
 - e. Pattern: **[Regular] [or] [short] [venturi]**.
 - f. Plug: Cast iron or bronze with sealant groove.
- C. Class 125, Cylindrical, Lubricated Plug Valves with Threaded Ends:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [R & M Energy Systems; a unit of Robbins & Myers, Inc.](#)
 - b. **<Insert manufacturer's name>.**
 - c. or approved equal.
 2. Description:
 - a. Standard: MSS SP-78, Type IV.
 - b. **NPS 2-1/2 to NPS 4** (DN 65 to DN 100), CWP Rating: **200 psig** (1380 kPa).
 - c. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
 - d. Pattern: **[Regular] [or] [short] [venturi]**.
 - e. Plug: Cast iron or bronze with sealant groove.
- D. Class 125, Cylindrical, Lubricated Plug Valves with Flanged Ends:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [R & M Energy Systems; a unit of Robbins & Myers, Inc.](#)
 - b. **<Insert manufacturer's name>.**
 - c. or approved equal.
 2. Description:
 - a. Standard: MSS SP-78, Type IV.
 - b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **200 psig** (1380 kPa).
 - c. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
 - d. Pattern: **[Regular] [or] [short] [venturi]**.

e. Plug: Cast iron or bronze with sealant groove.

E. Class 250, Lubricated Plug Valves with Threaded Ends:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Nordstrom Valves, Inc.](#)
- b. **<Insert manufacturer's name>**.
- c. or approved equal.

2. Description:

- a. Standard: MSS SP-78, **[Type I single gland] [or] [Type II regular gland]**.
- b. **NPS 2-1/2 to NPS 4** (DN 65 to DN 100), CWP Rating: **400 psig** (2760 kPa).
- c. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
- d. Pattern: **[Regular] [or] [short] [venturi]**.
- e. Plug: Cast iron or bronze with sealant groove.

F. Class 250, Lubricated Plug Valves with Flanged Ends:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Nordstrom Valves, Inc.](#)
- b. **<Insert manufacturer's name>**.
- c. or approved equal.

2. Description:

- a. Standard: MSS SP-78, **[Type I single gland] [or] [Type II regular gland]**.
- b. **NPS 2-1/2 to NPS 12** (DN 65 to DN 300), CWP Rating: **400 psig** (2760 kPa).
- c. **NPS 14 to NPS 24** (DN 350 to DN 600), CWP Rating: **300 psig** (2070 kPa).
- d. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
- e. Pattern: **[Regular] [or] [short] [venturi]**.
- f. Plug: Cast iron or bronze with sealant groove.

G. Class 250, Cylindrical, Lubricated Plug Valves with Threaded Ends:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [R & M Energy Systems; a unit of Robbins & Myers, Inc.](#)
- b. **<Insert manufacturer's name>**.
- c. or approved equal.

2. Description:

- a. Standard: MSS SP-78, Type IV.

- b. [NPS 2-1/2 to NPS 4 \(DN 65 to DN 100\)](#), CWP Rating: **400 psig** (2760 kPa).
- c. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
- d. Pattern: [**Regular**] [**or**] [**short**] [**venturi**].
- e. Plug: Cast iron or bronze with sealant groove.

H. Class 250, Cylindrical, Lubricated Plug Valves with Flanged Ends:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [R & M Energy Systems; a unit of Robbins & Myers, Inc.](#)
- b. **<Insert manufacturer's name>**.
- c. or approved equal.

2. Description:

- a. Standard: MSS SP-78, Type IV.
- b. [NPS 2-1/2 to NPS 12 \(DN 65 to DN 300\)](#), CWP Rating: **400 psig** (2760 kPa).
- c. Body Material: ASTM A 48/A 48M or ASTM A 126, Grade 40 cast iron with lubrication-sealing system.
- d. Pattern: [**Regular**] [**or**] [**short**] [**venturi**].
- e. Plug: Cast iron or bronze with sealant groove.

2.3 ECCENTRIC PLUG VALVES

A. 175 CWP, Eccentric Plug Valves with Resilient Seating.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Clow Valve Co.; a division of McWane, Inc.](#)
- b. [DeZurik Water Controls.](#)
- c. [Henry Pratt Company.](#)
- d. [Homestead Valve; a division of Olson Technologies, Inc.](#)
- e. [M & H Valve Company; a division of McWane, Inc.](#)
- f. [Milliken Valve Company.](#)
- g. [Val-Matic Valve & Manufacturing Corp.](#)
- h. **<Insert manufacturer's name>**.
- i. or approved equal.

2. Description:

- a. Standard: MSS SP-108.
- b. CWP Rating: **175 psig** (1200 kPa) minimum.
- c. Body and Plug: ASTM A 48/A 48M, gray iron; ASTM A 126, gray iron; or ASTM A 536, ductile iron.
- d. Bearings: Oil-impregnated bronze or stainless steel.
- e. Ends: Flanged.

- f. Stem-Seal Packing: Asbestos free.
- g. Plug, Resilient-Seating Material: Suitable for potable-water service unless otherwise indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside, before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide dielectric fittings wherever jointing dissimilar metals.
- C. Locate valves for easy access and provide separate support where necessary.
- D. Provide clearance for installation of insulation and access to valves and fittings.
- E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.
- F. Install valves with stems upright or horizontal, not inverted.

- G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.
- H. Install valves in horizontal piping with stem at or above center of pipe.
- I. Install valves in position to allow full stem movement.
- J. Install chainwheels on operators for plug valves [NPS 4 (DN 100)] <Insert pipe size> and larger and more than [96 inches (2400 mm)] <Insert dimension> above floor. Extend chains to [60 inches (1520 mm)] <Insert dimension> above finished floor.
- K. Install valve tags. Comply with requirements for valve tags and schedules in Section 230553 "Identification for HVAC Piping and Equipment."

3.4 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.5 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
 - 1. Shutoff Service: Plug valves.
- B. If valves with CWP ratings are unavailable, the same types of valves with higher CWP ratings may be substituted.
- C. Select valves with the following end connections:
 - 1. For Copper Tubing, NPS 2 (DN 50) and Smaller: Threaded ends.
 - 2. For Copper Tubing, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 3. For Copper Tubing, NPS 5 (DN 125) and Larger: Flanged ends.
 - 4. For Steel Piping, NPS 2 (DN 50) and Smaller: Threaded ends.
 - 5. For Steel Piping, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 6. For Steel Piping, NPS 5 (DN 125) and Larger: Flanged ends.
 - 7. For Grooved-End [Copper Tubing] [and] [Steel Piping] except Steam and Steam Condensate Piping: Valve ends may be grooved.

3.6 HOT-WATER AND CHILLED-WATER VALVE SCHEDULE

- A. Pipe NPS 2-1/2 (DN 65) and Larger:
 - 1. Lubricated Plug Valves: [Class 125] [Class 250], [regular gland] [cylindrical], [threaded] [flanged].

2. Eccentric Plug Valves: 175 CWP, resilient seating.

3.7 CONDENSER-WATER VALVE SCHEDULE

- A. Pipe **NPS 2-1/2 (DN 65)** and Larger: Lubricated plug valves, **[Class 125] [Class 250]**, **[regular gland] [cylindrical], [threaded] [flanged]**.

3.8 STEAM-CONDENSATE VALVE SCHEDULE

- A. Pipe **NPS 2-1/2 (DN 65)** and Larger: Lubricated plug valves, **[Class 125] [Class 250]**, **[regular gland] [cylindrical], [threaded] [flanged]**.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230523.16

SECTION 230529 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Metal pipe hangers and supports.
2. Trapeze pipe hangers.
3. Fiberglass pipe hangers.
4. Metal framing systems.
5. Fiberglass strut systems.
6. Thermal-hanger shield inserts.
7. Fastener systems.
8. Pipe stands.
9. Equipment supports.

B. Related Sections:

1. Section 055000 "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Section 230516 "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
3. **[Section 230548 "Vibration and Seismic Controls for HVAC"] [Section 230548.13 "Vibration Controls for HVAC"]** for vibration isolation devices.
4. **[Section 233113 "Metal Ducts"] [and] [Section 233116 "Nonmetal Ducts"]** for duct hangers and supports.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. MSS: Manufacturers Standardization Society of The Valve and Fittings Industry Inc.

1.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design trapeze pipe hangers and equipment supports, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Structural Performance: Hangers and supports for HVAC piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to [ASCE/SEI 7] <Insert requirement>.
 - 1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
 - 2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
 - 3. Design seismic-restraint hangers and supports for piping and equipment[**and obtain approval from authorities having jurisdiction**].

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated, including the following:
 - 1. Steel pipe hangers and supports.
 - 2. Thermal-hanger shield inserts.
 - 3. Powder-actuated fastener systems.
 - 4. Pipe positioning systems.
 - 5. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:[**Signed and sealed by a qualified professional engineer.**] Show fabrication and installation details and include calculations for the following; include Product Data for components:
 - 1. Trapeze pipe hangers.
 - 2. Metal framing systems.
 - 3. Pipe stands.
 - 4. Equipment supports.
- C. Delegated-Design Submittal: For trapeze hangers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 - 1. Detail fabrication and assembly of trapeze hangers.
 - 2. Design Calculations: Calculate requirements for designing trapeze hangers.

1.6 INFORMATIONAL SUBMITTALS

- A. Welding certificates.

1.7 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 QUALITY ASSURANCE

- A. Structural Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 METAL PIPE HANGERS AND SUPPORTS

- A. Carbon-Steel Pipe Hangers and Supports:
 - 1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
 - 2. Galvanized Metallic Coatings: Pregalvanized or hot dipped.
 - 3. Nonmetallic Coatings: Plastic coating, jacket, or liner.
 - 4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
 - 5. Hanger Rods: Continuous-thread rod, nuts, and washer made of [**carbon steel**] [**stainless steel**] <Insert material>.
- B. Stainless-Steel Pipe Hangers and Supports:
 - 1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
 - 2. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
 - 3. Hanger Rods: Continuous-thread rod, nuts, and washer made of [**stainless steel**] <Insert material>.

2.2 TRAPEZE PIPE HANGERS

- A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

2.3 METAL FRAMING SYSTEMS

- A. MFMA Manufacturer Metal Framing Systems:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Allied Tube & Conduit.](#)
 - b. [Cooper B-Line, Inc.](#)
 - c. [Flex-Strut Inc.](#)
 - d. [GS Metals Corp.](#)
 - e. [Thomas & Betts Corporation.](#)
 - f. [Unistrut Corporation](#); Tyco International, Ltd.
 - g. [Wesanco, Inc.](#)
 - h. **<Insert manufacturer's name>.**
 - i. or approved equal.
2. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
3. Standard: MFMA-4.
4. Channels: Continuous slotted steel channel with inturned lips.
5. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
6. Hanger Rods: Continuous-thread rod, nuts, and washer made of [**carbon steel**] [**stainless steel**] **<Insert material>.**
7. Metallic Coating: [**Electroplated zinc**] [**Hot-dipped galvanized**] [**Mill galvanized**] [**In-line, hot galvanized**] [**Mechanically-deposited zinc**].
8. Paint Coating: [**Vinyl**] [**Vinyl alkyd**] [**Epoxy**] [**Polyester**] [**Acrylic**] [**Amine**] [**Alkyd**] **<Insert paint type>.**
9. Plastic Coating: [**PVC**] [**Polyurethane**] [**Epoxy**] [**Polyester**] **<Insert plastic type>.**
10. Combination Coating: **<Insert coating materials in order of application>.**

2.4 THERMAL-HANGER SHIELD INSERTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Carpenter & Paterson, Inc.](#)
2. [Clement Support Services.](#)
3. [ERICO International Corporation.](#)
4. [National Pipe Hanger Corporation.](#)

5. [PHS Industries, Inc.](#)
6. [Pipe Shields, Inc.](#); a subsidiary of Piping Technology & Products, Inc.
7. [Piping Technology & Products, Inc.](#)
8. [Rilco Manufacturing Co., Inc.](#)
9. [Value Engineered Products, Inc.](#)
10. <Insert manufacturer's name>.

- B. Insulation-Insert Material for Cold Piping: [**ASTM C 552, Type II cellular glass with 100-psig (688-kPa)**] [**or**] [**ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa)**] minimum compressive strength and vapor barrier.
- C. Insulation-Insert Material for Hot Piping: [**Water-repellent treated, ASTM C 533, Type I calcium silicate with 100-psig (688-kPa)**] [**ASTM C 552, Type II cellular glass with 100-psig (688-kPa)**] [**or**] [**ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa)**] minimum compressive strength.
- D. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
- E. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
- F. Insert Length: Extend **2 inches (50 mm)** beyond sheet metal shield for piping operating below ambient air temperature.

2.5 FASTENER SYSTEMS

- A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hilti, Inc.
 - b. ITW Ramset/Red Head.
 - c. or approved equal.
- B. Mechanical-Expansion Anchors: Insert-wedge-type, [**zinc-coated**] [**stainless-**] steel anchors, for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. B-Line Systems, Inc.; a division of Cooper Industries.
 - b. Hilti, Inc.
 - c. ITW Ramset/Red Head.

2.6 PIPE STANDS

- A. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.
- B. Compact Pipe Stand: One-piece plastic unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
- C. Low-Type, Single-Pipe Stand: One-piece **[plastic] [stainless-steel]** base unit with plastic roller, for roof installation without membrane penetration.
- D. High-Type, Single-Pipe Stand:
1. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
 2. Base: **[Plastic] [Stainless steel]**.
 3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
 4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.
 5. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. ERICO/Michigan Hanger Co.
 - b. MIRO Industries.
 - c. Portable Pipe Hangers.
- E. High-Type, Multiple-Pipe Stand:
1. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
 2. Bases: One or more; plastic.
 3. Vertical Members: Two or more protective-coated-steel channels.
 4. Horizontal Member: Protective-coated-steel channel.
 5. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.
 6. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Portable Pipe Hangers.
 - b. or approved equal.
- F. Curb-Mounted-Type Pipe Stands: Shop- or field-fabricated pipe supports made from structural-steel shapes, continuous-thread rods, and rollers, for mounting on permanent stationary roof curb.

2.7 EQUIPMENT SUPPORTS

- A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

2.8 MISCELLANEOUS MATERIALS

- A. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; black and galvanized.
- B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
 - 1. Properties: Nonstaining, noncorrosive, and nongaseous.
 - 2. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

- A. Metal Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.
- B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.
 - 1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.
 - 2. Field fabricate from ASTM A 36/A 36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.
- C. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.
- D. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.
- E. Fastener System Installation:
 - 1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
 - 2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.
- F. Pipe Stand Installation:

1. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
 2. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Section 077200 "Roof Accessories" for curbs.
- G. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.
- H. Equipment Support Installation: Fabricate from welded-structural-steel shapes.
- I. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
- J. Install lateral bracing with pipe hangers and supports to prevent swaying.
- K. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, [NPS 2-1/2 (DN 65)] <Insert size> and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.
- L. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
- M. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.
- N. Insulated Piping:
1. Attach clamps and spacers to piping.
 - a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
 - b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
 - c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
 2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
 - a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.
 3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.

- a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe **NPS 4 (DN 100)** and larger if pipe is installed on rollers.
4. Shield Dimensions for Pipe: Not less than the following:
 - a. **NPS 1/4 to NPS 3-1/2 (DN 8 to DN 90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.**
 - b. **NPS 4 (DN 100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.**
 - c. **NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.**
 - d. **NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches (610 mm) long and 0.075 inch (1.91 mm) thick.**
 - e. **NPS 16 to NPS 24 (DN 400 to DN 600): 24 inches (610 mm) long and 0.105 inch (2.67 mm) thick.**
5. Pipes **NPS 8 (DN 200)** and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
6. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.2 EQUIPMENT SUPPORTS

- A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.
- B. Grouting: Place grout under supports for equipment and make bearing surface smooth.
- C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.3 METAL FABRICATIONS

- A. Cut, drill, and fit miscellaneous metal fabrications for **[trapeze pipe hangers] [and] [equipment supports]**.
- B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
- C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
 1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 2. Obtain fusion without undercut or overlap.
 3. Remove welding flux immediately.

4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.4 ADJUSTING

- A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.
- B. Trim excess length of continuous-thread hanger and support rods to [1-1/2 inches (40 mm)] <Insert dimension>.

3.5 PAINTING

- A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
 1. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils (0.05 mm).
- B. Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in [**Section 099113 "Exterior Painting"**] [**Section 099123 "Interior Painting"**] [**and**] [**Section 099600 "High Performance Coatings."**]
- C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

3.6 HANGER AND SUPPORT APPLICATIONS AND SCHEDULE

- A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
- B. Comply with MSS SP-69 for pipe-hanger selections and applications that are not specified in piping system Sections.
- C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.
- D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.
- E. Use carbon-steel [**pipe hangers and supports**] [**metal trapeze pipe hangers**] [**and**] [**metal framing systems**] and attachments for general service applications.

- F. Use **[stainless-steel pipe hangers] fiberglass strut systems** and **[stainless-steel] [or] [corrosion-resistant]** attachments for hostile environment applications.
- G. Use padded hangers for piping that is subject to scratching.
- H. Use thermal-hanger shield inserts for insulated piping and tubing.
- I. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes **NPS 1/2 to NPS 30** (DN 15 to DN 750).
 2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to **1050 deg F** (566 deg C), pipes **NPS 4 to NPS 24** (DN 100 to DN 600), requiring up to **4 inches** (100 mm) of insulation.
 3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes **NPS 3/4 to NPS 36** (DN 20 to DN 900), requiring clamp flexibility and up to **4 inches** (100 mm) of insulation.
 4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes **NPS 1/2 to NPS 24** (DN 15 to DN 600) if little or no insulation is required.
 5. Pipe Hangers (MSS Type 5): For suspension of pipes **NPS 1/2 to NPS 4** (DN 15 to DN 100), to allow off-center closure for hanger installation before pipe erection.
 6. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated, stationary pipes **NPS 3/4 to NPS 8** (DN 20 to DN 200).
 7. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated, stationary pipes **NPS 1/2 to NPS 8** (DN 15 to DN 200).
 8. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated, stationary pipes **NPS 1/2 to NPS 8** (DN 15 to DN 200).
 9. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated, stationary pipes **NPS 1/2 to NPS 8** (DN 15 to DN 200).
 10. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of noninsulated, stationary pipes **NPS 3/8 to NPS 8** (DN 10 to DN 200).
 11. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes **NPS 3/8 to NPS 3** (DN 10 to DN 80).
 12. U-Bolts (MSS Type 24): For support of heavy pipes **NPS 1/2 to NPS 30** (DN 15 to DN 750).
 13. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
 14. Pipe Saddle Supports (MSS Type 36): For support of pipes **NPS 4 to NPS 36** (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
 15. Pipe Stanchion Saddles (MSS Type 37): For support of pipes **NPS 4 to NPS 36** (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, and with U-bolt to retain pipe.
 16. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes **NPS 2-1/2 to NPS 36** (DN 65 to DN 900) if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.

17. Single-Pipe Rolls (MSS Type 41): For suspension of pipes **NPS 1 to NPS 30** (DN 25 to DN 750), from two rods if longitudinal movement caused by expansion and contraction might occur.
 18. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes **NPS 2-1/2 to NPS 24** (DN 65 to DN 600), from single rod if horizontal movement caused by expansion and contraction might occur.
 19. Complete Pipe Rolls (MSS Type 44): For support of pipes **NPS 2 to NPS 42** (DN 50 to DN 1050) if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
 20. Pipe Roll and Plate Units (MSS Type 45): For support of pipes **NPS 2 to NPS 24** (DN 50 to DN 600) if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
 21. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes **NPS 2 to NPS 30** (DN 50 to DN 750) if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.
- J. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers **NPS 3/4 to NPS 24** (DN 24 to DN 600).
 2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers **NPS 3/4 to NPS 24** (DN 20 to DN 600) if longer ends are required for riser clamps.
- K. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel Turnbuckles (MSS Type 13): For adjustment up to **6 inches** (150 mm) for heavy loads.
 2. Steel Clevises (MSS Type 14): For **120 to 450 deg F** (49 to 232 deg C) piping installations.
 3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
 4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
 5. Steel Weldless Eye Nuts (MSS Type 17): For **120 to 450 deg F** (49 to 232 deg C) piping installations.
- L. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
 2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joint construction, to attach to top flange of structural shape.
 3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
 4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.

5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
 6. C-Clamps (MSS Type 23): For structural shapes.
 7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
 8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
 9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
 10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
 11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
 12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
 - a. Light (MSS Type 31): 750 lb (340 kg).
 - b. Medium (MSS Type 32): 1500 lb (680 kg).
 - c. Heavy (MSS Type 33): 3000 lb (1360 kg).
 13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
 14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
 15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.
- M. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
 2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
 3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.
- N. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
 2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches (32 mm).
 3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
 4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
 5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.

6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
 7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
 8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
 - a. Horizontal (MSS Type 54): Mounted horizontally.
 - b. Vertical (MSS Type 55): Mounted vertically.
 - c. Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.
- O. Comply with MSS SP-69 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.
- P. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.
- Q. Use [**powder-actuated fasteners**] [or] [**mechanical-expansion anchors**] instead of building attachments where required in concrete construction.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230529

SECTION 230533 - HEAT TRACING FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes heat tracing for HVAC piping with the following electric heating cables:
 - 1. Plastic insulated, series resistance.
 - 2. Self-regulating, parallel resistance.
- B. Related Requirements:
 - 1. Section 210533 "Heat Tracing for Fire-Suppression Piping."
 - 2. Section 220533 "Heat Tracing for Plumbing Piping."
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 2. Schedule heating capacity, length of cable, spacing, and electrical power requirement for each electric heating cable required.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For electric heating cable.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

- B. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electric heating cables to include in operation and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.
1. Warranty Period: Minimum [**Three (3)**] [**Five (5)**] <Insert number> years from date of Substantial Completion.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PLASTIC-INSULATED, SERIES-RESISTANCE HEATING CABLES

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. Delta-Therm Corporation.
 2. Easy Heat; a division of EGS Electrical Group LLC.
 3. Orbit Manufacturing.
 4. Pyrotenax; a brand of Tyco Thermal Controls LLC.
 5. Raychem; a brand of Tyco Thermal Controls LLC.
 6. Watts Radiant, Inc.; a subsidiary of Watts Water Technologies, Inc.
 7. <Insert manufacturer's name>.
 8. or approved equal.
- B. Comply with IEEE 515.1.
- C. Heating Element: Single- or dual-stranded resistor wire. Terminate with waterproof, factory-assembled, nonheating leads with connectors at both ends.

- D. Electrical Insulating Jacket: Minimum 4.0-mil (0.10-mm) Kapton with silicone, Tefzel, or polyolefin.
- E. Cable Cover: Aluminum braid[**and silicone or Hylar outer jacket**].
- F. Maximum Operating Temperature (Power On): [150 deg F (65 deg C)] **<Insert temperature>**.
- G. Maximum Exposure Temperature (Power Off): [185 deg F (85 deg C)] **<Insert temperature>**.
- H. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- I. Capacities and Characteristics:
 - 1. Maximum Heat Output: [6 W/ft. (19.7 W/m)] [7.5 W/ft. (24.6 W/m)] maximum **<Insert value>**.
 - 2. Piping Diameter: **<Insert NPS (DN)>**.
 - 3. Number of Parallel Cables: **<Insert number>**.
 - 4. Spiral Wrap Pitch: **<Insert inches (mm)>**.
 - 5. Electrical Characteristics for Single-Circuit Connection:
 - a. Volts: [120] [208] [240] [277] [480] **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.2 SELF-REGULATING, PARALLEL-RESISTANCE HEATING CABLES

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. BriskHeat.
 - 2. Chromalox.
 - 3. Delta-Therm Corporation.
 - 4. Easy Heat; a division of EGS Electrical Group LLC.
 - 5. Pyrotenax; a brand of Tyco Thermal Controls LLC.
 - 6. Raychem; a brand of Tyco Thermal Controls LLC.
 - 7. Thermon Americas Inc.
 - 8. Trasor Corp.
 - 9. **<Insert manufacturer's name>**.
 - 10. or approved equal.
- B. Comply with IEEE 515.1.

- C. Heating Element: Pair of parallel **[No. 16] [No. 18]** AWG, **[tinned] [nickel-coated]**, stranded copper bus wires embedded in crosslinked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled, nonheating leads with connectors at one end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.
- D. Electrical Insulating Jacket: Flame-retardant polyolefin.
- E. Cable Cover: **[Tinned-copper] [Stainless-steel]** braid **[and polyolefin outer jacket with ultraviolet inhibitor]**.
- F. Maximum Operating Temperature (Power On): **[150 deg F (65 deg C)] <Insert temperature>**.
- G. Maximum Exposure Temperature (Power Off): **[185 deg F (85 deg C)] <Insert temperature>**.
- H. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- I. Capacities and Characteristics:
 - 1. Maximum Heat Output: **[3 W/ft. (9.8 W/m)] [5 W/ft. (16.4 W/m)] [8 W/ft. (26 W/m)] [10 W/ft. (32.8 W/m)] [12 W/ft. (39.4 W/m)] <Insert value>**.
 - 2. Piping Diameter: **<Insert NPS (DN)>**.
 - 3. Number of Parallel Cables: **<Insert number>**.
 - 4. Spiral Wrap Pitch: **<Insert inches (mm)>**.
 - 5. Electrical Characteristics for Single-Circuit Connection:
 - a. Volts: **[120] [208] [240] [277] [480] <Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 CONTROLS

- A. Remote bulb unit with adjustable temperature range from **[30 to 50 deg F (minus 1 to plus 10 deg C)] <Insert temperature range>**.
- B. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected cable.
- C. Remote bulb on capillary, resistance temperature device, or thermistor for directly sensing pipe-wall temperature.
- D. Corrosion-resistant, waterproof control enclosure.

2.4 ACCESSORIES

- A. Cable Installation Accessories: Fiberglass tape, heat-conductive putty, cable ties, silicone end seals and splice kits, and installation clips all furnished by manufacturer, or as recommended in writing by manufacturer.
- B. Warning Labels: Refer to Section 230553 "Identification for HVAC Piping and Equipment."
- C. Warning Tape: Continuously printed "Electrical Tracing"; vinyl, at least 3 mils (0.08 mm) thick, and with pressure-sensitive, permanent, waterproof, self-adhesive back.
 - 1. Width for Markers on Pipes with OD, Including Insulation, Less Than 6 Inches (150 mm): 3/4 inch (19 mm) minimum.
 - 2. Width for Markers on Pipes with OD, Including Insulation, 6 Inches (150 mm) or Larger: 1-1/2 inches (38 mm) minimum.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine surfaces and substrates to receive electric heating cables for compliance with requirements for installation tolerances and other conditions affecting performance.
 - 1. Ensure surfaces and pipes in contact with electric heating cables are free of burrs and sharp protrusions.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install electric heating cable across expansion joints according to manufacturer's written instructions; use slack cable to allow movement without damage to cable.
- B. Install electric heating cables after piping has been tested and before insulation is installed.
- C. Install electric heating cables according to IEEE 515.1.
- D. Install insulation over piping with electric cables according to Section 230719 "HVAC Piping Insulation."
- E. Install warning tape on piping insulation where piping is equipped with electric heating cables.
- F. Set field-adjustable switches and circuit-breaker trip ranges.

3.3 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Perform tests after cable installation but before application of coverings such as insulation, wall or ceiling construction, or concrete.
 - 2. Test cables for electrical continuity and insulation integrity before energizing.
 - 3. Test cables to verify rating and power input. Energize and measure voltage and current simultaneously.
- D. Repeat tests for continuity, insulation resistance, and input power after applying thermal insulation on pipe-mounted cables.
- E. Cables will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

3.5 PROTECTION

- A. Protect installed heating cables, including nonheating leads, from damage during construction.
- B. Remove and replace damaged heat-tracing cables.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230533

SECTION 230548.13 - VIBRATION CONTROLS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Elastomeric isolation pads.
2. Elastomeric isolation mounts.
3. Restrained elastomeric isolation mounts.
4. Open-spring isolators.
5. Housed-spring isolators.
6. Restrained-spring isolators.
7. Housed-restrained-spring isolators.
8. Pipe-riser resilient supports.
9. Resilient pipe guides.
10. Air-spring isolators.
11. Restrained-air-spring isolators.
12. Elastomeric hangers.
13. Spring hangers.
14. Vibration isolation equipment bases.
15. Restrained isolation roof-curb rails.

- B. Related Requirements:

1. Section 210548.13 "Vibration Controls for Fire Suppression" for devices for fire-suppression equipment and systems.
2. Section 220548.13 "Vibration Controls for Plumbing" for devices for plumbing equipment and systems.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.

2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device type required.
3. Include data substantiating that materials comply with requirements.

B. Shop Drawings:

1. Detail fabrication and assembly of equipment bases. Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
3. Include static and dynamic loads on each component on drawings.

C. Delegated-Design Submittal: For each vibration isolation device.

1. Include design calculations for selecting vibration isolators and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Show coordination of vibration isolation device installation for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and restraints, if any.
- B. Qualification Data: For testing agency.
- C. Welding certificates.
- D. Air-Mounting System Performance Certification: Include natural frequency, load, and damping test data[**performed by an independent agency**].

1.5 CLOSEOUT SUBMITTALS

- A. Manufacturer's Certificate: Certify that isolators are properly installed and adjusted to meet or exceed specified requirements.
- B. Operation and Maintenance Data: For [**air-spring mounts**] [**and**] [**restrained-air-spring mounts**] to include in operation and maintenance manuals.
- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Record actual locations of hangers including attachment points.

1.6 QUALITY ASSURANCE

- A. Maintain ASHRAE criteria for average noise criteria curves for all equipment at full load condition.
- B. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 ELASTOMERIC ISOLATION PADS

- A. Elastomeric Isolation Pads: **<Insert drawing designation>**.
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
 - 2. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
 - 3. Size: Factory or field cut to match requirements of supported equipment.
 - 4. Pad Material: Oil and water resistant with elastomeric properties.
 - 5. Surface Pattern: **[Smooth] [Ribbed] [Waffle]** pattern.
 - 6. Infused nonwoven cotton or synthetic fibers.
 - 7. Load-bearing metal plates adhered to pads.
 - 8. Sandwich-Core Material: **[Resilient] [and] [elastomeric] <Insert compound>**.
 - a. Surface Pattern: **[Smooth] [Ribbed] [Waffle]** pattern.
 - b. Infused nonwoven cotton or synthetic fibers.

2.2 ELASTOMERIC ISOLATION MOUNTS

A. Double-Deflection, Elastomeric Isolation Mounts: <Insert drawing designation>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Ace Mountings Co., Inc.
- b. California Dynamics Corporation.
- c. Isolation Technology, Inc.
- d. Kinetics Noise Control, Inc.
- e. Mason Industries, Inc.
- f. Vibration Eliminator Co., Inc.
- g. Vibration Isolation.
- h. Vibration Mountings & Controls, Inc.
- i. <Insert manufacturer's name>.
- j. or approved equal.

2. Mounting Plates:

- a. Top Plate: Encapsulated steel load transfer top plates, factory drilled and threaded[**with threaded studs or bolts**].
- b. Baseplate: Encapsulated steel bottom plates with holes provided for anchoring to support structure.

3. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.3 RESTRAINED ELASTOMERIC ISOLATION MOUNTS

A. Restrained Elastomeric Isolation Mounts: <Insert drawing designation>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Ace Mountings Co., Inc.
- b. California Dynamics Corporation.
- c. Isolation Technology, Inc.
- d. Kinetics Noise Control, Inc.
- e. Mason Industries, Inc.
- f. Vibration Eliminator Co., Inc.
- g. Vibration Isolation.
- h. Vibration Mountings & Controls, Inc.
- i. <Insert manufacturer's name>.
- j. or approved equal.

2. Description: All-directional isolator with restraints containing two separate and opposing elastomeric elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

- a. Housing: Cast-ductile iron or welded steel.
- b. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.4 OPEN-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators: <Insert drawing designation>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Ace Mountings Co., Inc.
- b. California Dynamics Corporation.
- c. Isolation Technology, Inc.
- d. Kinetics Noise Control, Inc.
- e. Mason Industries, Inc.
- f. Vibration Eliminator Co., Inc.
- g. Vibration Isolation.
- h. Vibration Mountings & Controls, Inc.
- i. <Insert manufacturer's name>.
- j. or approved equal.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Baseplates: Factory-drilled steel plate for bolting to structure with an elastomeric isolator pad attached to the underside. Baseplates shall limit floor load to 500 psig (3447 kPa).
7. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

2.5 HOUSED-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators in Two-Part Telescoping Housing: <Insert drawing designation>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Ace Mountings Co., Inc.
- b. California Dynamics Corporation.
- c. Isolation Technology, Inc.
- d. Kinetics Noise Control, Inc.
- e. Mason Industries, Inc.
- f. Vibration Eliminator Co., Inc.

- g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.
 - i. <Insert manufacturer's name>.
 - j. or approved equal.
- 2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
- 3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
- 4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
- 5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
- 6. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators.
 - a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig (3447 kPa).
 - b. Top housing with [attachment and leveling bolt] [threaded mounting holes and internal leveling device] [elastomeric pad].

2.6 RESTRAINED-SPRING ISOLATORS

- A. Freestanding, Laterally Stable, Open-Spring Isolators with Vertical-Limit Stop Restraint: <Insert drawing designation>.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.
 - i. <Insert manufacturer's name>.
 - j. or approved equal.
 - 2. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.
 - a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig (3447 kPa).
 - b. Top plate with [threaded mounting holes] [elastomeric pad].
 - c. Internal leveling bolt that acts as blocking during installation.
 - 3. Restraint: Limit stop as required for equipment and authorities having jurisdiction.

4. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
5. Minimum Additional Travel: 50 percent of the required deflection at rated load.
6. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
7. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.7 HOUSED-RESTRAINED-SPRING ISOLATORS

- A. Freestanding, Steel, Open-Spring Isolators with Vertical-Limit Stop Restraint in Two-Part Telescoping Housing: **<Insert drawing designation>**.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Ace Mountings Co., Inc.](#)
 - b. [California Dynamics Corporation.](#)
 - c. [Isolation Technology, Inc.](#)
 - d. [Kinetics Noise Control, Inc.](#)
 - e. [Mason Industries, Inc.](#)
 - f. [Vibration Eliminator Co., Inc.](#)
 - g. [Vibration Isolation.](#)
 - h. [Vibration Mountings & Controls, Inc.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
 2. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators. Housings are equipped with **[adjustable]** **[non-adjustable]** snubbers to limit vertical movement.
 - a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig (3447 kPa).
 - b. Threaded top housing with adjustment bolt and cap screw to fasten and level equipment.
 3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
 4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
 5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.8 PIPE-RISER RESILIENT SUPPORT

- A. Description: All-directional, acoustical pipe anchor consisting of two steel tubes separated by a minimum **1/2-inch-** (13-mm-) thick neoprene **<Insert drawing designation>**.

1. Vertical-Limit Stops: Steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions.
2. Maximum Load Per Support: **500 psig** (3.45 MPa) on isolation material providing equal isolation in all directions.

2.9 RESILIENT PIPE GUIDES

- A. Description: Telescopic arrangement of two steel tubes or post and sleeve arrangement separated by a minimum **1/2-inch-** (13-mm-) thick neoprene **<Insert drawing designation>**.
1. Factory-Set Height Guide with Shear Pin: Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.10 AIR-SPRING ISOLATORS

- A. Freestanding, Single or Multiple, Compressed-Air Bellows: **<Insert drawing designation>**.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. **Firestone Industrial Products Company.**
 - b. **Mason Industries, Inc.**
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Bellows Assembly: Upper and lower powder-coated steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows or similar elastomeric material.
 3. Maximum Natural Frequency: 3 Hz.
 4. Operating Pressure Range: **25 to 100 psig** (172 to 690 kPa).
 5. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
 6. Tank valves.

2.11 RESTRAINED-AIR-SPRING ISOLATORS

- A. Freestanding, Single or Multiple, Compressed-Air Bellows with Vertical-Limit Stop Restraint: **<Insert drawing designation>**.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. **Firestone Industrial Products Company.**
 - b. **Mason Industries, Inc.**
 - c. **<Insert manufacturer's name>**.

- d. or approved equal.
2. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.
 - a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to **500 psig** (3447 kPa).
 - b. Top plate with **[threaded mounting holes] [elastomeric pad]**.
 - c. Internal leveling bolt that acts as blocking during installation.
3. Restraint: Limit stop as required for equipment and authorities having jurisdiction.
4. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
5. Minimum Additional Travel: 50 percent of the required deflection at rated load.
6. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
7. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
8. Bellows Assembly: Upper and lower powder-coated steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows or similar elastomeric material.
9. Maximum Natural Frequency: 3 Hz.
10. Operating Pressure Range: **25 to 100 psig** (172 to 690 kPa).
11. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
12. Tank valves.

2.12 ELASTOMERIC HANGERS

A. Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods: **<Insert drawing designation>**.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. **Ace Mountings Co., Inc.**
 - b. **California Dynamics Corporation.**
 - c. **Isolation Technology, Inc.**
 - d. **Kinetics Noise Control, Inc.**
 - e. **Mason Industries, Inc.**
 - f. **Vibration Eliminator Co., Inc.**
 - g. **Vibration Mountings & Controls, Inc.**
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Frame: Steel, fabricated with a connection for an upper threaded hanger rod and an opening on the underside to allow for a maximum of 30 degrees of angular lower hanger-rod misalignment without binding or reducing isolation efficiency.
3. Dampening Element: Molded, oil-resistant rubber, neoprene, or other elastomeric material with a projecting bushing for the underside opening preventing

steel-to-steel contact.

2.13 SPRING HANGERS

A. Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression: **<Insert drawing designation>**.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Kinetics Noise Control, Inc.
 - d. Mason Industries, Inc.
 - e. Vibration Eliminator Co., Inc.
 - f. Vibration Isolation.
 - g. Vibration Mountings & Controls, Inc.
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
7. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.
8. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
9. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

2.14 VIBRATION ISOLATION EQUIPMENT BASES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. California Dynamics Corporation.
2. Kinetics Noise Control.
3. Mason Industries, Inc.
4. Vibration Eliminator Co., Inc.
5. Vibration Isolation.
6. Vibration Mountings & Controls, Inc.
7. **<Insert manufacturer's name>**.

8. or approved equal.

B. Steel Rails: Factory-fabricated, welded, structural-steel rails.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide rails.

a. Include supports for suction and discharge elbows for pumps.

2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Rails shall have shape to accommodate supported equipment.

3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

C. Steel Bases: Factory-fabricated, welded, structural-steel bases and rails.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.

a. Include supports for suction and discharge elbows for pumps.

2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.

3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

D. Concrete Inertia Base: **[Factory-fabricated]** [or] **[field-fabricated]**, welded, structural-steel bases and rails ready for placement of cast-in-place concrete.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.

a. Include supports for suction and discharge elbows for pumps.

2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.

3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

4. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.

2.15 RESTRAINED ISOLATION ROOF-CURB RAILS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ace Mountings Co., Inc.
 2. California Dynamics Corporation.
 3. Kinetics Noise Control.
 4. Mason Industries, Inc.
 5. Thybar Corporation.
 6. <Insert manufacturer's name>.
 7. or approved equal.
- B. Description: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment.
- C. Upper Frame: Upper frame shall provide continuous and captive support for equipment.
- D. Lower Support Assembly: The lower support assembly shall be formed sheet metal section containing adjustable and removable steel springs that support upper frame. The lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials and shall be insulated with a minimum of 2 inches (50 mm) of rigid glass-fiber insulation on inside of assembly. Adjustable, restrained-spring isolators shall be mounted on elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.
- E. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch (6 mm) thick.
- F. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and equipment to receive vibration isolation control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 VIBRATION CONTROL DEVICE INSTALLATION

- A. Coordinate the location of embedded connection hardware with supported equipment

attachment and mounting points and with requirements for concrete reinforcement and formwork specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

- B. Installation of vibration isolators must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.

3.3 AIR-SPRING ISOLATORS INSTALLATION

- A. Independent Isolator Installation:

- 1. Install tank valve into each air isolator.
- 2. Inflate each isolator to [**height**] [**and**] [**pressure**] specified on Drawings.

- B. Pressure-Regulated Isolator Installation:

- 1. Coordinate the constant pressure-regulated air supply to air springs with the requirements for piping and connections specified in Section 221513 "General-Service Compressed-Air Piping."
- 2. Connect all pressure regulators to a single dry, filtered [**facility**] [**constant**] air supply.
- 3. Inflate isolators to [**height**] [**and**] [**or**] [**pressure**] specified on Drawings.

3.4 VIBRATION ISOLATION EQUIPMENT BASES INSTALLATION

- A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

3.5 MANUFACTURER'S FIELD SERVICES

- A. Inspect isolated equipment after installation and submit report. Include static deflections.

3.6 PIPE ISOLATION SCHEDULE

Pipe Size (in)	Isolated Distance from Equipment (Pipe Diameters)
1	120
2	90
3	80
4	75
6	60
8	60

10	54
12	50
16	45
24	38

3.7 EQUIPMENT ISOLATION SCHEDULE

Isolated Equipment	Base	Type	Static Deflection
Roof Mounted AHUs	Roof Curb	E	2"
Roof Mounted AHU, MAU Fans	Steel Frame	B	2"
Roof Mounted Fans, MAU's	Roof Curb	D	0.1"
Chillers	Concrete Pad	D	0.2" (provide 3/4" thick pads)
Cooling Towers	Roof Curb	D	0.1"
Piping	NA	C	0.5"

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230548.13

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Equipment labels.
 - 2. Warning signs and labels.
 - 3. Pipe labels.
 - 4. Duct labels.
 - 5. Stencils.
 - 6. Valve tags.
 - 7. Warning tags.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 REFERENCES

- A. Materials and workmanship shall conform to the latest issue of all industry standards, publications, or regulations referenced in this section and with the following references as applicable. Refer to Section 014225 "Reference Standards" for listing of issuing organizations or agencies.
- B. Applicable Standards:
 - 1. American Society of Mechanical Engineers (ASME).
 - 2. ASME A13.1 - Scheme for the Identification of Piping Systems.
 - 3. International Building Code (IBC) with the Denver Amendments.
 - 4. International Fire Code (IFC) with the Denver Amendments.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Provide manufacturers catalog literature for each type of product.
 - 1. Include data substantiating that materials comply with requirements.

- B. Samples: For color coding, wording, letter style and size, and graphic representation required for each identification material and device.
- C. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.
 - 1. Submit list of wording, symbols, letter size, and color coding for mechanical identification.
- D. Valve numbering scheme.
- E. Valve Schedules: For each piping system to include in maintenance manuals.
 - 1. Include valve chart and schedule, including valve tag number, location, function, and valve manufacturer's name and model number.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of tagged valves.

1.6 COORDINATION

- A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
- B. Coordinate installation of identifying devices with locations of access panels and doors.
- C. Install identifying devices before installing acoustical ceilings and similar concealment.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

- A. Metal Labels for Equipment:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Brady Corporation.](#)
 - b. [Brimar Industries, Inc.](#)
 - c. [Carlton Industries, LP.](#)
 - d. [Champion America.](#)
 - e. [Craftmark Identification Systems.](#)
 - f. [emedco.](#)
 - g. [Kolbi Pipe Marker Co.](#)
 - h. [LEM Products Inc.](#)
 - i. [Marking Services Inc.](#)
 - j. [Seton Identification Products.](#)
 - k. **<Insert manufacturer's name>.**
 - l. or approved equal.
2. Material and Thickness: **[Brass, 0.032-inch (0.8-mm)] [stainless steel, 0.025-inch (0.64-mm)] [aluminum, 0.032-inch (0.8-mm)] [or] [anodized aluminum, 0.032-inch (0.8-mm)]** minimum thickness, and having predrilled or stamped holes for attachment hardware.
3. Letter Color: **[Black] [Blue] [Red] [White] [Yellow] <Insert color>.**
4. Background Color: **[Black] [Blue] [Red] [White] [Yellow] <Insert color>.**
5. Minimum Label Size: Length and width vary for required label content, but not less than **2-1/2 by 3/4 inch** (64 by 19 mm).
6. Minimum Letter Size: **1/4 inch** (6.4 mm) for name of units if viewing distance is less than **24 inches** (600 mm), **1/2 inch** (13 mm) for viewing distances up to **72 inches** (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.
7. Fasteners: Stainless-steel **[rivets] [or] [self-tapping screws]**.
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Plastic Labels for Equipment:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Brady Corporation.](#)
 - b. [Brimar Industries, Inc.](#)
 - c. [Carlton Industries, LP.](#)
 - d. [Champion America.](#)
 - e. [Craftmark Identification Systems.](#)
 - f. [emedco.](#)
 - g. [Kolbi Pipe Marker Co.](#)
 - h. [LEM Products Inc.](#)
 - i. [Marking Services Inc.](#)
 - j. [Seton Identification Products.](#)
 - k. **<Insert manufacturer's name>.**
 - l. or approved equal.

2. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [1/16 inch (1.6 mm)] [1/8 inch (3.2 mm)] <Insert dimension> thick, and having predrilled holes for attachment hardware.
 3. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
 4. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
 5. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
 6. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
 7. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.
 8. Fasteners: Stainless-steel [rivets] [or] [self-tapping screws].
 9. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- C. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), and the Specification Section number and title where equipment is specified.
- D. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch (A4) bond paper. Tabulate equipment identification number, and identify Drawing numbers where equipment is indicated (plans, details, and schedules) and the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.2 WARNING SIGNS AND LABELS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Brady Corporation](#).
 2. [Brimar Industries, Inc.](#)
 3. [Carlton Industries, LP](#).
 4. [Champion America](#).
 5. [Craftmark Identification Systems](#).
 6. [emedco](#).
 7. [LEM Products Inc.](#)
 8. [Marking Services Inc.](#)
 9. [NMC](#).
 10. [Seton Identification Products](#).
 11. [Stranco, Inc.](#)
 12. <Insert manufacturer's name>.
 13. or approved equal.

- B. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [1/16 inch (1.6 mm)] [1/8 inch (3.2 mm)] <Insert dimension> thick, and having predrilled holes for attachment hardware.
- C. Letter Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
- D. Background Color: [Black] [Blue] [Red] [White] [Yellow] <Insert color>.
- E. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
- F. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
- G. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.
- H. Fasteners: Stainless-steel [rivets] [or] [self-tapping screws].
- I. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- J. Label Content: Include caution and warning information plus emergency notification instructions.

2.3 PIPE LABELS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Actioncraft Products, Inc.](#)
 - 2. [Brady Corporation.](#)
 - 3. [Brimar Industries, Inc.](#)
 - 4. [Carlton Industries, LP.](#)
 - 5. [Champion America.](#)
 - 6. [Craftmark Identification Systems.](#)
 - 7. [emedco.](#)
 - 8. [Kolbi Pipe Marker Co.](#)
 - 9. [LEM Products Inc.](#)
 - 10. [Marking Services Inc.](#)
 - 11. [Seton Identification Products.](#)
 - 12. <Insert manufacturer's name>.
 - 13. or approved equal.
- B. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction according to ASME A13.1.
- C. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to [partially cover] [cover full] circumference of pipe and to attach to pipe without fasteners or adhesive.

- D. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.
- E. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings; also include pipe size and an arrow indicating flow direction.
 - 1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions or as separate unit on each pipe label to indicate flow direction.
 - 2. Lettering Size: **[Size letters according to ASME A13.1 for piping] [At least 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm) and proportionately larger lettering for greater viewing distances].**

2.4 DUCT LABELS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. [Brady Corporation.](#)
 - 2. [Brimar Industries, Inc.](#)
 - 3. [Carlton Industries, LP.](#)
 - 4. [Champion America.](#)
 - 5. [Craftmark Identification Systems.](#)
 - 6. [emedco.](#)
 - 7. [Kolbi Pipe Marker Co.](#)
 - 8. [LEM Products Inc.](#)
 - 9. [Marking Services Inc.](#)
 - 10. [Seton Identification Products.](#)
 - 11. **<Insert manufacturer's name>.**
 - 12. or approved equal.
- B. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [1/16 inch (1.6 mm)] [1/8 inch (3.2 mm)] **<Insert dimension>** thick, and having predrilled holes for attachment hardware.
- C. Letter Color: **[Black] [Blue] [Red] [White] [Yellow] <Insert color>.**
- D. Background Color: **[Black] [Blue] [Red] [White] [Yellow] <Insert color>.**
- E. Maximum Temperature: Able to withstand temperatures up to **160 deg F (71 deg C).**
- F. Minimum Label Size: Length and width vary for required label content, but not less than **2-1/2 by 3/4 inch (64 by 19 mm).**
- G. Minimum Letter Size: **1/4 inch (6.4 mm)** for name of units if viewing distance is less than **24 inches (600 mm)**, **1/2 inch (13 mm)** for viewing distances up to **72 inches (1830 mm)**, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.

- H. Fasteners: Stainless-steel [rivets] [or] [self-tapping screws].
- I. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- J. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings; also include duct size and an arrow indicating flow direction.
 - 1. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions or as separate unit on each duct label to indicate flow direction.

2.5 STENCILS

A. Stencils for Piping:

- 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Brimar Industries, Inc.](#)
 - b. [Carlton Industries, LP.](#)
 - c. [Champion America.](#)
 - d. [Craftmark Identification Systems.](#)
 - e. [Kolbi Pipe Marker Co.](#)
 - f. [Marking Services Inc.](#)
 - g. <Insert manufacturer's name>.
 - h. or approved equal.
- 2. **Lettering Size: [Size letters according to ASME A13.1 for piping] [At least 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm) and proportionately larger lettering for greater viewing distances].**
- 3. **Stencil Material: [Aluminum] [Brass] [Fiberboard] [Fiberboard or metal] <Insert material>.**
- 4. **Stencil Paint: Exterior, gloss, [alkyd enamel] [acrylic enamel] <Insert paint type> in colors complying with recommendations in ASME A13.1 unless otherwise indicated. Paint may be in pressurized spray-can form.**
- 5. **Identification Paint: Exterior, [alkyd enamel] [acrylic enamel] <Insert paint type> in colors according to ASME A13.1 unless otherwise indicated. Paint may be in pressurized spray-can form.**

B. Stencils for Ducts:

- 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Brimar Industries, Inc.](#)
 - b. [Carlton Industries, LP.](#)
 - c. [Champion America.](#)
 - d. [Craftmark Identification Systems.](#)

- e. [Kolbi Pipe Marker Co.](#)
 - f. [Marking Services Inc.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
2. Lettering Size: Minimum letter height of **1-1/4 inches** (32 mm) for viewing distances up to **15 feet** (4-1/2 m) and proportionately larger lettering for greater viewing distances.
 3. Stencil Material: [**Aluminum**] [**Brass**] [**Fiberboard**] [**Fiberboard or metal**] **<Insert material>**.
 4. Stencil Paint: Exterior, gloss, [**alkyd enamel**] [**acrylic enamel**] **<Insert paint type>**. Paint may be in pressurized spray-can form.
 5. Identification Paint: Exterior, [**alkyd enamel**] [**acrylic enamel**] **<Insert paint type>**. Paint may be in pressurized spray-can form.
- C. Stencils for Access Panels and Door Labels, Equipment Labels, and Similar Operational Instructions:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Brimar Industries, Inc.](#)
 - b. [Carlton Industries, LP.](#)
 - c. [Champion America.](#)
 - d. [Craftmark Identification Systems.](#)
 - e. [Kolbi Pipe Marker Co.](#)
 - f. [Marking Services Inc.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
 2. Lettering Size: Minimum letter height of **1/2 inch** (13 mm) for viewing distances up to **72 inches** (1830 mm) and proportionately larger lettering for greater viewing distances.
 3. Stencil Material: [**Aluminum**] [**Brass**] [**Fiberboard**] [**Fiberboard or metal**] **<Insert material>**.
 4. Stencil Paint: Exterior, gloss, [**alkyd enamel**] [**acrylic enamel**] **<Insert paint type>**. Paint may be in pressurized spray-can form.
 5. Identification Paint: Exterior, [**alkyd enamel**] [**acrylic enamel**] **<Insert paint type>**. Paint may be in pressurized spray-can form.

2.6 VALVE TAGS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. [Actioncraft Products, Inc.](#)
 2. [Brady Corporation.](#)
 3. [Brimar Industries, Inc.](#)
 4. [Carlton Industries, LP.](#)

5. [Champion America.](#)
6. [Craftmark Identification Systems.](#)
7. [emedco.](#)
8. [Kolbi Pipe Marker Co.](#)
9. [LEM Products Inc.](#)
10. [Marking Services Inc.](#)
11. [Seton Identification Products.](#)
12. **<Insert manufacturer's name>.**
13. or approved equal.

B. Description: Stamped or engraved with **1/4-inch (6.4-mm)** letters for piping system abbreviation and **1/2-inch (13-mm)** numbers.

1. Tag Material: [**Brass, 0.032-inch (0.8-mm)**] [**stainless steel, 0.025-inch (0.64-mm)**] [**aluminum, 0.032-inch (0.8-mm)**] [**or**] [**anodized aluminum, 0.032-inch (0.8-mm)**] minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Fasteners: Brass [**wire-link chain**] [**or**] [**beaded chain**] [**or**] [**S-hook**].

C. Valve Schedules: For each piping system, on **8-1/2-by-11-inch (A4)** bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

1. Valve-tag schedule shall be included in operation and maintenance data.

2.7 WARNING TAGS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Brady Corporation.](#)
2. [Brimar Industries, Inc.](#)
3. [Carlton Industries, LP.](#)
4. [Champion America.](#)
5. [Craftmark Identification Systems.](#)
6. [emedco.](#)
7. [Kolbi Pipe Marker Co.](#)
8. [LEM Products Inc.](#)
9. [Marking Services Inc.](#)
10. [Seton Identification Products.](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

B. Description: Preprinted or partially preprinted accident-prevention tags of plasticized card stock with matte finish suitable for writing.

1. Size: [3 by 5-1/4 inches (75 by 133 mm) **minimum**] [Approximately 4 by 7 inches (100 by 178 mm)] <Insert size>.
2. Fasteners: [Brass grommet and wire] [Reinforced grommet and wire or string].
3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
4. Color: Safety-yellow background with black lettering.

2.8 CEILING TACKS

- A. Description: Steel with 3/4 inch diameter color coded head.
- B. Color code ceiling tacks as follows:
 1. Yellow: HVAC equipment.
 2. Red: Fire dampers/smoke dampers.
 3. Green: Plumbing valves.
 4. Blue: Heating/cooling valves.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.
- B. Prepare surfaces in accordance with Division 09 for stencil painting.

3.2 GENERAL INSTALLATION REQUIREMENTS

- A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
- B. Coordinate installation of identifying devices with locations of access panels and doors.
- C. Install identifying devices before installing acoustical ceilings and similar concealment.
- D. Equipment: Identify air handling units, pumps, heat transfer equipment, tanks, and water treatment devices with plastic nameplates or stencil painting. Small devices, such as in-line pumps, may be identified with metal tags. At a minimum, the nameplate shall contain the following information:
 1. Equipment Tag.
 2. Equipment location.
 3. Service Area.

4. Flowrate (cfm/gpm).
 5. Capacity (btuh/kw).
 6. **<Equipment owner>**
- E. Equipment and terminal devices above ceiling: provide adhesive backed plastic nameplate on ceiling grid support directly below equipment identifying unit tag and temperature control node number.
1. Example:
 - a. VAV-01 NODE 067.
- F. Controls: Identify control panels and major control components outside panels with plastic nameplates. Key to control schematics.

3.3 EQUIPMENT LABEL INSTALLATION

- A. Install or permanently fasten labels on each major item of mechanical equipment.
- B. Locate equipment labels where accessible and visible.

3.4 PIPE LABEL INSTALLATION

- A. Identify piping, concealed or exposed, with plastic pipe markers. Tags may be used on ½" or smaller diameter non-insulated piping. Identify service, flow direction, and pressure. Install in clear view and align with axis of piping. Locate identification not to exceed 20 feet on straight runs including risers and drops, adjacent to each valve and "T", at each side of penetration of structure or enclosure, and at each obstruction.
- B. Piping Color Coding: Painting of piping is specified in [**Section 099123 "Interior Painting."**] [**Section 099600 "High-Performance Coatings."**]
- C. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels, complying with ASME A13.1, [**with painted, color-coded bands or rectangles**] on each piping system.
 1. Identification Paint: Use for contrasting background.
 2. Stencil Paint: Use for pipe marking.
- D. Pipe Label Locations: Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
 1. Near each valve and control device.
 2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
 3. Near penetrations and on both sides of through walls, floors, ceilings, and inaccessible enclosures.

4. At access doors, manholes, and similar access points that permit view of concealed piping.
 5. Near major equipment items and other points of origination and termination.
 6. Spaced at maximum intervals of [50 feet (15 m)] <Insert dimension> along each run. Reduce intervals to [25 feet (7.6 m)] <Insert dimension> in areas of congested piping and equipment.
 7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.
- E. Directional Flow Arrows: Arrows shall be used to indicate direction of flow in pipes, including pipes where flow is allowed in both directions.
- F. Pipe Label Color Schedule:
1. Chilled-Water Piping: [White letters on a safety-green background] [Black letters on a safety-orange background] <Insert colors>.
 2. Condenser-Water Piping: [White letters on a safety-green background] [Black letters on a safety-orange background] <Insert colors>.
 3. Heating Water Piping: [White letters on a safety-green background] [Black letters on a safety-orange background] <Insert colors>.
 4. Refrigerant Piping: [Black letters on a safety-orange background] [White letters on a safety-purple background] [Black letters on a safety-white background] [White letters on a safety-gray background] [White letters on a safety-black background] <Insert colors>.
 5. Low-Pressure Steam Piping: [White letters on a safety-purple background] [Black letters on a safety-white background] [White letters on a safety-gray background] [White letters on a safety-black background] <Insert colors>.
 6. High-Pressure Steam Piping: [White letters on a safety-purple background] [Black letters on a safety-white background] [White letters on a safety-gray background] [White letters on a safety-black background] <Insert colors>.
 7. Steam Condensate Piping: [White letters on a safety-purple background] [Black letters on a safety-white background] [White letters on a safety-gray background] [White letters on a safety-black background] <Insert colors>.

3.5 DUCT LABEL INSTALLATION

- A. Install [plastic-laminated] duct labels with permanent adhesive or stenciled painting on air ducts in the following color codes:
1. Green: For cold-air of general supply ducts.
 2. Yellow: For hot-air supply ducts.
 3. Blue: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
 4. ASME A13.1 Colors and Designs: For hazardous material exhaust.
 5. Letter Size: Minimum 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
- B. Stenciled Duct Label Option: Stenciled labels showing service and flow direction may

be provided instead of plastic-laminated duct labels, at Installer's option, if lettering larger than 1 inch (25 mm) high is needed for proper identification because of distance from normal location of required identification.

- C. Locate labels near points where ducts enter into and exit from concealed spaces and at maximum intervals of [50 feet (15 m)] **<Insert dimension>** in each space where ducts are exposed or concealed by removable ceiling system and/or each side of a penetration of structure or enclosure and at each obstruction and at air-handling equipment.

3.6 VALVE-TAG INSTALLATION

- A. Identify all valves, including fire protection valves, in main and branch piping located inside the building. Use tags secured with brass 'S' hooks or brass chains.
- B. Stamp tags with a unique prefix to identify system to which applied, followed by a number (Example: CW-1, CW-2, etc.). In general, prefix shall match system abbreviations used on drawings where applicable.
- C. Provide a typewritten listing of valves including: valve identification number, location, function, normal position, service, and area served. Mount list as specified and directed. Include additional copy in operation and maintenance manuals.
- D. Show valve tag designations on the project record document drawings, including schematic flow diagrams where included with construction documents.
- E. Contractor shall prepare and install where directed, in aluminum frames with clear plastic protective cover, a valve location diagram in the form of a series of flow diagrams with each automatic or manually actuated control or shut-off valve clearly identified in sequence with its individual valve tag number. Automatic control valves shall be tagged to match designations shown on the temperature control drawings, and the specified valve charts shall be installed adjacent to valve location diagrams.
- F. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

1. Valve-Tag Size and Shape:

- a. Chilled Water: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] **<Insert shape>**.
- b. Condenser Water: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] **<Insert shape>**.
- c. Refrigerant: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] **<Insert shape>**.
- d. Hot Water: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] **<Insert shape>**.
- e. Gas: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] **<Insert shape>**.
- f. Low-Pressure Steam: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round]

- g. [square] <Insert shape>. High-Pressure Steam: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] <Insert shape>.
- h. Steam Condensate: [1-1/2 inches (38 mm)] [2 inches (50 mm)], [round] [square] <Insert shape>.

2. Valve-Tag Colors:

- a. Toxic and Corrosive Fluids: Black letters on a safety-orange background.
- b. Flammable Fluids: Black letters on a safety-yellow background.
- c. Combustible Fluids: White letters on a safety-brown background.
- d. Potable and Other Water: White letters on a safety-green background.
- e. Compressed Air: White letters on a safety-blue background.
- f. Defined by User: White letters on a safety-purple background, black letters on a safety-white background, white letters on a safety-gray background, and white letters on a safety-black background

3.7 WARNING-TAG INSTALLATION

- A. Write required message on, and attach warning tags to, equipment and other items where required.

3.8 VALVE CHART AND SCHEDULE

- A. Provide valve chart and schedule in aluminum frame with clear plastic shield. Install at location as directed by DEN Project Manager.

3.9 PIPING IDENTIFICATION SCHEDULE

- A. Pipe identification and color coding for general-use piping systems shall be in accordance with the following schedule. For plumbing piping identification schedule, reference Section 220553 "Identification for Plumbing Piping and Equipment":

Classification	Band Color	Stenciled Legend
Chilled Water Supply	Green	Ch. Water Supp.
Chilled Water Return	Green	Ch. Water Ret.
Condenser Water Supply	Green	Cond. Water Supp.
Condenser Water Return	Green	Cond. Water Ret.
Natural Gas*	Yellow	Nat. Gas
L.P. Gas*	Yellow	L.P. Gas
Gas Vent*	Yellow	Gas Vent
Hot Water Heating Supply	Yellow	H.W. Htg. Supp.
Hot Water Heating Return	Yellow	H.W. Htg. Ret.
Compressed Air	Blue	Comp. Air
Snow Melting Supply	Yellow	Snow Melt Supp.
Snow Melting Return	Yellow	Snow Melt Ret.
Blow Down	Yellow	Blow Dn.

Refrigerant Hot Gas	Green	Refr. Hot Gas
Refrigerant Liquid	Green	Refr. Liq.
Water Treatment	Green	Water Trtmt.
Humidifier	Green	Humidifier
Expansion Tank No.	Yellow	Exp. Tank. No.
Gasoline	Yellow	Gasoline
Gasoline Vent	Yellow	Gasoline Vent
Fuel Oil (heating)	Yellow	Fuel Oil Htg.
Fuel Oil (generator)	Yellow	Fuel Oil Gen.
Diesel Exhaust	Yellow	Engine Exh.
Refrigerant Relief	Yellow	Refr. Relief
Condensate Return	Yellow	Cond Ret.
Glycol Supply (PCA)	Green	Gly. Sup.
Glycol Return (PCA)	Green	Gly. Ret.

- B. Overflow condensate drain termination shall have a minimum 6"x6" placard that reads, "If water is observed from the pipe below, immediately contact Maintenance Control at (303) 342-2800".
1. Placard shall have red background with white lettering.
 2. Minimum lettering height shall be ½".
 3. Mount placard a minimum of 48" above finish floor.
- C. Paint exterior piping and duct systems to match wall colors.
- D. For fuel piping systems, piping identification shall conform to the following schedule:

Fuel Type	Band Colors	Stenciled Legend
Jet A	Black/Black Band	Jet A
Jet A-1	Black/2 Black Bands	Jet A-1
JP-4 (Jet B)	Black/3 Yellow Bands	JP-4
Avgas 115	Red/Purple Band	Avgas 115
Avgas 100	Red/Green Band	Avgas 100
Avgas 100LL	Red/Blue Band	Avgas 100LL
Avgas 80	Red/Red Band	Avgas 80

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230553

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This section of the Specifications covers testing and balancing of environmental systems, including, but not limited to distribution systems and the connected equipment and apparatus. The testing and balancing of all environmental systems shall be the responsibility of a single Testing, Adjusting, and Balancing (TAB) firm.
- B. Related Work Specified Elsewhere: General Requirements of Division 01 and Section 230400 "Basic Mechanical Requirements," pertain to and are hereby made part of the Work of this section of the Specifications.
- C. Section Includes:
 - 1. Balancing, Testing and Adjusting Air Systems:
 - a. Constant-volume air systems.
 - b. Dual-duct systems.
 - c. Variable-air-volume systems.
 - d. Multizone systems.
 - e. Induction-unit systems.
 - 2. Balancing, Testing and Adjusting Hydronic Piping Systems:
 - a. Constant-flow hydronic systems.
 - b. Variable-flow hydronic systems.
 - c. Primary-secondary hydronic systems.
 - 3. Balancing steam systems.
 - 4. Testing, Adjusting, and Balancing Equipment:
 - a. Heat exchangers.
 - b. Motors.
 - c. Chillers.
 - d. Cooling towers.
 - e. Condensing units.
 - f. Boilers.
 - g. Heat-transfer coils.

5. Testing, adjusting, and balancing existing systems and equipment.
6. Sound tests.
7. Vibration tests.
8. Duct leakage tests.
9. Space pressurization testing and adjusting.
10. Control system verification.

D. Related Sections:

1. Section 014510 "Contractor Quality Control".
2. Section 014520 "Contractor Quality Control for FAA Funded Projects".
3. Section 017515 "System Startup, Testing and Training".
4. Section 230400 "Basic Mechanical Requirements".

E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ALLOWANCES

- A. Cash Allowance: Include under provisions of Division 01.
- B. Allowance includes testing, adjusting, and balancing of mechanical systems. Work is included in this section and is part of the Contract Sum/Price.

1.4 DEFINITIONS

- A. Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.
- B. AABC: Associated Air Balance Council.
- C. Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to indicated quantities.
- D. Barrier or Boundary: Construction, either vertical or horizontal, such as walls, floors, and ceilings that are designed and constructed to restrict the movement of airflow, smoke, odors, and other pollutants.
- E. BAS: Building automation systems.
- F. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.
- G. NC: Noise criteria.
- H. NEBB: National Environmental Balancing Bureau.

- I. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.
 - J. RC: Room criteria.
 - K. Report Forms: Test data sheets for recording test data in logical order.
 - L. Smoke-Control System: An engineered system that uses fans to produce airflow and pressure differences across barriers to limit smoke movement.
 - M. Smoke-Control Zone: A space within a building that is enclosed by smoke barriers and is a part of a zoned smoke-control system.
 - N. Stair Pressurization System: A type of smoke-control system that is intended to positively pressurize stair towers with outdoor air by using fans to keep smoke from contaminating the stair towers during an alarm condition.
 - O. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.
 - P. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.
 - Q. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
 - R. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.
 - S. TAB: Testing, adjusting, and balancing.
 - T. TABB: Testing, Adjusting, and Balancing Bureau.
 - U. TAB Specialist: An independent entity meeting qualifications to perform TAB work.
 - V. TDH: Total dynamic head.
 - W. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.
 - X. Test: A procedure to determine quantitative performance of systems or equipment.
 - Y. Testing, Adjusting, and Balancing (TAB) Firm: The entity responsible for performing and reporting TAB procedures.
- 1.5 REFERENCES
- A. Materials and workmanship shall conform to the latest issue of all industry standards, publications, or regulations referenced in this section and with the following references

as applicable. Refer to Section 014225 "Referenced Standards" for listing of issuing organizations or agencies.

B. Applicable Standards:

1. Associated Air Balance Council (AABC):
 - a. National Standards for Total System Balance.
2. Air Diffusion Council (ADC):
 - a. Test Code for Grilles, Registers, and Diffusers.
3. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE):
 - a. ASHRAE 111 - Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-conditioning, and Refrigeration Systems.
4. International Building Code (IBC) with the Denver Amendments.
5. International Fire Code (IFC) with the Denver Amendments.
6. National Environmental Balancing Bureau (NEBB):
 - a. Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.
7. Sheet Metal and Air Conditioning Contractor's National Association (SMACNA):
 - a. HVAC Systems Testing, Adjusting, and Balancing.

1.6 PREINSTALLATION MEETINGS

- A. TAB Conference: If requested by the Owner, conduct a TAB conference at **[Project site] [Location and time as determined by DEN Project Manager] <Insert location>** after approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Provide a minimum of **[14] <Insert number>** days' advance notice to DEN Project Manager of scheduled meeting time and location, with meeting to convene minimum **[one (1)] <Insert number>** week prior to commencing work of this Section.
- B. Attendance shall include representatives of all systems and equipment Installers having performed, or in the process of performing, project work subject to testing, balancing, and adjustment by the TAB firm.
- C. Conference agenda shall include review of status of installation and completion of each system requiring testing balancing and adjusting, for the purpose of confirming that the schedule of work to be performed will be planned so as to ensure readiness of systems.

1. Minimum Agenda Items:
 - a. The Contract Documents examination report.
 - b. The TAB plan.
 - c. Needs for coordination and cooperation of trades and subcontractors.
 - d. Proposed procedures for documentation and communication flow.

1.7 ACTION SUBMITTALS

- A. Submit name of adjusting and balancing agency for approval within **[30] <Insert number>** days after award of Contract to ensure that the TAB firm has met the requirements this section of the Specifications and is on the Project from the outset of construction.
- B. LEED Submittals:
 1. Air-Balance Report for Prerequisite IEQ 1: Documentation indicating that work complies with ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
 2. TAB Report for Prerequisite EA 2: Documentation indicating that work complies with ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."
- C. All TAB submittals shall be electronically submitted in PDF format to the DEN Project Manager and directly to the DEN Mechanical Engineer [**Lee Walinchus: lee.walinchus@flydenver.com**].
- D. Field Reports: Indicate deficiencies in systems that would prevent proper testing, adjusting, and balancing of systems and equipment to achieve specified performance.
- E. Prior to commencing work, submit report forms or outlines indicating adjusting, balancing, and equipment data required.
- F. Submit draft copies of report for review prior to final acceptance of Project. Provide final copies for DEN Project Manager and for inclusion in operating and maintenance manuals.
- G. Include detailed procedures, agenda, sample report forms [**and copy of AABC National Project Performance Guaranty**] **<Insert requirement>** prior to commencing system balance.
- H. Test Reports: Indicate data on AABC National Standards for Total System Balance forms, or forms prepared following ASHRAE 111, NEBB or TABB forms. When necessary, supplement with forms containing information indicated in Schedules.
- I. Final Report: At least fifteen (15) days prior to Contractor's request for final inspection, submit in letter size, a single PDF file of the final test report on applicable reporting forms for review. Each individual final reporting form must bear the signature of the person who recorded data and that of the reporting organization. Identify instruments of all types that were used and last date of calibration of each. Report shall include all items listed in PART 3- Execution.

- J. A statement outlining all abnormal or notable conditions not covered in above data.
- K. Proposed resolutions to equipment that is performing outside of the specified performance ranges.

1.8 INFORMATIONAL SUBMITTALS

- A. Qualification Data: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.
- B. Contract Documents Examination Report: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.
- C. Strategies and Procedures Plan: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.
- D. System Readiness Checklists: Within [30] [60] [90] <Insert number> days of Contractor's Notice to Proceed, submit system readiness checklists as specified in "Preparation" Article.
- E. Examination Report: Submit a summary report of the examination review required in "Examination" Article.
- F. Certified TAB reports.
- G. Sample report forms.
- H. Instrument calibration reports, to include the following:
 - 1. Instrument type and make.
 - 2. Serial number.
 - 3. Application.
 - 4. Dates of use.
 - 5. Dates of calibration.

1.9 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- B. Record actual locations of [flow measuring stations] [balancing valves and rough setting].

1.10 QUALITY ASSURANCE

- A. Sequence work to commence after completion of systems and schedule completion of work before Substantial Completion of Project.
- B. Schedule and provide assistance in final adjustment and test of **[life safety] [smoke evacuation] [smoke control]** system with Fire Authority.
- C. TAB Specialists Qualifications: Certified by **[AABC] [NEBB] [or] [TABB]**.
 - 1. TAB Field Supervisor: Employee of the TAB specialist and certified by **[AABC] [NEBB] [or] [TABB]**.
 - 2. TAB Technician: Employee of the TAB specialist and certified by **[AABC] [NEBB] [or] [TABB]** as a TAB technician.
- D. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."
- E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
- F. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.11 COORDINATION

- A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.
- B. Notice: Notify the DEN Project Manager, DEN Mechanical Inspector and DEN Mechanical Engineer in writing a minimum of 72 hours prior to testing of any equipment and/or systems. Include scheduled test dates and times.
- C. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.12 FIELD CONDITIONS

- A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.
- B. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.13 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 017835 "Warranties and Bonds" and Section 230400 "Basic HVAC Requirements".
- B. National Project Performance Guarantee: Provide a guarantee on AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" forms stating that AABC will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Duration of Guarantee shall be [60] [90] [120] [365] days. Guarantee includes the following provisions:
 - 1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
 - 2. Systems are balanced to optimum performance capabilities within design and installation limits.
- C. Special Guarantee: Provide a guarantee on NEBB forms stating that NEBB will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Duration of Guarantee shall be [60] [90] [120] [365] days. Guarantee shall include the following provisions:
 - 1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
 - 2. Systems are balanced to optimum performance capabilities within design and installation limits.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

- A. Subject to compliance with requirements, engage one of the following :
 - 1. Able Balance Corp.
 - 2. Griffith Engineering Service.
 - 3. Jedi Balancing, Inc.
 - 4. JPG Engineering, Inc.
 - 5. TAB Services, Inc.
 - 6. <Insert TAB specialist's name>.
 - 7. or approved equal.

3.2 EXAMINATION

- A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems designs that may preclude proper TAB of systems and equipment.
- B. Examine installed systems for balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual

- volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.
- C. Examine the approved submittals for HVAC systems and equipment.
 - D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems output, and statements of philosophies and assumptions about HVAC system and equipment controls.
 - E. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.
 - F. Examine equipment performance data including fan and pump curves.
 - 1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
 - 2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.
 - G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
 - H. Examine test reports specified in individual system and equipment Sections.
 - I. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.
 - J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.
 - K. Examine strainers. Verify that startup screens have been replaced by permanent screens with indicated perforations.
 - L. Examine control valves for proper installation for their intended function of throttling, diverting, or mixing fluid flows.
 - M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
 - N. Examine system pumps to ensure absence of entrained air in the suction piping.
 - O. Examine operating safety interlocks and controls on HVAC equipment.
 - P. Ensure the Following Conditions:

1. Systems are started and operating in a safe and normal condition.
2. Temperature control systems are installed complete and operable.
3. Proper thermal overload protection is in place for electrical equipment.
4. Final filters are clean and in place. If required, install temporary media in addition to final filters.
5. Duct systems are clean of debris.
6. Fans are rotating correctly.
7. Fire, smoke, and volume dampers are in place and open.
8. Air coil fins are cleaned and combed.
9. Access doors are closed and duct end caps are in place.
10. Air outlets are installed and connected.
11. Duct system leakage is minimized.
12. Return air paths are not obstructed (i.e. walls to structure).
13. Hydronic systems are flushed, filled, and vented.
14. Pumps are rotating correctly.
15. Proper strainer baskets are clean and in place.
16. Service and balance valves are open.

- Q. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.3 PREPARATION

- A. Provide instruments required for testing, adjusting, and balancing operations. Make instruments available to DEN Project Manager to facilitate spot checks during testing.
- B. Provide additional balancing devices as required.
- C. Prepare a TAB plan that includes the following:
1. Equipment and systems to be tested.
 2. Strategies and step-by-step procedures for balancing the systems.
 3. Instrumentation to be used.
 4. Sample forms with specific identification for all equipment.
- D. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:
1. Airside:
 - a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
 - b. Duct systems are complete with terminals installed.
 - c. Volume, smoke, and fire dampers are open and functional.
 - d. Clean filters are installed.
 - e. Fans are operating, free of vibration, and rotating in correct direction.
 - f. Variable-frequency controllers' startup is complete and safeties are verified.
 - g. Automatic temperature-control systems are operational.

- h. Ceilings are installed.
- i. Windows and doors are installed.
- j. Suitable access to balancing devices and equipment is provided.

2. Hydronics:

- a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
- b. Piping is complete with terminals installed.
- c. Water treatment is complete.
- d. Systems are flushed, filled, and air purged.
- e. Strainers are pulled and cleaned.
- f. Control valves are functioning per the sequence of operation.
- g. Shutoff and balance valves have been verified to be 100 percent open.
- h. Pumps are started and proper rotation is verified.
- i. Pump gage connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.
- j. Variable-frequency controllers' startup is complete and safeties are verified.
- k. Suitable access to balancing devices and equipment is provided.

3.4 TEMPERATURE CONTROLS

- A. Verify that controllers are calibrated and commissioned.
- B. Check transmitter and controller locations and note conditions that would adversely affect control functions.
- C. Record controller settings and note variances between set points and actual measurements.
- D. Check the operation of limiting controllers (i.e., high-temperature and low-temperature controllers).
- E. Check free travel and proper operation of control devices such as damper and valve operators.
- F. Check the sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water flow measurements. Note the speed of response to input changes.
- G. Check the interaction of electrically operated switch transducers.
- H. Check the interaction of interlock and lockout systems.
- I. Check main control supply-air pressure and observe compressor and dryer operations.
- J. Record voltages of power supply and controller output. Determine whether the system operates on a grounded or nongrounded power supply.
- K. Note operation of electric actuators using spring return for proper fail-safe operations.

- L. VAV Boxes (Fan Powered and Shut off): Verify the following and report any discrepancies to the responsible installer:
- M. Velocity pressure sensor is receiving the proper signal and is then sending that signal to the regulator.
- N. Primary air damper will allow design flows without going to end point settings.
- O. Thermostats are calibrated.
- P. Control pressure is compatible with the primary damper motor range, dead band range and heating electric P.E. or valve motor range.
- Q. Direct acting or reverse acting controls are properly installed.
- R. Primary fan static pressure controls are receiving the proper signal in their installed location and transmitting this signal to the fan controller.
- S. Include a written certificate (include in balance report) that the above items are functioning properly.

3.5 GENERAL PROCEDURES FOR TESTING AND BALANCING

- A. Perform testing and balancing procedures on each system according to the procedures contained in [**AABC's "National Standards for Total System Balance"**] [**ASHRAE 111**] [**NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"**] [**SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing"**] and in this Section.
- B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.
 - 1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts. Restore vapor barrier and finish according to insulation Specifications for this Project.
 - 2. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."
 - 3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 230713 "Duct Insulation," Section 230716 "HVAC Equipment Insulation," and Section 230719 "HVAC Piping Insulation."
- C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
- D. Take and report testing and balancing measurements in [**inch-pound (IP)**] units.

3.6 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

- A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.
- B. Prepare schematic diagrams of systems' "as-built" duct layouts.
- C. For variable-air-volume systems, develop a plan to simulate diversity.
- D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.
- E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.
- F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
- G. Verify that motor starters are equipped with properly sized thermal protection.
- H. Check dampers for proper position to achieve desired airflow path.
- I. Check for airflow blockages.
- J. Check condensate drains for proper connections and functioning.
- K. Check for proper sealing of air-handling-unit components.
- L. Verify that air duct system is sealed as specified in Section 233113 "Metal Ducts."

3.7 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

- A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 - 1. Measure fan static pressures to determine actual static pressure as follows:
 - a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
 - b. Measure static pressure directly at the fan outlet or through the flexible connection.
 - c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection, and downstream from duct restrictions.
 - d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.
 - 2. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and air-treating equipment.

- a. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.
 3. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.
 4. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
 5. Obtain approval from DEN Project Manager for adjustment of fan speed higher or lower than indicated speed. Make required adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.
 6. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full cooling, full heating, economizer, and any other operating modes to determine the maximum required brake horsepower.
- B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.
1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.
 - a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.
 2. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.
- C. Measure terminal outlets and inlets without making adjustments.
1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.
- D. Adjust terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using volume dampers rather than extractors and the dampers at air terminals.
1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
 2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.8 PROCEDURES FOR DUAL-DUCT SYSTEMS

A. Adjust the dual-duct systems as follows:

1. Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge. On systems with separate hot-deck and cold-deck fans, verify the location of the sensor on each deck.
2. Verify that the system is under static pressure control.
3. Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
4. Calibrate and balance each terminal unit's hot deck and cold deck for maximum and minimum design airflow as follows:
 - a. Adjust controls so that terminal is calling for full cooling. Some controllers require starting with minimum set point. Verify calibration procedure for specific project.
 - b. Measure airflow and adjust calibration factors as required for design cold-deck maximum airflow and hot-deck minimum airflow. Record calibration factors.
 - c. When maximum airflow is correct, balance the air outlets downstream from terminal units.
 - d. Adjust controls so that terminal is calling for full heating.
 - e. Measure airflow and adjust calibration factors as required for design cold-deck minimum airflow and hot-deck maximum airflow. Record calibration factors. If no minimum calibration is available, note any deviation from design airflow.
5. After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.
 - a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
 - b. Set terminals for maximum airflow. If system design includes diversity (cooling coil or fan), adjust terminals for maximum and minimum airflow so that connected total matches cooling coil or fan selection and simulates actual load in the building. In systems with separate hot-deck and cold-deck fans, diversity consideration applies to each individual fan.
 - c. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
 - d. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - e. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.
6. Measure the fan(s) static pressures as follows:

- a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report any artificial loading of filters at the time static pressures are measured.
7. Set final return and outside airflow to the fan(s) while operating at maximum return airflow and minimum outdoor airflow.
- a. Balance the return-air ducts and inlets the same as described for constant-volume air systems.
 - b. Verify that all terminal units are meeting design airflow under system maximum flow.
8. Re-measure the inlet static pressure at the most critical terminal unit and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls contractor.
9. Verify final system conditions as follows:
- a. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
 - b. Re-measure and confirm that total airflow is within design.
 - c. Re-measure final fan operating data, rpms, volts, amps, and static profile.
 - d. Mark final settings.
 - e. Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.
 - f. Verify tracking between supply and return fans.
10. Record final fan-performance data.

3.9 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

- A. **Compensating for Diversity:** When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a maximum set-point airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.
- B. **Pressure-Independent, Variable-Air-Volume Systems:** After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
 1. Set outside-air dampers at minimum and return- and exhaust-air dampers at a position that simulates full-cooling load.
 2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering

- static pressure for the critical terminal unit is not less than the sum of terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within indicated airflow.
 4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
 5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.
 - a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
 6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
 7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
 8. Record the final fan performance data.
- C. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
1. Balance systems similar to constant-volume air systems.
 2. Set terminal units and supply fan at full-airflow condition.
 3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
 4. Readjust fan airflow for final maximum readings.
 5. Measure operating static pressure at the sensor that controls the supply fan, if one is installed, and verify operation of the static-pressure controller.
 6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
 7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.
 - a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.
 8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
- D. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan

systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.
2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
3. Set terminal units at full-airflow condition.
4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Adjust terminal units for minimum airflow.
6. Measure static pressure at the sensor.
7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

3.10 PROCEDURES FOR MULTIZONE SYSTEMS

- A. Position the unit's automatic zone dampers for maximum flow through the cooling coil.
- B. The procedures for multizone systems will utilize the zone balancing dampers to achieve the indicated airflow within the zone.
- C. After balancing, place the unit's automatic zone dampers for maximum heating flow. Retest zone airflows and record any variances.
- D. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 1. Measure total airflow.
 - a. Set outside-air, return-air and relief-air dampers for proper position that simulates minimum outdoor air conditions.
 - b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
 - c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.
 2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.

- c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
 4. Obtain approval from [Architect] [Owner] [Construction Manager] [commissioning authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
 - E. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
 1. Measure airflow of submain and branch ducts.
 2. Adjust submain and branch duct volume dampers for specified airflow.
 3. Re-measure each submain and branch duct after all have been adjusted.
 - F. Adjust air inlets and outlets for each space to indicated airflows.
 1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
 2. Measure inlets and outlets airflow.
 3. Adjust each inlet and outlet for specified airflow.
 4. Re-measure each inlet and outlet after they have been adjusted.
 - G. Verify final system conditions.
 1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
 2. Re-measure and confirm that total airflow is within design.
 3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
 4. Mark all final settings.
 5. Test system in economizer mode. Verify proper operation and adjust if necessary.
 6. Measure and record all operating data.
 7. Record final fan-performance data.
- 3.11 PROCEDURES FOR INDUCTION-UNIT SYSTEMS
- A. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.

- B. Adjust each induction unit.
- C. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
1. Measure total airflow.
 - a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
 - b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
 - c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.
 2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
 4. Obtain approval from [**Architect**] [**Owner**] [**Construction Manager**] [**commissioning authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- D. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
1. Measure airflow of submain and branch ducts.
 2. Adjust submain and branch duct volume dampers for specified airflow.
 3. Re-measure each submain and branch duct after all have been adjusted.
- E. Balance airflow to each induction unit by measuring the nozzle pressure and comparing it to the manufacturer's published data for nozzle pressure versus cfm. Adjust the unit's inlet damper to achieve the required nozzle pressure for design cfm.

- F. Verify final system conditions.
1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
 2. Re-measure and confirm that total airflow is within design.
 3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
 4. Mark all final settings.
 5. Test system in economizer mode. Verify proper operation and adjust if necessary.
 6. Measure and record all operating data.
 7. Record final fan-performance data.

3.12 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

- A. Prepare test reports with pertinent design data and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against approved pump flow rate. Correct variations that exceed plus or minus 5%.
- B. Prepare schematic diagrams of systems' "as-constructed" piping layouts.
- C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:
1. Open all manual valves for maximum flow.
 2. Check expansion tank liquid level.
 3. Check makeup-water-station pressure gage for adequate pressure for highest vent.
 4. Check flow-control valves for specified sequence of operation and set at indicated flow.
 5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
 6. Set system controls so automatic valves are wide open to heat exchangers.
 7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
 8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.13 PROCEDURES FOR HYDRONIC SYSTEMS

- A. Measure water flow at pumps. Use the following procedures, except for positive-displacement pumps:
1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
 2. Check system resistance. With all valves open, read pressure differential across

- the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
 3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
 4. Report flow rates that are not within plus or minus 5% of design.
 - B. Set calibrated balancing valves, if installed, at calculated presettings.
 - C. Measure flow at all stations and adjust, where necessary, to obtain first balance.
 1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.
 - D. Measure flow at main balancing station and set main balancing device to achieve flow that is 5% greater than indicated flow.
 - E. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:
 1. Determine the balancing station with the highest percentage over indicated flow.
 2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
 3. Record settings and mark balancing devices.
 - F. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.
 - G. Measure the differential-pressure control valve settings existing at the conclusions of balancing.
- 3.14 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS
- A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.
- 3.15 PROCEDURES FOR PRIMARY-SECONDARY-FLOW HYDRONIC SYSTEMS
- A. Balance the primary system crossover flow first, then balance the secondary system.
- 3.16 PROCEDURES FOR STEAM SYSTEMS
- A. Measure and record upstream and downstream pressure of each piece of equipment.

- B. Measure and record upstream and downstream steam pressure of pressure-reducing valves.
- C. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
- D. Check settings and operation of each safety valve. Record settings.
- E. Verify the operation of each steam trap.

3.17 PROCEDURES FOR HEAT EXCHANGERS

- A. Measure water flow through all circuits.
- B. Adjust water flow to within specified tolerances.
- C. Measure inlet and outlet water temperatures.
- D. Measure inlet steam pressure.
- E. Check settings and operation of safety and relief valves. Record settings.

3.18 PROCEDURES FOR MOTORS

- A. Motors 1/2 HP and Larger: Test at final balanced conditions and record the following data:
 - 1. Manufacturer's name, model number, and serial number.
 - 2. Motor horsepower rating.
 - 3. Motor rpm.
 - 4. Efficiency rating.
 - 5. Phase and hertz.
 - 6. Nameplate and measured voltage, each phase.
 - 7. Nameplate and measured amperage, each phase.
 - 8. Starter size and thermal-protection-element rating.
 - 9. Service factor and frame size.
- B. Motors Driven by Variable-Frequency Controllers:
 - 1. Test for proper operation at speeds varying from minimum to maximum.
 - 2. Test manual bypass of controller to prove proper operation.
 - 3. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

3.19 PROCEDURES FOR CHILLERS

- A. Balance water flow through each evaporator and condenser to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in

a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. For water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
6. Capacity: Calculate in tons of cooling.
7. For air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.20 PROCEDURES FOR COOLING TOWERS

- A. Tests in paragraph below do not comply with CTI STD-105, "Acceptance Test Code." Shut off makeup water for the duration of the test, and verify that makeup and blowdown systems are fully operational after tests and before leaving the equipment.
- B. Balance total condenser-water flows to towers. Measure and record the following data:
 1. Condenser-water flow to each cell of the cooling tower.
 2. Entering- and leaving-water temperatures.
 3. Wet- and dry-bulb temperatures of entering air.
 4. Wet- and dry-bulb temperatures of leaving air.
 5. Condenser-water flow rate recirculating through the cooling tower.
 6. Cooling-tower spray pump discharge pressure.
 7. Condenser-water flow through bypass.
 8. Fan and motor operating data.
 9. Adjust water level and feed rate of makeup-water system.

3.21 PROCEDURES FOR CONDENSING UNITS

- A. Verify proper rotation of fans.
- B. Measure entering- and leaving-air temperatures.
- C. Record fan and motor operating data.

3.22 PROCEDURES FOR BOILERS

- A. Hydronic Boilers:

1. Measure and record entering- and leaving-water temperatures.
2. Measure and record water flow.
3. Record relief valve pressure setting.

B. Steam Boilers:

1. Measure and record entering-water temperature.
2. Measure and record feed water flow.
3. Measure and record leaving-steam pressure and temperature.
4. Record relief valve pressure setting.

3.23 PROCEDURES FOR HEAT-TRANSFER COILS

A. Water Coils: Measure, adjust, and record the following data for each water coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop for major (more than 20 gpm) equipment coils, excluding unitary equipment such as reheat coils, unit heaters, and fan-coil units.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.

B. Electric Coils: Measure, adjust, and record the following data for each electric heating coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Steam Coils: Measure, adjust, and record the following data for each steam coil:

1. Dry-bulb temperature of entering and leaving air.
2. Airflow.
3. Inlet steam pressure.

D. Refrigerant Coils: Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.24 PROCEDURES FOR COMMERCIAL KITCHEN HOODS

- A. Reference Section 233813 "Commercial Kitchen Hoods" for more information on kitchen hood equipment.
- B. Measure, adjust, and record the airflow of each kitchen hood. For kitchen hoods designed with integral makeup air, measure and adjust the exhaust and makeup airflow. Measure airflow by duct Pitot-tube traverse. If a duct Pitot-tube traverse is not possible, provide an explanation in the report of the reason(s) why and also the reason why the method used was chosen.
 - 1. Install welded test ports in the sides of the exhaust duct for the duct Pitot-tube traverse. Install each test port with a threaded cap that is liquid tight.
- C. After balancing is complete, do the following:
 - 1. Measure and record the static pressure at the hood exhaust-duct connection.
 - 2. Measure and record the hood face velocity. Make measurements at multiple points across the face of the hood. Perform measurements at a maximum of 12 inches between points and between any point and the perimeter. Calculate the average of the measurements recorded. Verify that the hood average face velocity complies with the Contract Documents and governing codes.
 - 3. Check the hood for capture and containment of smoke using a smoke emitting device. Observe the smoke pattern. Make adjustments to room airflow patterns to achieve optimum results.
- D. Visually inspect the hood exhaust duct throughout its entire length in compliance with authorities having jurisdiction. Begin at the hood connection and end at the point it discharges outdoors. Report findings.
 - 1. Check duct slopes as required.
 - 2. Verify that duct access is installed as required.
 - 3. Verify that point of termination is as required.
 - 4. Verify that duct air velocity is within the range required.
 - 5. Verify that duct is within a fire-rated enclosure.
- E. Report deficiencies.

3.25 PROCEDURES FOR SPACE PRESSURIZATION MEASUREMENTS AND ADJUSTMENTS

- A. Before testing for space pressurization, observe the space to verify the integrity of the space boundaries. Verify that windows and doors are closed and applicable safing, gaskets, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.
- B. Measure, adjust, and record the pressurization of each room, each zone, and each building by adjusting the supply, return, and exhaust airflows to achieve the indicated conditions.

- C. Measure space pressure differential where pressure is used as the design criteria and measure airflow differential where differential airflow is used as the design criteria for space pressurization.
 - 1. For pressure measurements, measure and record the pressure difference between the intended spaces at the door with all doors in the space closed. Record the high-pressure side, low-pressure side, and pressure difference between each adjacent space.
 - 2. For applications with cascading levels of space pressurization, begin in the most critical space and work to the least critical space.
 - 3. Test room pressurization first, then zones, and finish with building pressurization.
- D. To achieve indicated pressurization, set the supply airflow to the indicated conditions and adjust the exhaust and return airflow to achieve the indicated pressure or airflow difference.
- E. For spaces with pressurization being monitored and controlled automatically, observe and adjust the controls to achieve the desired set point.
 - 1. Compare the values of the measurements taken to the measured values of the control system instruments and report findings.
 - 2. Check the repeatability of the controls by successive tests designed to temporarily alter the ability to achieve space pressurization. Test overpressurization and underpressurization, and observe and report on the system's ability to revert to the set point.
 - 3. For spaces served by variable-air-volume supply and exhaust systems, measure space pressurization at indicated airflow and minimum airflow conditions.
- F. In spaces that employ multiple modes of operation, such as normal mode and emergency mode or occupied mode and unoccupied mode, measure, adjust, and record data for each operating mode.
- G. Record indicated conditions and corresponding initial and final measurements. Report deficiencies.

3.26 WATER SYSTEM PROCEDURE

- A. Adjust water systems to provide required or design quantities.
- B. Hydronic Systems with Meters: Use calibrated [**Venturi tubes, orifices, or other metered**] fittings and pressure gages to determine flow rates for system balance. On completion of the balance, the following information shall be recorded in the report: Flow meter or calibrated valve size and brand, required flow rate and pressure drop, valve settings on meters or valves with a readable scale, flow rate in both full coil flow and full bypass modes.
- C. Hydronic Systems Without Meters: Where flow metering devices are not installed, base flow balance on temperature difference across various heat transfer elements in the system. On completion of the balance the following information shall be recorded

in the report:

1. Design entering and leaving water temperature/pressure drop.
 2. Final balance entering and leaving water temperature/pressure drop.
- D. The hydronic system(s) shall be balanced being certain that the path to one terminal is fully open. Total system flow shall be adjusted at pump by restricting the discharge balance valve. Indicate final valve position on report.
- E. Adjust systems to provide specified pressure drops and flows through heat transfer elements prior to thermal testing. Perform balancing by measurement of temperature differential in conjunction with air balancing.
- F. Effect system balance with automatic control valves fully open to heat transfer elements. Control valve bypass loops shall be set with the balancing valve to provide equal flow in either mode. Confirm in writing.
- G. Effect adjustment of water distribution systems by means of balancing cocks, valves, and fittings. Do not use service or shut-off valves for balancing unless indexed for balance point.
- H. Where available pump capacity is less than total flow requirements or individual system parts, full flow in one part may be simulated by temporary restriction of flow to other parts.

3.27 SOUND TESTS

- A. Perform sound-pressure-level measurements with an octave-band analyzer complying with ANSI S1.4 for Type 1 sound-level meters and ANSI S1.11 for octave-band filters. Comply with requirements in ANSI S1.13, unless otherwise indicated.
- B. Calibrate sound meters before each day of testing. Use a calibrator provided with the sound meter complying with ANSI S1.40 and that has NIST certification.
- C. Use a microphone that is suitable for the type of sound levels measured. For areas where air velocities exceed 100 fpm, use a windscreen on the microphone.
- D. Perform sound-level testing after air and water balancing and equipment testing are complete.
- E. Close windows and doors to the space.
- F. Perform measurements when the space is not occupied and when the occupant noise level from other spaces in the building and outside are at a minimum.
- G. Clear the space of temporary sound sources so unrelated disturbances will not be measured. Position testing personnel during measurements to achieve a direct line-of-sight between the sound source and the sound-level meter.
- H. Take sound measurements at a height approximately 48 inches above the floor and at

least 36 inches from a wall, column, and other large surface capable of altering the measurements.

- I. Take sound measurements in dBA and in each of the 8 unweighted octave bands in the frequency range of 63 to 8000 Hz.
- J. Take sound measurements with the HVAC systems off to establish the background sound levels and take sound measurements with the HVAC systems operating.
 1. Calculate the difference between measurements. Apply a correction factor depending on the difference and adjust measurements.
- K. Perform sound testing at **<Insert number>** locations on Project for each of the following space types. For each space type tested, select a measurement location that has the greatest sound level. If testing multiple locations for each space type, select at least one location that is near and at least one location that is remote from the predominant sound source.
 1. Private office.
 2. Open office area.
 3. Conference room.
 4. Hold rooms
 5. Each space with an indicated noise criterion of NC 40 and lower that is adjacent to a mechanical equipment room or roof mounted equipment.
 6. Inside each mechanical equipment room.
 7. **<Insert other spaces.>**

3.28 VIBRATION TESTS

- A. After systems are balanced and construction is Substantially Complete, measure and record vibration levels on equipment having motor horsepower equal to or greater than **[10] [15] [25]<Insert number>**.
- B. Use a vibration meter meeting the following criteria:
 1. Solid-state circuitry with a piezoelectric accelerometer.
 2. Velocity range of 0.1 to 10 inches per second.
 3. Displacement range of 1 to 100 mils.
 4. Frequency range of at least 0 to 1000 Hz.
 5. Capable of filtering unwanted frequencies.
- C. Calibrate the vibration meter before each day of testing.
 1. Use a calibrator provided with the vibration meter.
 2. Follow vibration meter and calibrator manufacturer's calibration procedures.
- D. Perform vibration measurements when other building and outdoor vibration sources are at a minimum level and will not influence measurements of equipment being tested.

1. Turn off equipment in the building that might interfere with testing.
 2. Clear the space of people.
- E. Perform vibration measurements after air and water balancing and equipment testing is complete.
- F. Clean equipment surfaces in contact with the vibration transducer.
- G. Position the vibration transducer according to manufacturer's written instructions and to avoid interference with the operation of the equipment being tested.
- H. Measure and record vibration on rotating equipment over 3 hp.
- I. Measure and record equipment vibration, bearing vibration, equipment base vibration, and building structure vibration. Record velocity and displacement readings in the horizontal, vertical, and axial planes.
1. Pumps:
 - a. Pump Bearing: Drive end and opposite end.
 - b. Motor Bearing: Drive end and opposite end.
 - c. Pump Base: Top and side.
 - d. Building: Floor.
 - e. Piping: To and from the pump after flexible connections.
 2. Fans and HVAC Equipment with Fans:
 - a. Fan Bearing: Drive end and opposite end.
 - b. Motor Bearing: Drive end and opposite end.
 - c. Equipment Casing: Top and side.
 - d. Equipment Base: Top and side.
 - e. Building: Floor.
 - f. Ductwork: To and from equipment after flexible connections.
 - g. Piping: To and from equipment after flexible connections.
 3. Chillers and HVAC Equipment with Compressors:
 - a. Compressor Bearing: Drive end and opposite end.
 - b. Motor Bearing: Drive end and opposite end.
 - c. Equipment Casing: Top and side.
 - d. Equipment Base: Top and side.
 - e. Building: Floor.
 - f. Piping: To and from equipment after flexible connections.
- J. For equipment with vibration isolation, take floor measurements with the vibration isolation blocked solid to the floor and with the vibration isolation floating. Calculate and report the differences.
- K. Inspect, measure, and record vibration isolation.
1. Verify that vibration isolation is installed in the required locations.

2. Verify that installation is level and plumb.
3. Verify that isolators are properly anchored.
4. For spring isolators, measure the compressed spring height, the spring OD, and the travel-to-solid distance.
5. Measure the operating clearance between each inertia base and the floor or concrete base below. Verify that there is unobstructed clearance between the bottom of the inertia base and the floor.

L. Reporting:

1. Report shall record location and the system tested.
2. Include horizontal-vertical-axial measurements for tests.
3. Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from the AABC National Standards. Acceptable levels of vibration are normally "smooth" to "good."
4. Include in report General Machinery Vibration Severity Chart, with conditions plotted.

3.29 DUCT LEAKAGE TESTS

- A. Witness the duct pressure testing performed by Installer.
- B. Verify that proper test methods are used and that leakage rates are within specified tolerances.
- C. Report deficiencies observed.

3.30 CONTROLS VERIFICATION

- A. In conjunction with system balancing, perform the following:
 1. Verify temperature control system is operating within the design limitations.
 2. Confirm that the sequences of operation are in compliance with Contract Documents.
 3. Verify that controllers are calibrated and function as intended.
 4. Verify that controller set points are as indicated.
 5. Verify the operation of lockout or interlock systems.
 6. Verify the operation of valve and damper actuators.
 7. Verify that controlled devices are properly installed and connected to correct controller.
 8. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
 9. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.
- B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.31 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

- A. Before any demolition work or duct work alterations are made, measure airflow, temperature, static pressure and electrical measurements on main equipment serving the branch line. VAV systems shall be ramped to 100% before measurements are taken.
- B. Perform a preconstruction inspection of existing equipment that is to remain and be reused.
1. Measure and record the operating speed, airflow, and static pressure of each fan.
 2. Measure motor voltage and amperage. Compare the values to motor nameplate information.
 3. Check the refrigerant charge.
 4. Check the condition of filters.
 5. Check the condition of coils.
 6. Check the operation of the drain pan and condensate-drain trap.
 7. Check bearings and other lubricated parts for proper lubrication.
 8. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.
- C. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:
1. New filters are installed.
 2. Coils are clean and fins combed.
 3. Drain pans are clean.
 4. Fans are clean.
 5. Bearings and other parts are properly lubricated.
 6. Deficiencies noted in the preconstruction report are corrected.
- D. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.
1. Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.
 2. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
 3. If calculations increase or decrease the airflow rates and water flow rates by more than 5 percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5 percent or less, equipment adjustments are not required.
 4. Balance each air outlet.
- E. After all branch line ductwork modifications are complete and TAB services have been

performed, measure airflow, temperature, static pressure and electrical measurements on main equipment serving the branch line. VAV systems shall be ramped to 100% before measurements are taken.

3.32 TOLERANCES

- A. Set HVAC system's airflow rates and water flow rates within the following tolerances:
 - 1. Supply, Return, and Exhaust Fans and Equipment with Fans: Minus 5 to plus 10 percent] <Insert value>.
 - 2. Air Outlets and Inlets: [Zero to plus 10 percent] <Insert value>.
 - 3. Heating-Water Flow Rate: [Zero to plus 10 percent] <Insert value>.
 - 4. Cooling-Water Flow Rate: [Zero to plus 5 percent] <Insert value>.
- B. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.
- C. Supply, return and exhaust airflow rate tolerances shall be identical for each system. (IE: If an AHU is balanced to 97% of design airflow rate, the corresponding exhaust fan should match this 97% tolerance.)

3.33 ADJUSTING

- A. Ensure recorded data represents actual measured or observed conditions.
- B. Permanently mark settings of valves, dampers, and other adjustment devices allowing settings to be restored. Set and lock memory stops.
- C. After adjustment, take measurements to verify balance has not been disrupted or that such disruption has been rectified.
- D. Leave systems in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes, and restoring thermostats to specified settings.
- E. At final inspection, recheck random selections of data recorded in report. Recheck points or areas as selected and witnessed by the DEN Project Manager.
- F. Check and adjust systems approximately six months after final acceptance and submit report.

3.34 PROGRESS REPORTING

- A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems balancing devices. Recommend changes and additions to systems balancing devices to facilitate proper performance measuring and balancing. Recommend

changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

- B. Status Reports: Prepare [**weekly**] [**biweekly**] [**monthly**] <Insert time interval> progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.35 SCHEDULES

- A. Equipment Requiring Testing, Adjusting, and Balancing:

1. Fire Pumps
2. Sprinkler Air Compressor
3. Electric Water Coolers
4. Plumbing Pumps
5. HVAC Pumps
6. Water Tube Boilers
7. Packaged Steel Water Tube Boilers
8. Packaged Steel Fire Tube Boilers
9. Forced Air Furnaces
10. Direct Fired Furnaces
11. Reciprocating Water Chillers
12. Air Cooled Water Chillers
13. Centrifugal Water Chillers
14. Absorption Water Chillers
15. Induced Draft Cooling Tower
16. Blow Through Cooling Tower
17. Air Cooled Refrigerant Condensers
18. Packaged Roof Top Heating/Cooling Units
19. Packaged Terminal Air Conditioning Units
20. Unit Air Conditioners
21. Computer Room Air Conditioning Units
22. Air Coils
23. Evaporative Humidifier
24. Sprayed Coil Dehumidifier
25. Terminal Heat Transfer Units
26. Induction Units
27. Air Handling Units
28. Fans
29. Air Filters
30. Air Terminal Units
31. Air Inlets and Outlets
32. Controls Compressor

3.36 ELECTRIC HEATERS

- A. Check staging of heating devices and reset if required for proper operation.

3.37 MOTOR STARTERS AND THERMAL HEATERS

- A. Coordinate the requirement for the exchange of thermal overloads as required for proper motor protection on magnetic and manual starters. Check for correct sizing and notify Installers responsible for supply of proper devices of corrections or replacements needed.

3.38 FINAL REPORT

- A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.
3. Certify validity and accuracy of field data.

- B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and Product Data.

- C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB specialist.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:
 - a. Indicated versus final performance.
 - b. Final performance percentage of design performance.
 - c. Equipment system or zone service.
 - d. Notable characteristics of systems.

- e. Description of system operation sequence if it varies from the Contract Documents.
12. Nomenclature sheets for each item of equipment.
 13. A set of contract document drawings indicating 'as-built' conditions shall be included in the report with all terminals (VAV boxes, outlets, inlets, coils, unit heaters, etc.) and thermostat locations clearly marked and all equipment designated. Locations of all tests shall be clearly indicated.
 14. Data for terminal units, including manufacturer's name, type, size, and fittings.
 15. Notes to explain why certain final data in the body of reports vary from indicated values and proposed resolutions for equipment measured outside of the acceptable specified ranges.
 16. Test conditions for fans and pump performance forms including the following:
 - a. Settings for outdoor-, return-, and exhaust-air dampers.
 - b. Conditions of filters.
 - c. Cooling coil, wet- and dry-bulb conditions.
 - d. Face and bypass damper settings at coils.
 - e. Fan drive settings including settings and percentage of maximum pitch diameter.
 - f. Inlet vane settings for variable-air-volume systems.
 - g. Settings for supply-air, static-pressure controller.
 - h. Other system operating conditions that affect performance.
- D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
1. Quantities of outdoor, supply, return, and exhaust airflows.
 2. Water and steam flow rates.
 3. Duct, outlet, and inlet sizes.
 4. Pipe and valve sizes and locations.
 5. Terminal units.
 6. Balancing stations.
 7. Position of balancing devices.
- E. Equipment measurements shall include the following information.
1. Instrument list including instrument, manufacturer, model, serial number, range, calibration date.
 2. Data to be submitted for systems having electric motor drives, except as otherwise indicated, shall in all cases include the following to the extent applicable:
 - a. Electric Motor data including manufacturer, HP, Voltage, phase, amperage (name plate, actual (in all operating modes), no load), service factor, efficiency, power factor, starter size (brand, model, enclosure type, installed thermal heaters and the rating of the heaters, required thermal heaters and the rating of the heaters if different than installed).
 - b. For motors controlled by variable frequency controllers, test data shall include amperage at one-third, two-thirds, and full speed motor RPM.

- c. V-Belt Drive data including identification/location, required driven RPM; driven sheave (diameter and RPM), belt (size and quality), motor sheave (diameter and RPM), center-to-center distance (maximum, minimum and final).
3. Air Moving Equipment data including location, manufacturer, model, supply airflow (specified and actual), return airflow (specified and actual), outside airflow (specified and actual), total static pressure (specified and actual), inlet pressure, discharge pressure, fan RPM, motor and V-belt drive data. Include Manufacturer's fan curves.
4. Static pressure across each individual component of the system and the total system.
5. Exhaust Fan data including location, manufacturer, model, airflow (specified and actual), total static pressure (specified and actual), inlet pressure, discharge pressure (specified and actual), inlet pressure, discharge pressure, fan RPM, motor and V-belt drive data. Include Manufacturer's fan curves.
6. Outside/Return Air data including identification/ location, supply airflow (specified and actual), return airflow (specified and actual), outside airflow (specified and actual), return air temperature, outside air temperature, mixed air temperature (specified and actual).
7. Air Terminal Device data including air terminal number, room number/location, terminal type, terminal size, area factor, design velocity, design airflow, test (final) velocity, test (final) airflow, percent of design airflow.
8. Terminal Unit data including manufacturer, type (constant, variable, dual duct, reheat, fan powered parallel, fan powered-series), identification/number, location, model, size, minimum static pressure, minimum airflow (specified and actual), maximum airflow (specified and actual), inlet static pressure, fan air quantity (specified and actual) on fan powered terminal units. Include discharge air temperature for maximum cooling airflow and for maximum heating airflow for units equipped with heating coils.
9. Duct Traverse data including system zone/branch, duct size, area, design velocity, design airflow, test velocity, test airflow, duct static pressure, air temperature, and air correction factor.
10. Air Monitoring Station data including identification/ location, system, size, area, design velocity, design airflow, test (final) velocity, test (final) airflow.
11. Total CFM (required and final) for each fan system, including cabinet heaters, fan coils, etc.
12. Electric Duct Heater data including manufacturer, identification number, location, model, design KW, number of stages, phase, voltage, amperage, test voltage (each phase), test amperage (each phase), airflow (specified and actual), temperature rise (specified and actual).
13. Pump data including identification/number, manufacturer, size/model, impeller, service, flow rate (specified and actual), pressure drop (specified and actual), discharge pressure, suction pressure, total operating head pressure, shut-off (discharge and suction pressures), shut-off (total head pressure), and motor data. Include manufacturer's pump curves.
14. Chiller data including identification/number, manufacturer, capacity, model, evaporator leaving water temperature (specified and actual), evaporator pressure drop (specified and actual), evaporator water flow rate (specified and actual), condenser entering water temperature (specified and actual), condenser leaving

- water temperature (specified and actual), condenser pressure drop (specified and actual), condenser water flow rate (specified and actual), motor amperage.
15. Cooling Tower data including tower identification number, manufacturer, model, rated capacity, entering air WB temperature (specified and actual), leaving air WB temperature (specified and actual), ambient air DB temperature, condenser water entering temperature, condenser water leaving temperature, condenser water flow rate, fan RPM, motor data, wind velocity and direction.
 16. Air Cooled Condenser data including identification number, location, manufacturer, model, entering DB air temperature (specified and actual), leaving DB air temperature (specified and actual), number of compressors, and motor data.
 17. Heat Exchanger data including identification/number, location, service, manufacturer, model, primary water entering temperature (specified and actual), primary water leaving temperature (specified and actual), primary water flow (specified and actual), primary water pressure drop (specified and actual), secondary water entering temperature (specified and actual), secondary water flow (specified and actual), secondary water pressure drop (specified and actual).
 18. Boiler data including entering and leaving water temperature, gas flow rate, flue gas analysis (copy of manufacturer's analysis report), entering and leaving water pressures, and motor data (if applicable).
 19. Cooling Coil data including identification/number, location, service, manufacturer, airflow (specified and actual), entering air DB and WB temperatures (specified and actual), leaving air DB and WB temperatures (specified and actual), water flow (specified and actual), water pressure drop (specified and actual), entering water temperature (specified and actual), leaving water temperature (specified and actual), air pressure drop (specified and actual).
 20. Heating Coil data including identification/number, location, service, manufacturer, airflow (specified and actual), water flow (specified and actual), water pressure drop (specified and actual), entering and leaving water temperatures (specified and actual), entering and leaving air temperatures (specified and actual), air pressure drop (specified and actual).
 21. Heat Release Equipment (i.e. unit heaters, cabinet heaters, finned tube radiation, etc.) data including identification/number, location, manufacturer, inlet and outlet water temperatures (specified and actual), inlet and outlet water pressures (specified and actual), entering and leaving air temperatures (specified and actual - where applicable), and motor data (where applicable).
 22. Flow Measuring Station and Calibrated Balancing Valve data including identification, location, size, manufacturer, model, flow rate (specified and actual), pressure drop (specified and actual), station or valve calibrated setting.
 23. Gas flow and pressure to each piece of mechanical equipment and gas pressure at meter under full flow.
 24. Measurement of existing equipment data prior to new work start.
 - a. Date of test on original equipment
 - b. Equipment tag
 - c. Inlet static pressure (inches WC)
 - d. Outlet static pressure (inches WC)
 - e. Outlet airflow (CFM)
 - f. Coil entering air and water temperatures (F).
 - g. Coil leaving air and water temperatures (F).

- h. Motor electrical data, HP, voltage, and amperage at test time.
25. Measurement of existing equipment data upon completion of new work.
- a. Date of test on original equipment
 - b. Equipment tag
 - c. Inlet static pressure (inches WC)
 - d. Outlet static pressure (inches WC)
 - e. Outlet airflow (CFM)
 - f. Coil entering air and water temperatures (F).
 - g. Coil leaving air and water temperatures (F).
 - h. Motor electrical data, HP, voltage, and amperage at test time.
26. Sound Measurement: Record sound measurements on octave band and dBA test forms and on an NC or RC chart indicating the decibel level measured in each frequency band for both "background" and "HVAC system operating" readings. Record each tested location on a separate NC or RC chart. Record the following on the forms:
- a. Date and time of test. Record each tested location on its own NC curve.
 - b. Sound meter manufacturer, model number, and serial number.
 - c. Space location within the building including floor level and room number.
 - d. Diagram or color photograph of the space showing the measurement location.
 - e. Time weighting of measurements, either fast or slow.
 - f. Description of the measured sound: steady, transient, or tonal.
 - g. Description of predominant sound source.
 - h. Record measured octave bands with all area HVAC equipment off and all area HVAC equipment on.
 - i. Sound data curves for measured equipment and/or spaces with baseline [NC-35] [NC-40] [NC-45] curves for compliance.
27. Vibration Test: Where vibration limitations are specified or shown on the drawings, work shall include measurement and reporting of as-installed systems performance, including the following data:
- a. Location of points:
 - 1) Fan bearing, drive end.
 - 2) Fan bearing, opposite end.
 - 3) Motor bearing, center (if applicable).
 - 4) Motor bearing, drive end.
 - 5) Motor bearing, opposite end.
 - 6) Casing (bottom or top).
 - 7) Casing (side).
 - 8) Duct after flexible connection (discharge).
 - 9) Duct after flexible connection (suction).
 - b. Test readings:

- 1) Horizontal, velocity and displacement.
 - 2) Vertical, velocity and displacement.
 - 3) Axial, velocity and displacement.
 - c. Normally acceptable readings, velocity, and acceleration.
 - d. Unusual conditions at time of test.
 - e. Vibration source (if non-complying).
 28. Indoor-Air Quality Measurement Reports for Each HVAC System:
 - a. HVAC system designation.
 - b. Date and time of test.
 - c. Outdoor temperature, relative humidity, wind speed, and wind direction at start of test.
 - d. Room number or similar description for each location.
 - e. Measurements at each location.
 - f. Observed deficiencies.
 29. Instrument Calibration Reports:
 - a. Report Data:
 - 1) Instrument type and make.
 - 2) Serial number.
 - 3) Application.
 - 4) Dates of use.
 - 5) Dates of calibration.
 30. Measurements outside of tolerance: If the final measurements differ from the design measurements in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED." TAB firm shall provide recommendations and/or solutions for resolving all FAILED measurements.
- F. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:
1. Unit Data:
 - a. Unit identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and unit size.
 - e. Manufacturer's serial number.
 - f. Unit arrangement and class.
 - g. Discharge arrangement.
 - h. Sheave make, size in inches (mm), and bore.
 - i. Center-to-center dimensions of sheave and amount of adjustments in inches (mm).
 - j. Number, make, and size of belts.
 - k. Number, type, and size of filters.

2. Motor Data:

- a. Motor make, and frame type and size.
- b. Horsepower and rpm.
- c. Volts, phase, and hertz.
- d. Full-load amperage and service factor.
- e. Sheave make, size in inches (mm), and bore.
- f. Center-to-center dimensions of sheave and amount of adjustments in inches (mm).

3. Test Data (Indicated and Actual Values):

- a. Total airflow rate in cfm (L/s).
- b. Total system static pressure in inches wg (Pa).
- c. Fan rpm.
- d. Discharge static pressure in inches wg (Pa).
- e. Filter static-pressure differential in inches wg (Pa).
- f. Preheat-coil static-pressure differential in inches wg (Pa).
- g. Cooling-coil static-pressure differential in inches wg (Pa).
- h. Heating-coil static-pressure differential in inches wg (Pa).
- i. Outdoor airflow in cfm (L/s).
- j. Return airflow in cfm (L/s).
- k. Outdoor-air damper position.
- l. Return-air damper position.
- m. Vortex damper position.

G. Apparatus-Coil Test Reports:

1. Coil Data:

- a. System identification.
- b. Location.
- c. Coil type.
- d. Number of rows.
- e. Fin spacing in fins per inch (mm) o.c.
- f. Make and model number.
- g. Face area in sq. ft. (sq. m).
- h. Tube size in NPS (DN).
- i. Tube and fin materials.
- j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

- a. Airflow rate in cfm (L/s).
- b. Average face velocity in fpm (m/s).
- c. Air pressure drop in inches wg (Pa).
- d. Outdoor-air, wet- and dry-bulb temperatures in deg F (deg C).
- e. Return-air, wet- and dry-bulb temperatures in deg F (deg C).
- f. Entering-air, wet- and dry-bulb temperatures in deg F (deg C).
- g. Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).

- h. Water flow rate in **gpm** (L/s).
 - i. Water pressure differential in **feet of head or psig** (kPa).
 - j. Entering-water temperature in **deg F** (deg C).
 - k. Leaving-water temperature in **deg F** (deg C).
 - l. Refrigerant expansion valve and refrigerant types.
 - m. Refrigerant suction pressure in **psig** (kPa).
 - n. Refrigerant suction temperature in **deg F** (deg C).
 - o. Inlet steam pressure in **psig** (kPa).
- H. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:
- 1. Unit Data:
 - a. System identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and unit size.
 - e. Manufacturer's serial number.
 - f. Fuel type in input data.
 - g. Output capacity in **Btu/h** (kW).
 - h. Ignition type.
 - i. Burner-control types.
 - j. Motor horsepower and rpm.
 - k. Motor volts, phase, and hertz.
 - l. Motor full-load amperage and service factor.
 - m. Sheave make, size in **inches** (mm), and bore.
 - n. Center-to-center dimensions of sheave and amount of adjustments in **inches** (mm).
 - 2. Test Data (Indicated and Actual Values):
 - a. Total airflow rate in **cfm** (L/s).
 - b. Entering-air temperature in **deg F** (deg C).
 - c. Leaving-air temperature in **deg F** (deg C).
 - d. Air temperature differential in **deg F** (deg C).
 - e. Entering-air static pressure in **inches wg** (Pa).
 - f. Leaving-air static pressure in **inches wg** (Pa).
 - g. Air static-pressure differential in **inches wg** (Pa).
 - h. Low-fire fuel input in **Btu/h** (kW).
 - i. High-fire fuel input in **Btu/h** (kW).
 - j. Manifold pressure in **psig** (kPa).
 - k. High-temperature-limit setting in **deg F** (deg C).
 - l. Operating set point in **Btu/h** (kW).
 - m. Motor voltage at each connection.
 - n. Motor amperage for each phase.
 - o. Heating value of fuel in **Btu/h** (kW).
- I. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:
 - a. System identification.
 - b. Location.
 - c. Coil identification.
 - d. Capacity in **Btu/h** (kW).
 - e. Number of stages.
 - f. Connected volts, phase, and hertz.
 - g. Rated amperage.
 - h. Airflow rate in **cfm** (L/s).
 - i. Face area in **sq. ft.** (sq. m).
 - j. Minimum face velocity in **fpm** (m/s).

2. Test Data (Indicated and Actual Values):
 - a. Heat output in **Btu/h** (kW).
 - b. Airflow rate in **cfm** (L/s).
 - c. Air velocity in **fpm** (m/s).
 - d. Entering-air temperature in **deg F** (deg C).
 - e. Leaving-air temperature in **deg F** (deg C).
 - f. Voltage at each connection.
 - g. Amperage for each phase.

J. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:
 - a. System identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and size.
 - e. Manufacturer's serial number.
 - f. Arrangement and class.
 - g. Sheave make, size in **inches** (mm), and bore.
 - h. Center-to-center dimensions of sheave and amount of adjustments in **inches** (mm).
2. Motor Data:
 - a. Motor make, and frame type and size.
 - b. Horsepower and rpm.
 - c. Volts, phase, and hertz.
 - d. Full-load amperage and service factor.
 - e. Sheave make, size in **inches** (mm), and bore.
 - f. Center-to-center dimensions of sheave, and amount of adjustments in **inches** (mm).
 - g. Number, make, and size of belts.
3. Test Data (Indicated and Actual Values):

- a. Total airflow rate in **cfm** (L/s).
 - b. Total system static pressure in **inches wg** (Pa).
 - c. Fan rpm.
 - d. Discharge static pressure in **inches wg** (Pa).
 - e. Suction static pressure in **inches wg** (Pa).
- K. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:
1. Report Data:
 - a. System and air-handling-unit number.
 - b. Location and zone.
 - c. Traverse air temperature in **deg F** (deg C).
 - d. Duct static pressure in **inches wg** (Pa).
 - e. Duct size in **inches** (mm).
 - f. Duct area in **sq. ft.** (sq. m).
 - g. Indicated airflow rate in **cfm** (L/s).
 - h. Indicated velocity in **fpm** (m/s).
 - i. Actual airflow rate in **cfm** (L/s).
 - j. Actual average velocity in **fpm** (m/s).
 - k. Barometric pressure in **psig** (Pa).
- L. Air-Terminal-Device Reports:
1. Unit Data:
 - a. System and air-handling unit identification.
 - b. Location and zone.
 - c. Apparatus used for test.
 - d. Area served.
 - e. Make.
 - f. Number from system diagram.
 - g. Type and model number.
 - h. Size.
 - i. Effective area in **sq. ft.** (sq. m).
 2. Test Data (Indicated and Actual Values):
 - a. Airflow rate in **cfm** (L/s).
 - b. Air velocity in **fpm** (m/s).
 - c. Preliminary airflow rate as needed in **cfm** (L/s).
 - d. Preliminary velocity as needed in **fpm** (m/s).
 - e. Final airflow rate in **cfm** (L/s).
 - f. Final velocity in **fpm** (m/s).
 - g. Space temperature in **deg F** (deg C).
- M. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:
 - a. System and air-handling-unit identification.
 - b. Location and zone.
 - c. Room or riser served.
 - d. Coil make and size.
 - e. Flowmeter type.

 2. Test Data (Indicated and Actual Values):
 - a. Airflow rate in **cfm** (L/s).
 - b. Entering-water temperature in **deg F** (deg C).
 - c. Leaving-water temperature in **deg F** (deg C).
 - d. Water pressure drop in **feet of head or psig** (kPa).
 - e. Entering-air temperature in **deg F** (deg C).
 - f. Leaving-air temperature in **deg F** (deg C).
- N. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:
1. Unit Data:
 - a. Unit identification.
 - b. Location.
 - c. Service.
 - d. Make and size.
 - e. Model number and serial number.
 - f. Water flow rate in **gpm** (L/s).
 - g. Water pressure differential in **feet of head or psig** (kPa).
 - h. Required net positive suction head in **feet of head or psig** (kPa).
 - i. Pump rpm.
 - j. Impeller diameter in **inches** (mm).
 - k. Motor make and frame size.
 - l. Motor horsepower and rpm.
 - m. Voltage at each connection.
 - n. Amperage for each phase.
 - o. Full-load amperage and service factor.
 - p. Seal type.

 2. Test Data (Indicated and Actual Values):
 - a. Static head in **feet of head or psig** (kPa).
 - b. Pump shutoff pressure in **feet of head or psig** (kPa).
 - c. Actual impeller size in **inches** (mm).
 - d. Full-open flow rate in **gpm** (L/s).
 - e. Full-open pressure in **feet of head or psig** (kPa).
 - f. Final discharge pressure in **feet of head or psig** (kPa).
 - g. Final suction pressure in **feet of head or psig** (kPa).
 - h. Final total pressure in **feet of head or psig** (kPa).
 - i. Final water flow rate in **gpm** (L/s).

- j. Voltage at each connection.
- k. Amperage for each phase.

O. Instrument Calibration Reports:

1. Report Data:

- a. Instrument type and make.
- b. Serial number.
- c. Application.
- d. Dates of use.
- e. Dates of calibration.

3.39 VERIFICATION OF TAB REPORT

- A. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of [**Architect**] [**Owner**] [**Construction Manager**] [**commissioning authority**].
- B. [**Architect**] [**Owner**] [**Construction Manager**] [**Commissioning authority**] shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
- C. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
- D. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.
- E. If TAB work fails, proceed as follows:
 - 1. TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
 - 2. If the second final inspection also fails, Owner may contract the services of another TAB specialist to complete TAB work according to the Contract Documents and deduct the cost of the services from the original TAB specialist's final payment.
 - 3. If the second verification also fails, [**Owner**] [**design professional**] [**Architect**] may contact AABC Headquarters regarding the AABC National Performance Guaranty.
- F. Prepare test and inspection reports.

3.40 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the Final Report.
2. Randomly check the following for each system:
 - a. Measure airflow of at least 10% of air outlets.
 - b. Measure water flow of at least 5% of terminals.
 - c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
 - d. Measure sound levels at two locations.
 - e. Measure space pressure of at least 10% of locations.
 - f. Verify that balancing devices are marked with final balance position.
 - g. Note deviations to the Contract Documents in the Final Report.

B. Final Inspection:

1. After initial inspection is complete and evidence by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by DEN Project Manager, DEN Mechanical Engineer or their designated representative(s).
2. TAB firm test and balance engineer shall conduct the inspection in the presence of DEN Project Manager, DEN Mechanical Engineer or their designated representative(s).
3. DEN Project Manager, DEN Mechanical Engineer or their designated representative(s) shall randomly select measurements documented in the final report to be rechecked. The rechecking shall be limited to either 10% of the total measurements recorded, or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If the rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10% of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.
6. TAB firm shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes and resubmit the final report.
7. Request a second final inspection. If the second final inspection also fails, Owner shall contract the services of another TAB firm to complete the testing and balancing in accordance with the Contract Documents and deduct the cost of the services from the final payment.

3.41 ADDITIONAL TESTS

- A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.
- B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230593

SECTION 230596 - HVAC SMOKE CONTROL TESTING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This section of the Specifications covers smoke testing as required by code. The smoke testing shall be the responsibility of a single Smoke Testing Agency (STA).
- B. Smoke testing shall be performed in compliance with the most current version of the Denver Amendments to the International Fire Code and Appendices.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. General: Submit the following according to the Conditions of the Contract and Division 01 Specification Sections.
- B. Submit draft copies of report for review prior to final acceptance of Project. Resubmit until accepted by DEN Project Manager and DEN Life Safety Team.
- C. Submit name of Smoke Testing Agency (STA) for approval within **[30]** thirty days after award of Contract to ensure that the STA firm has met the requirements this section of the Specifications and is on the project from the outset of construction.
- D. Within seven (7) days of completion and acceptance of testing of the smoke-control systems, architecture, and life safety activation systems, a copy of all operational and acceptance testing documentation shall be provided to the DEN Project Manager. This documentation shall be available for reference for periodic testing and maintenance. In addition, this information shall be submitted to the fire prevention bureau within 7 days of completion and acceptance testing.

1.4 CLOSEOUT SUBMITTALS

- A. Final Report: Submit one electronic copy containing a PDF version of the entire report, book-marked, indexed and without security. Reports shall include but not be limited to the following:

1. Title page including company name, address and telephone number; project name and location; PE number; Project Engineer; Project Contractor; project altitude.
2. An as-built set of contract drawings shall be included in the report to include floor plans, reflected ceiling plans, equipment schedules, sequence of operations and locations of all tests and measurements.
3. Provide a brief description of the smoke control systems installed in the building being tested, and state the year the building received its construction permit.
4. Describe in general terms the operating test procedures, if the tests were performed by someone other than the engineer submitting the report. Include a list of operating test and performance test deficiencies along with a schedule of the proposed corrective action.
- B. Describe detailed procedures followed during the operating tests, if operating tests were performed by the engineer submitting the report on the performance tests. Describe detailed procedures followed during the performance tests.
- C. List test equipment used and outside air temperature and wind conditions at the time the test were conducted.
- D. State sequences and timing of the system operations during all performance tests (e.g. smoke detector activation time, fan start times, dampers assume correct position time, etc.)
- E. List the location of the test measurements and the measured values for pressure differentials and door opening forces for each test.
- F. Record any operational defects and performance deficiencies with respect to the smoke-control Code and state recommendations and a schedule for corrective action. Retest and record the results.
- G. Include a statement that the smoke-control systems, as installed and tested, operated as required by the Code. If any part of the smoke-control system did not operate as required by the Code, state what action shall be taken to correct the deficiencies, and include documentation of the retest and certification that each deficiency has been cleared.
- H. The test report shall be either written by or written under the direct supervision of the engineer who supervised the testing. The test report shall bear the seal and signature of the engineer of record.
- I. Revised smoke control matrix in Microsoft Excel Format. Obtain the latest version of this file from the DEN Mechanical Engineer. Submit file directly to DEN Mechanical Engineer and DEN Project Manager.
- J. All pages shall be rotated to normal reading view.

1.5 QUALITY ASSURANCE

- A. Company specializing in the testing and balancing of systems specified in this Section with minimum of three years documented experience, and Licensed in the State of Colorado to Practice Mechanical Engineering.
- B. Acceptable Agencies: Subject to conformance with specified requirements, the following agencies are acceptable:
 - 1. Arappco Engineering Company.
 - 2. BradShaw Solutions.
 - 3. Impact Engineering.
 - 4. Rolf Jensen and Associates.
 - 5. Toombs and Associates.
 - 6. or approved equal.

1.6 PUBLICATIONS AND REFERENCE MATERIALS

- A. The most stringent interpretations of standards shall apply. All appendices and annex of standards shall apply.
- B. Materials, workmanship and testing procedures shall conform to the latest issue of all industry standards, publications, or regulations referenced in this section and with the following references as applicable:
 - 1. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE):
 - a. Publication, Design of Smoke Management Systems, 1992 Edition.
 - b. Guideline 5-1994 (RA 2001) - Commissioning Smoke Management Systems.
 - c. Standard 149-2000 - Laboratory Methods of Testing Fans Used to Exhaust Smoke in Smoke Management Systems (ANSI approved).
 - 2. International Building Code (IBC) with Denver Amendments.
 - 3. International Mechanical Code (IMC) with Denver Amendments.
 - 4. International Fire Code (IFC) with Denver Amendments.
 - 5. National Fire Protection Association (NFPA).
 - a. NFPA 70 - National Electrical Code.
 - b. NFPA 72 - National Fire Alarm Code.
 - c. NFPA 90A - Standard for the Installation of Air Conditioning and Ventilating Systems.
 - d. NFPA 92A - Recommended Practice for Smoke-Control Systems.
 - e. NFPA 92B - Standard for Smoke Management Systems in Malls, Atria, and Large Areas.
 - f. NFPA 101 - Life Safety Code.
 - 6. Underwriter Laboratories (UL):

- a. UL 555 - Standard for Safety Fire Dampers.
- b. UL 555S - Standard for Safety Leakage Rated Dampers for Use in Smoke Control Systems.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 OPERATIONAL TESTING

- A. General: The intent of operational testing is to establish that the installation complies with the specified design, is functioning properly, and is ready for acceptance testing. Testing shall be in compliance with the current Denver Amendments of the International Fire Code.
- B. Prior to testing the project manager and appropriate subcontractors shall verify completeness of building construction. Completeness of the following, but not limited to the following, architectural features shall be verified:
 1. Fire stopping.
 2. Doors/closers.
 3. Glazing.
 4. Smoke Partitions and Ceilings.
 5. Fire Alarm System.
 6. Sprinkler System.
 7. Lighting and emergency lighting.
 8. Exit Signage.
 9. Building Paging System.
 10. HVAC Systems.
- C. The following table shall be used for shaft pressure testing:

Shaft:	Operating Static Pressure (in w.g.):	Testing Static Pressure (in w.g.):
West Stairway	1.3	2.0
East Stairway	1.5	2.3
Main Elevator	1.7	2.5
Hoistway/Lobby		
Outside Air	2.9	3.5
General/Pressurization Shaft		
Relief/Life Safety Exhaust Shaft	-3.5	-5.3

1. NOTE: To minimize the effort of determining where the preceding shafts might lack integrity, pressure testing should take place for only two or three floors at a time.

- D. Operational testing of each individual mechanical life safety system and fire protection system shall be performed prior to interconnection to the overall smoke control system. Each test shall be individually documented, including such items as airflow rate, motor speed, voltage, and amperage. Submit operational test reports in accordance with Section 230400 "Basic HVAC Requirements".
- E. Testing shall include the following subsystems to the extent that they affect the operation of the smoke control systems and concurrent testing of other systems:
 - 1. Fire protective signaling system.
 - 2. Building Automation System (including DDC temperature controls system).
 - 3. HVAC equipment.
 - 4. Electrical equipment.
 - 5. Power sources.
 - 6. Emergency power systems.
 - 7. Automatic fire suppression systems.
 - 8. Automatic operating doors and closures.

3.2 OPERATING TESTS

- A. General: The following smoke-control system tests shall be conducted:
 - 1. Verify proper status indication of smoke-control dampers (i.e., "open/closed") and fans (i.e., "on/off") by visual observation at each damper and fan location, and at the Firefighter's Smoke Control Station (FSCS).
 - 2. Verify that all smoke-control dampers and fans assume the correct operating condition under both normal and fire modes, and when the manual override switches at the FSCS are placed in the "auto" position.
 - 3. Verify the manual override switches function properly for smoke-control dampers and fans.
 - 4. Items 1, 2, and 3 above shall be performed by a qualified service technician familiar with the proper operation of smoke-control systems. The STA engineer shall review the results of the tests and shall provide a summary with the documentation provided to the building department and fire prevention bureau.
 - 5. A copy of the test procedures and an accurate log of the tests shall be maintained in the Building Fire Command Center and at either the building management's office or the maintenance office. Any defects, system modifications, and repairs shall be recorded in the log.

3.3 ACCEPTANCE TESTING.

- A. Acceptance testing shall be performed in compliance with local Building Department and Fire Prevention Bureau requirements. The Acceptance testing shall be performed by a Colorado Licensed Mechanical Engineer having a minimum of five (5) years experience performing smoke testing in the Denver Region. The intent of acceptance testing is to demonstrate that the final integrated system installation complies with the specified design and is functioning properly.

- B. Prior to the official acceptance testing of the smoke-control systems, the construction manager, engineer of record and appropriate subcontractors shall confirm that all systems are installed, balanced and operating properly in accordance with the design documents and in accordance with the applicable codes. The construction manager shall then notify the building department and fire prevention bureau that the systems are ready for acceptance testing.
- C. All of the following should be present for the acceptance testing:
1. Fire Prevention Bureau.
 2. Building Department.
 3. Construction Manager.
 4. DEN Life Safety Group.
 5. Engineer of Record.
 6. Owner's Representative.
 7. DEN HVAC personnel
- D. Testing shall be performed during the evening and early morning hours, subject to approval from Federal Agencies operating facilities impacted by the testing. Additional fees payable by the Contractor to the Code Agencies for witnessing off-hour testing and or retesting shall be paid by the Contractor prior to testing.
- E. All documentation from the operational testing should be available for review prior to the acceptance test.
- F. A copy of this testing procedure shall be provided, in advance of the acceptance testing, to the Denver Fire Prevention Bureau, Engineer of Record, and the DEN Life Safety Team. This testing procedure shall include a list of testing equipment that will be used, any smoke generating devices to be used, and on which floors the demonstrations will be done. The procedure shall comply with the International Fire Code requirements.
- G. Smoke generating devices and types of smoke generated shall be approved by the code agencies prior to testing.
- H. The Contractor shall provide all equipment required for testing including ladders, radios, pressure gauges, etc. The smoke generating device(s) shall produce at least the volume of smoke required to fill the space being tested within 5 minutes or as required by the code agencies.

3.4 TEST EQUIPMENT

- A. The Contractor shall provide the following equipment:
1. Calibrated test instruments to read differential pressure with ranges from 0-0.25 in. w.g. and 0-0.50 in. w.g. with 50 feet of tubing.
 2. Spring scale with a range of 0-100 lbs.
 3. Anemometer.
 4. Flow-measuring hood (optional).

5. Door wedges.
6. Tissue paper (for indicating airflow direction).
7. Products that simulate smoke.
8. Materials for recording data.
9. Signs for indicating that a test of the smoke-control system is in progress and that doors must not be opened (or closed).
10. Several two-way radios to coordinate equipment operation and for data recording.

3.5 PROCEDURES FOR SMOKE-CONTROL SYSTEM TESTING

- A. The Contractor shall provide all personnel required to assure timely completion of the testing. The personnel shall include but not be limited to the following:
 1. Electrical Contractor Personnel.
 2. HVAC Contractor Personnel.
 3. Fire Protection Contractor Personnel.
 4. DEN approved security guards to secure doors.
 5. Fire Alarm programming personnel (MCS).
 6. Smoke Testing Agency.
- B. Testing Conference: The Contractor, in cooperation with the DEN Project Manager, shall arrange a conference with all interested parties with at least seven (7) days prior notice to the scheduled testing time to review all aspects of the testing.
- C. The Contractor shall stage equipment with the HVAC subcontractor to assure that vertical access equipment and optional supply and return grilles are available for relocation and replacement at the time of testing.
- D. Prior to beginning acceptance testing, all building equipment shall be placed in normal operation mode, including equipment that is not used to implement smoke control, such as toilet exhaust, HVAC systems, etc.
- E. These acceptance tests shall be performed in conjunction with the fire alarm and fire protection systems to demonstrate proper activation upon activation of any system device.
- F. Should the Fire Prevention Bureau or Fire Department personnel deem it appropriate, smoke or products that simulate smoke shall be used to activate the smoke control systems.
- G. Testing procedures shall comply with acceptable practices as approved by the Denver Fire Prevention Bureau. Procedures include but are not limited to the following:
 1. Measure and record wind speed and direction, outside-air temperature, and relative humidity on each test day.
 2. After air balancing is complete, perform the following pressurization testing for each smoke-control zone in the system:

- a. Verify the boundaries of each smoke-control zone.
 - b. With the HVAC systems in their normal mode of operation and smoke control not operating, measure and record the pressure difference across each smoke-control zone. Make measurements after closing doors that separate the zones. Make one measurement across each door. Clearly indicate the high and low pressure side of each door.
 - c. With the system operating in the smoke-control mode and with each zone in the smoke-control system activated, perform the following:
 - 1) Measure and record the pressure difference across each door that separates the smoke zone from adjacent zones. Make measurements with doors that separate the smoke zone from the other zones closed. Clearly indicate the high and low pressure side of the door. Doors that have a tendency to open slightly due to the pressure difference should have one pressure measurement made while held closed and another measurement made with the door open.
 - 2) Continue to activate each separate zoned smoke-control system and make pressure difference measurements.
 - 3) After testing a smoke zone's smoke-control system, deactivate the HVAC systems involved and return them to their normal operating mode before activating another zone's smoke-control system.
 - 4) Verify that controls necessary to prevent excessive pressure differences are functional.
3. Operational Tests:
- a. Check the proper activation of each zoned smoke-control system in response to all means of activation, both automatic and manual.
 - b. Check automatic activation in response to fire alarm signals received from the building's fire alarm and detection system. Initiate a separate alarm for each means of activation to ensure that the proper operation of the correct zoned smoke-control system occurs.
 - c. Check and record the proper operation of fans, dampers, and related equipment as outlined below for each separate zone of the smoke-control system.
 - 1) Fire zone in which a smoke-control system automatically activates.
 - 2) Type of signal that activates a smoke-control system, such as pull station, sprinkler water flow, or smoke detector.
 - 3) Smoke zone(s) where maximum mechanical exhaust to the outside is implemented and no supply air is provided.
 - 4) Positive pressure smoke-control zone(s) where maximum air supply is implemented and no exhaust to the outside is provided.
 - 5) Fan(s) "ON" as required to implement the smoke-control system. Multiple- or variable-speed fans should be further noted as "MAX. VOLUME" to verify that the intended control configuration is achieved.
 - 6) Fan(s) "OFF" as required to implement the smoke-control system.
 - 7) Damper(s) "OPEN" where maximum airflow must be achieved.

- 8) Damper(s) "CLOSED" where no airflow should take place.
- 9) Auxiliary functions to achieve the smoke-control system configuration such as changes or override of normal operating pressure and temperature-control set points.
- 10) If standby\emergency power is provided for the smoke-control system, test to verify that the system functions while operating under both normal and standby\emergency power.

- H. The acceptance test shall demonstrate that the correct outputs are produced for a given input for each sequence of operation specified. These sequences shall include:
1. Normal mode.
 2. Automatic smoke-control mode for each alarm (exhaust and pressurization).
 3. Manual overrides for each of the above modes.
 4. Return to normal operation.
- I. Conduct additional tests required by authorities having jurisdiction. Unless required by authorities having jurisdiction, perform testing without the use of smoke or products that simulate smoke.
- J. Prepare a complete report of observations, measurements, and deficiencies.

3.6 SHUT DOWN OF SYSTEMS NOT PART OF THE SMOKE-CONTROL SYSTEMS

- A. Verify the proper shutdown of all HVAC systems exceeding 2,000 cfm that are not part of the smoke-control systems, in response to all means of activation, both automatic and manual, as described in the Mechanical Life Safety Systems Sequences of Operation. For the automatic life safety activating systems each individual device shall be tested to demonstrate shut-down of the HVAC systems that are not part of the smoke-control systems.

3.7 OPERATION OF FIRE ALARM SYSTEM DURING TESTING

- A. The fire alarm system and sequencing shall be tested by the Contractor prior to smoke test. The DEN Life Safety Team and a representative from the Contractor's fire alarm contractor shall be present in the building fire command center during the entire time of each test. Operation of the fire alarm system shall be in the control of the DEN Life Safety Team.

3.8 STAIRWAY PRESSURIZATION SYSTEMS

- A. With all building HVAC systems in normal operation, measure and record the pressure difference across each stairway door while the door is closed. After recording the pressure difference, use the spring scale to measure and record the force necessary to open the stairway door. This recorded information will be the base data for the remaining test.
- B. Verify the proper activation of the stairway pressurization systems in response to all

means of activation, both automatic and manual, as described in the Mechanical Life Safety Systems Sequences of Operation. For the automatic activating systems each individual device shall be tested to demonstrate activation of the smoke-control systems.

- C. With the stairway pressurization systems activated, measure and record the pressure difference across each door with the door closed. Next measure and record the force required to open each door. With a door remaining open measure and record the differential pressure across the remaining closed doors.

3.9 ELEVATOR HOISTWAY, ELEVATOR LOBBY AND GENERAL OFFICE SPACE PRESSURIZATION

- A. With all building HVAC systems in normal operation, measure and record the pressure difference across each elevator lobby door while the door is closed. After recording the pressure difference, use the spring scale to measure and record the force necessary to open the stairway door. This recorded information will be the base data for the remaining test.
- B. Verify the proper activation of the stairway pressurization systems, elevator hoistway and lobby systems, and general office space pressurization systems in response to all means of activation, both automatic and manual, as described in the Mechanical Life Safety Systems Sequences of Operation. For the automatic activating systems, each individual device shall be tested to demonstrate activation of the smoke-control systems.
- C. With the stairway pressurization systems, elevator hoistway and lobby systems, and general office space pressurization systems activated, measure and record the pressure difference across each door with the door closed. Next measure and record the force required to open each door. With a door remaining open measure and record the differential pressure across the remaining closed doors.
- D. With all of the smoke-control systems remaining in operation, open six doors on various levels (for example two doors on level 5 and one each on levels 1, 3, 7 and 9). Measure and record the air velocity across the open doorways on each level. Repeat this test under three additional random scenarios. The required air velocity across the door opening is 200 feet per minute minimum. To allow for continuous flow there must be a path for the air to relieve from the building. For testing purposes, one window should be left out on each floor. A means for temporarily sealing this window opening should be available.
- E. The following paragraph is an example of specific testing requirements for specialized systems. The Engineer shall revise these sections as necessary to adequately describe testing procedures for this Project.

3.10 ELEVATOR RECALL

- A. During all smoke-control system tests confirm that the elevators return to the

designated return floor and perform as required by the Code.

3.11 SMOKE CONTROL MATRIX

- A. The Smoke Control Matrix attached is available from the DEN Mechanical Engineer. This matrix shall be updated by the Testing Agency to reflect all conditions at the time of testing. Update all addresses tested or added and resubmit this matrix in accordance with Part 1.
- B. The Engineer shall insert the Microsoft Excel Matrix into this document at this point. NO EXCEPTIONS.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230596

SECTION 230713 - DUCT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes insulating the following duct services:
 - 1. Indoor, concealed supply and outdoor air.
 - 2. Indoor, exposed supply and outdoor air.
 - 3. Indoor, concealed return located in unconditioned space.
 - 4. Indoor, exposed return located in unconditioned space.
 - 5. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
 - 6. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
 - 7. Indoor, concealed oven and warewash exhaust.
 - 8. Indoor, exposed oven and warewash exhaust.
 - 9. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
 - 10. Indoor, exposed exhaust between isolation damper and penetration of building exterior.
 - 11. Outdoor, concealed supply and return.
 - 12. Outdoor, exposed supply and return.
- B. Related Sections:
 - 1. Section 230716 "HVAC Equipment Insulation."
 - 2. Section 230719 "HVAC Piping Insulation."
 - 3. Section 233113 "Metal Ducts" for duct liners.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Submit products description, list of materials and thickness for each service, and locations. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).
 - 1. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
2. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail insulation application at elbows, fittings, dampers, specialties and flanges for each type of insulation.
3. Detail application of field-applied jackets.
4. Detail application at linkages of control devices.

D. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product, and intended use. Sample sizes are as follows:

1. Sheet Form Insulation Materials: 12 inches (300 mm) square.
2. Sheet Jacket Materials: 12 inches (300 mm) square.
3. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
 2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.
- C. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by DEN Project Manager. Use materials indicated for the completed Work.
1. Ductwork Mockups:
 - a. One 10-foot (3-m) section each of rectangular and round straight duct.
 - b. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.
 - c. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.
 - d. One rectangular and round transition fitting.
 - e. Four support hangers for round and rectangular ductwork.
 - f. Each type of damper and specialty.
 2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
 3. Notify DEN Project Manager seven (7) days in advance of dates and times when mockups will be constructed.
 4. Obtain DEN Project Manager's approval of mockups before starting insulation application.
 5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless DEN Project Manager specifically approves such deviations in writing.
 6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
 7. Demolish and remove mockups when directed.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.
- B. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 01.
- C. Deliver materials to site in original factory packaging, labeled with manufacturer's density, thickness, and "R" value.
- D. Store insulation in original wrapping and protect from weather and construction traffic.
- E. Protect insulation against dirt, water, chemical, and mechanical damage.

1.8 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.
- C. Coordinate installation and testing of heat tracing.

1.9 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type II for sheet materials.
1. **Products:** Subject to compliance with requirements, provide one of the following:
- a. [Aeroflex USA, Inc.; Aerocel.](#)
 - b. [Armacell LLC; AP Armaflex.](#)
 - c. [K-Flex USA; Insul-Sheet, K-Flex Gray Duct Liner, and K-FLEX LS.](#)
 - d. **<Insert manufacturer's name; product name or designation>.**
 - e. or approved equal.
- G. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, **[Type I] [Type II with factory-applied vinyl jacket] [Type III with factory-applied FSK jacket] [Type III with factory-applied FSP jacket]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. **Products:** Subject to compliance with requirements, provide one of the following:
- a. [CertainTeed Corp.; SoftTouch Duct Wrap.](#)
 - b. [Johns Manville; Microlite.](#)
 - c. [Knauf Insulation; Friendly Feel Duct Wrap.](#)
 - d. [Manson Insulation Inc.; Alley Wrap.](#)
 - e. [Owens Corning; SOFTR All-Service Duct Wrap.](#)
 - f. **<Insert manufacturer's name; product name or designation>.**
 - g. or approved equal.
- H. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation **[without factory-applied jacket] [with**

factory-applied ASJ] [with factory-applied FSK jacket]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. **Products:** Subject to compliance with requirements, provide one of the following:

- a. [CertainTeed Corp.: Commercial Board.](#)
- b. [Fibrex Insulations Inc.: FBX.](#)
- c. [Johns Manville: 800 Series Spin-Glas.](#)
- d. [Knauf Insulation: Insulation Board.](#)
- e. [Manson Insulation Inc.: AK Board.](#)
- f. [Owens Corning: Fiberglas 700 Series.](#)
- g. **<Insert manufacturer's name; product name or designation>.**
- h. or approved equal.

I. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied **[ASJ] [FSK jacket]** complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is **2.5 lb/cu. ft. (40 kg/cu. m)** or more. Thermal conductivity (k-value) at **100 deg F (55 deg C)** is **0.29 Btu x in./h x sq. ft. x deg F (0.042 W/m x K)** or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. **Products:** Subject to compliance with requirements, provide one of the following:

- a. [CertainTeed Corp.: CrimpWrap.](#)
- b. [Johns Manville: MicroFlex.](#)
- c. [Knauf Insulation: Pipe and Tank Insulation.](#)
- d. [Manson Insulation Inc.: AK Flex.](#)
- e. [Owens Corning: Fiberglas Pipe and Tank Insulation.](#)
- f. **<Insert manufacturer's name; product name or designation>.**
- g. or approved equal.

J. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C 534 or ASTM C 1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.

1. **Products:** Subject to compliance with requirements, provide one of the following:

- a. [Armacell LLC: Tubolit.](#)
- b. [Nomaco Insulation: IMCOLOCK, IMCOSHEET, NOMALOCK, and NOMAPLY.](#)
- c. **<Insert manufacturer's name; product name or designation>.**
- d. or approved equal.

2.2 FIRE-RATED INSULATION SYSTEMS

A. Fire-Rated Board: Structural-grade, press-molded, xonolite calcium silicate, fireproofing board suitable for operating temperatures up to **1700 deg F (927 deg C).**

Comply with ASTM C 656, Type II, Grade 6. Tested and certified to provide a [1] [2]-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. [Johns Manville; Super Firetemp M.](#)
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.

B. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a [1] [2]-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. [CertainTeed Corp.; FlameChek.](#)
 - b. [Johns Manville; Firetemp Wrap.](#)
 - c. [Nelson Fire Stop Products; Nelson FSB Flameshield Blanket.](#)
 - d. [Thermal Ceramics; FireMaster Duct Wrap.](#)
 - e. [3M; Fire Barrier Wrap Products.](#)
 - f. [Unifrax Corporation; FyreWrap.](#)
 - g. **<Insert manufacturer's name; product name or designation>.**
 - h. or approved equal.

2.3 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. [Aeroflex USA, Inc.; Aero seal.](#)
 - b. [Armacell LLC; Armaflex 520 Adhesive.](#)
 - c. [Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-75.](#)
 - d. [K-Flex USA; R-373 Contact Adhesive.](#)
 - e. **<Insert manufacturer's name; product name or designation>.**
 - f. or approved equal.

2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-03/11-70.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - e. **<Insert manufacturer's name; product name or designation>.**
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. ASJ Adhesive, and FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
1. **Products:** Subject to compliance with requirements, **provide one of the following:**
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-50.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - e. **<Insert manufacturer's name; product name or designation>.**
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- E. PVC Jacket Adhesive: Compatible with PVC jacket.
1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Dow Corning Corporation; 739, Dow Silicone.
 - b. Johns Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive.
 - c. P.I.C. Plastics, Inc.; Welding Adhesive.
 - d. Speedline Corporation; Polyco VP Adhesive.
 - e. **<Insert manufacturer's name; product name or designation>.**

- f. or approved equal.
2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-03/11-90.
 - b. Vimasco Corporation; 749.
 - c. **<Insert manufacturer's name; product name or designation>.**
 - d. or approved equal.
2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, **0.013 perm** (0.009 metric perm) at **43-mil** (1.09-mm) dry film thickness.
3. Service Temperature Range: **Minus 20 to plus 180 deg F** (Minus 29 to plus 82 deg C).
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.

C. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below ambient services.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-30.
 - b. Eagle Bridges - Marathon Industries; 501.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-35.
 - d. Mon-Eco Industries, Inc.; 55-10.
 - e. **<Insert manufacturer's name; product name or designation>.**
 - f. or approved equal.
2. Water-Vapor Permeance: ASTM F 1249, **0.05 perm** (0.03 metric perm) at **35-mil** (0.9-mm) dry film thickness.

3. Service Temperature Range: 0 to 180 deg F (Minus 18 to plus 82 deg C).
 4. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
 5. Color: White.
- D. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below ambient services.
1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Encacel.
 - b. Eagle Bridges - Marathon Industries; 570.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 60-03/11-96.
 - d. **<Insert manufacturer's name; product name or designation>.**
 - e. or approved equal.
 2. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.033 metric perm) at 30-mil (0.8-mm) dry film thickness.
 3. Service Temperature Range: Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C).
 4. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
 5. Color: White.
- E. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
 - b. Eagle Bridges - Marathon Industries; 550.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
 - d. Mon-Eco Industries, Inc.; 55-50.
 - e. Vimasco Corporation; WC-1/WC-5.
 - f. **<Insert manufacturer's name; product name or designation>.**
 - g. or approved equal.
 2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms (1.2 metric perms) at 0.0625-inch (1.6-mm) dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
 4. Solids Content: 60 percent by volume and 66 percent by weight.
 5. Color: White.

2.5 LAGGING ADHESIVES

- A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.
1. For indoor applications, use lagging adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 2. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-50 AHV2.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-36.
 - c. Vimasco Corporation; 713 and 714.
 - d. **<Insert manufacturer's name; product name or designation>.**
 - e. or approved equal.
 3. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct insulation.
 4. Service Temperature Range: **0 to plus 180 deg F** (Minus 18 to plus 82 deg C).
 5. Color: White.
 - a. SEALANTS
- B. FSK and Metal Jacket Flashing Sealants:
1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. **<Insert manufacturer's name; product name or designation>.**
 - f. or approved equal.
 2. Materials shall be compatible with insulation materials, jackets, and substrates.
 3. Fire- and water-resistant, flexible, elastomeric sealant.
 4. Service Temperature Range: **Minus 40 to plus 250 deg F** (Minus 40 to plus 121 deg C).
 5. Color: Aluminum.
 6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. ASJ Flashing Sealants, and Vinyl and PVC Jacket Flashing Sealants:

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: **Minus 40 to plus 250 deg F** (Minus 40 to plus 121 deg C).
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.6 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
 1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
 2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
 3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
 4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
 5. Vinyl Jacket: White vinyl with a permeance of **1.3 perms** (0.86 metric perm) when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.7 FIELD-APPLIED FABRIC-REINFORCING MESH

- A. Woven Glass-Fiber Fabric: Approximately **6 oz./sq. yd.** (203 g/sq. m) with a thread count of **5 strands by 5 strands/sq. in.** (2 strands by 2 strands/sq. mm) for covering ducts.
 1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Chil-Glas No. 5.
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.

B. Woven Polyester Fabric: Approximately **1 oz./sq. yd.** (34 g/sq. m) with a thread count of **10 strands by 10 strands/sq. in.** (4 strands by 4 strands/sq. mm), in a Leno weave, for ducts.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
 - b. Vimasco Corporation; Elastafab 894.
 - c. **<Insert manufacturer's name; product name or designation>.**
 - d. or approved equal.

2.8 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of **8 oz./sq. yd.** (271 g/sq. m).

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Alpha Associates, Inc.; Alpha-Maritex 84215 and 84203/1185RW, Luben 59.
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.

2.9 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. Johns Manville; Zeston.
 - b. P.I.C. Plastics, Inc.; FG Series.
 - c. Proto Corporation; LoSmoke.
 - d. Speedline Corporation; SmokeSafe.
 - e. **<Insert manufacturer's name; product name or designation>.**
 - f. or approved equal.
2. Adhesive: As recommended by jacket material manufacturer.
3. Color: **[White] [Color-code jackets based on system. Color as selected by DEN Project Manager].**

D. Metal Jacket:

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. **Childers Brand, Specialty Construction Brands, Inc.**, a business of H. B. Fuller Company; Metal Jacketing Systems.
 - b. **ITW Insulation Systems**; Aluminum and Stainless Steel Jacketing.
 - c. **RPR Products, Inc.**; Insul-Mate.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.

2. Aluminum Jacket: Comply with **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005, Temper H-14.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size]**.
 - b. Finish and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper] [3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.
 - d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.

3. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size]**.
 - b. Material, finish, and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper] [3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.
 - d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.

- E. Self-Adhesive Outdoor Jacket: **60-mil- (1.5-mm-) thick**, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with **[white] [stucco-embossed]** aluminum-foil facing.
 1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. **Polyguard Products, Inc.**; Alumaguard 60.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.10 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
- Products:** Subject to compliance with requirements, provide one of the following:
 - [ABI, Ideal Tape Division](#); 428 AWF ASJ.
 - [Avery Dennison Corporation](#), Specialty Tapes Division; Fasson 0836.
 - [Compac Corporation](#); 104 and 105.
 - [Venture Tape](#); 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
 - <Insert manufacturer's name; product name or designation>**.
 - or approved equal.
 - Width: **3 inches** (75 mm).
 - Thickness: **11.5 mils** (0.29 mm).
 - Adhesion: **90 ounces force/inch** (1.0 N/mm) in width.
 - Elongation: 2 percent.
 - Tensile Strength: **40 lbf/inch** (7.2 N/mm) in width.
 - ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
- Products:** Subject to compliance with requirements, provide one of the following:
 - [ABI, Ideal Tape Division](#); 491 AWF FSK.
 - [Avery Dennison Corporation](#), Specialty Tapes Division; Fasson 0827.
 - [Compac Corporation](#); 110 and 111.
 - [Venture Tape](#); 1525 CW NT, 1528 CW, and 1528 CW/SQ.
 - <Insert manufacturer's name; product name or designation>**.
 - or approved equal.
 - Width: **3 inches** (75 mm).
 - Thickness: **6.5 mils** (0.16 mm).
 - Adhesion: **90 ounces force/inch** (1.0 N/mm) in width.
 - Elongation: 2 percent.
 - Tensile Strength: **40 lbf/inch** (7.2 N/mm) in width.
 - FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
- C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.
- Products:** Subject to compliance with requirements, provide one of the following:
 - [ABI, Ideal Tape Division](#); 370 White PVC tape.
 - [Compac Corporation](#); 130.
 - [Venture Tape](#); 1506 CW NS.
 - <Insert manufacturer's name; product name or designation>**.
 - or approved equal.

2. Width: **2 inches** (50 mm).
3. Thickness: **6 mils** (0.15 mm).
4. Adhesion: **64 ounces force/inch** (0.7 N/mm) in width.
5. Elongation: 500 percent.
6. Tensile Strength: **18 lbf/inch** (3.3 N/mm) in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. **ABI**, Ideal Tape Division; 488 AWF.
 - b. **Avery Dennison Corporation**, Specialty Tapes Division; Fasson 0800.
 - c. **Compac Corporation**; 120.
 - d. **Venture Tape**; 3520 CW.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Width: **2 inches** (50 mm).
3. Thickness: **3.7 mils** (0.093 mm).
4. Adhesion: **100 ounces force/inch** (1.1 N/mm) in width.
5. Elongation: 5 percent.
6. Tensile Strength: **34 lbf/inch** (6.2 N/mm) in width.

2.11 SECUREMENTS

A. Bands:

1. **Products:** Subject to compliance with requirements, provide one of the following:
 - a. **ITW Insulation Systems**; Gerrard Strapping and Seals.
 - b. **RPR Products, Inc.**; Insul-Mate Strapping, Seals, and Springs.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, [**Type 304**] [**or**] [**Type 316**]; **0.015 inch** (0.38 mm) thick, [**1/2 inch** (13 mm)] [**3/4 inch** (19 mm)] wide with [**wing seal**] [**or**] [**closed seal**].
3. Aluminum: **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, **0.020 inch** (0.51 mm) thick, [**1/2 inch** (13 mm)] [**3/4 inch** (19 mm)] wide with [**wing seal**] [**or**] [**closed seal**].
4. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [**0.106-inch-** (2.6-mm-)] [**0.135-inch-** (3.5-mm-)] diameter shank, length to suit depth of insulation indicated.

- a. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1) [AGM Industries, Inc.](#); CWP-1.
 - 2) [GEMCO; CD.](#)
 - 3) [Midwest Fasteners, Inc.](#); CD.
 - 4) [Nelson Stud Welding](#); TPA, TPC, and TPS.
 - 5) **<Insert manufacturer's name; product name or designation>.**
 - 6) or approved equal.

2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [0.106-inch- (2.6-mm-)] [0.135-inch- (3.5-mm-)] diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.
 - a. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1) [AGM Industries, Inc.](#); CHP-1.
 - 2) [GEMCO](#); Cupped Head Weld Pin.
 - 3) [Midwest Fasteners, Inc.](#); Cupped Head.
 - 4) [Nelson Stud Welding](#); CHP.
 - 5) **<Insert manufacturer's name; product name or designation>.**
 - 6) or approved equal.

3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
 - a. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1) [AGM Industries, Inc.](#); Tactoo Perforated Base Insul-Hangers.
 - 2) [GEMCO](#); Perforated Base.
 - 3) [Midwest Fasteners, Inc.](#); Spindle.
 - 4) **<Insert manufacturer's name; product name or designation>.**
 - 5) or approved equal.

 - b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.
 - c. Spindle: [**Copper- or zinc-coated, low-carbon steel**] [**Aluminum**] [**Stainless steel**], fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.
 - d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness

indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

- a. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1) **GEMCO**; Nylon Hangers.
 - 2) **Midwest Fasteners, Inc.**; Nylon Insulation Hangers.
 - 3) **<Insert manufacturer's name; product name or designation>**.
 - 4) or approved equal.
 - b. Baseplate: Perforated, nylon sheet, **0.030 inch** (0.76 mm) thick by **1-1/2 inches** (38 mm) in diameter.
 - c. Spindle: Nylon, **0.106-inch-** (2.6-mm-) diameter shank, length to suit depth of insulation indicated, up to **2-1/2 inches** (63 mm).
 - d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.
5. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
- a. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1) **AGM Industries, Inc.**; Tactoo Self-Adhering Insul-Hangers.
 - 2) **GEMCO**; Peel & Press.
 - 3) **Midwest Fasteners, Inc.**; Self Stick.
 - 4) **<Insert manufacturer's name; product name or designation>**.
 - 5) or approved equal.
 - b. Baseplate: Galvanized carbon-steel sheet, **0.030 inch** (0.76 mm) thick by **2 inches** (50 mm) square.
 - c. Spindle: [**Copper- or zinc-coated, low-carbon steel**] [**Aluminum**] [**Stainless steel**], fully annealed, **0.106-inch-** (2.6-mm-) diameter shank, length to suit depth of insulation indicated.
 - d. Adhesive-backed base with a peel-off protective cover.
6. Insulation-Retaining Washers: Self-locking washers formed from **0.016-inch-** (0.41-mm-) thick, [**galvanized-steel**] [**aluminum**] [**stainless-steel**] sheet, with beveled edge sized as required to hold insulation securely in place but not less than **1-1/2 inches** (38 mm) in diameter.
- a. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1) **AGM Industries, Inc.**; RC-150.
 - 2) **GEMCO**; R-150.

- 3) [Midwest Fasteners, Inc.](#); WA-150.
 - 4) [Nelson Stud Welding](#); Speed Clips.
 - 5) **<Insert manufacturer's name; product name or designation>**.
 - 6) or approved equal.
- b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.
7. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from **0.016-inch** (0.41-mm-) thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than **1-1/2 inches** (38 mm) in diameter.
- a. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1) [GEMCO](#).
 - 2) [Midwest Fasteners, Inc.](#)
 - 3) **<Insert manufacturer's name>**.
 - 4) or approved equal.
- C. Staples: Outward-clinching insulation staples, nominal **3/4-inch**- (19-mm-) wide, stainless steel or Monel.
- D. Wire: [**0.080-inch** (2.0-mm) **nickel-copper alloy**] [**0.062-inch** (1.6-mm) **soft-annealed, stainless steel**] [**0.062-inch** (1.6-mm) **soft-annealed, galvanized steel**].
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [C & F Wire](#).
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
- 2.12 CORNER ANGLES
- A. PVC Corner Angles: [**30 mils** (0.8 mm)] **<Insert dimension>** thick, minimum **1 by 1 inch** (25 by 25 mm), PVC according to ASTM D 1784, Class 16354-C. White or color-coded to match adjacent surface.
 - B. Aluminum Corner Angles: [**0.040 inch** (1.0 mm)] **<Insert dimension>** thick, minimum **1 by 1 inch** (25 by 25 mm), aluminum according to **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14.

PART 3 - Stainless-Steel Corner Angles: [0.024 inch (0.61 mm)] <Insert dimension> thick, minimum 1 by 1 inch (25 by 25 mm), stainless steel according to ASTM A 167 or ASTM A 240/A 240M, [Type 304] [or] [Type 316].EXECUTION

3.1 ENVIRONMENTAL REQUIREMENTS

- A. Maintain ambient temperatures and conditions required by manufacturers of adhesives, mastics, and insulation cements.
- B. Maintain temperature during and after installation for minimum period of 24 hours.

3.2 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 - 1. Verify that systems to be insulated have been tested and are free of defects.
 - 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 PREPARATION

- A. Install materials after ductwork has been tested and approved.
- B. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.4 GENERAL INSTALLATION REQUIREMENTS

- A. Install materials in accordance with manufacturer's instructions and N.I.C.A standards.
- B. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.
- C. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.
- D. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- E. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- F. Install multiple layers of insulation with longitudinal and end seams staggered.
- G. Keep insulation materials dry during application and finishing.

- H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- I. Install insulation with least number of joints practical.
- J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Provide insulation with vapor barrier when air conveyed may be below ambient temperature, and for all runs of heating duct which exceed 75 feet in maximum air-travel distance.
 - 2. Install insulation continuously through hangers and around anchor attachments.
 - 3. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 - 4. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
- K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- L. Install insulation with factory-applied jackets as follows:
 - 1. Draw jacket tight and smooth.
 - 2. Cover circumferential joints with 3-inch- (75-mm-) wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches (100 mm) o.c.
 - 3. Overlap jacket longitudinal seams at least 1-1/2 inches (38 mm). Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at [2 inches (50 mm)] [4 inches (100 mm)] o.c.
 - a. For below ambient services, apply vapor-barrier mastic over staples.
 - 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 - 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.
- M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches (100 mm) beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

- P. High Temperature Insulation Application: Secure insulation with wires and treat joints as recommended by the manufacturer.
- Q. Walk-in Plenum Application: Adhere insulation on interior surface of plenum with adhesive for 100 percent coverage. Secure insulation with weld pins and split washers, 12" center to center. Seal and smooth joints. Do not use nail- type fasteners.

3.5 PENETRATIONS

- A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
 - 1. Seal penetrations with flashing sealant.
 - 2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 - 3. Extend jacket of outdoor insulation outside roof flashing at least **2 inches (50 mm)** below top of roof flashing.
 - 4. Seal jacket to roof flashing with flashing sealant.
- B. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
 - 1. Seal penetrations with flashing sealant.
 - 2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 - 3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least **2 inches (50 mm)**.
 - 4. Seal jacket to wall flashing with flashing sealant.
- C. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least **2 inches (50 mm)**.
 - 1. Comply with requirements in Section 078413 "Penetration Firestopping".
- E. Insulation Installation at Floor Penetrations:
 - 1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least **2 inches (50 mm)**.

2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

- F. Where staples are used to secure insulation covering requiring vapor barrier, the staples shall be sealed with a vapor barrier mastic.

3.6 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

- A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.7 INSTALLATION OF MINERAL-FIBER INSULATION

- A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for [100] [50] <Insert number> percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
 - a. On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
 - b. On duct sides with dimensions larger than 18 inches (450 mm), place pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
 - c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
 - d. Do not overcompress insulation during installation.
 - e. Impale insulation over pins and attach speed washers.
 - f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

- a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
 - b. Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches (75 mm).
5. Overlap unfaced blankets a minimum of 2 inches (50 mm) on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches (450 mm) o.c.
 6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
 7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.
- B. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for [100] [50] <Insert number> percent coverage of duct and plenum surfaces.
 2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
 3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
 - a. On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
 - b. On duct sides with dimensions larger than 18 inches (450 mm), space pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
 - c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
 - d. Do not overcompress insulation during installation.
 - e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
 4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from one edge and one end of insulation segment. Secure laps to adjacent insulation section with

1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

- a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
 - b. Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches (75 mm).
5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.

3.8 FIELD-APPLIED JACKET INSTALLATION

- A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.
1. Draw jacket smooth and tight to surface with 2-inch (50-mm) overlap at seams and joints.
 2. Embed glass cloth between two 0.062-inch- (1.6-mm-) thick coats of lagging adhesive.
 3. Completely encapsulate insulation with coating, leaving no exposed insulation.
- B. Where FSK jackets are indicated, install as follows:
1. Draw jacket material smooth and tight.
 2. Install lap or joint strips with same material as jacket.
 3. Secure jacket to insulation with manufacturer's recommended adhesive.
 4. Install jacket with 1-1/2-inch (38-mm) laps at longitudinal seams and 3-inch- (75-mm-) wide joint strips at end joints.
 5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.
- C. Where PVC jackets are indicated, install with 1-inch (25-mm) overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

- D. Where metal jackets are indicated, install with **2-inch (50-mm)** overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands **12 inches (300 mm)** o.c. and at end joints.

3.9 FIRE-RATED INSULATION SYSTEM INSTALLATION

- A. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.
- B. Insulate duct access panels and doors to achieve same fire rating as duct.
- C. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Section 078413 "Penetration Firestopping."

3.10 FINISHES

- A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

1. Flat Acrylic Finish: [**Two**] <Insert number> finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

- a. Finish Coat Material: Interior, flat, latex-emulsion size.

- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- C. Color: Final color as selected by DEN Project Manager. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless-steel jackets.

3.11 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:

1. Inspect ductwork, randomly selected by DEN Project Manager, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to **[one]** <Insert number> location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.
- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.12 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.
3. Indoor, concealed return located in unconditioned space.
4. Indoor, exposed return located in unconditioned space.
5. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
6. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
7. Indoor, concealed oven and warewash exhaust.
8. Indoor, exposed oven and warewash exhaust.
9. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
10. Indoor, exposed exhaust between isolation damper and penetration of building exterior.
11. Outdoor, concealed supply and return.
12. Outdoor, exposed supply and return.

B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
3. Factory-insulated flexible ducts.
4. Factory-insulated plenums and casings.
5. Flexible connectors.
6. Vibration-control devices.
7. Factory-insulated access panels and doors.
8. Nameplates and data plates.
9. Access panels and doors in air-distribution systems.

3.13 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

- A. Concealed, round and flat-oval, supply-air duct insulation shall be **[one of]** the following:
1. Flexible Elastomeric: **[1 inch (25 mm)]** <Insert dimension> thick.

2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- B. Concealed, round and flat-oval, return-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- C. Concealed, round and flat-oval, outdoor-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- D. Concealed, round and flat-oval, exhaust-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- E. Concealed, rectangular, supply-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.

3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- F. Concealed, rectangular, return-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- G. Concealed, rectangular, outdoor-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- H. Concealed, rectangular, exhaust-air duct insulation between isolation damper and penetration of building exterior shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- I. Concealed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated [blanket] [or] [board]; thickness as required to achieve 2-hour fire rating.
- J. Concealed, supply-air plenum insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.

3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- K. Concealed, return-air plenum insulation shall be [**one of**] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- L. Concealed, outdoor-air plenum insulation shall be [**one of**] the following:
1. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- M. Concealed, exhaust-air plenum insulation shall be [**one of**] the following:
1. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- N. Exposed, round and flat-oval, supply-air duct insulation shall be [**one of**] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 5. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- O. Exposed, round and flat-oval, return-air duct insulation shall be [**one of**] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.

2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 5. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- P. Exposed, round and flat-oval, outdoor-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 5. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- Q. Exposed, round and flat-oval, exhaust-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 5. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- R. Exposed, rectangular, supply-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96 kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- S. Exposed, rectangular, return-air duct insulation shall be [one of] the following:

1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- T. Exposed, rectangular, outdoor-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- U. Exposed, rectangular, exhaust-air duct insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- V. Exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated [blanket] [or] [board]; thickness as required to achieve 2-hour fire rating.
- W. Exposed, supply-air plenum insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- X. Exposed, return-air plenum insulation shall be [one of] the following:
1. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.

2. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
3. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
4. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.

Y. Exposed, outdoor-air plenum insulation shall be [**one of**] the following:

1. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
2. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

Z. Exposed, exhaust-air plenum insulation shall be [**one of**] the following:

1. Mineral-Fiber Blanket: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
2. Mineral-Fiber Board: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

3.14 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a duct system, selection from materials listed is Contractor's option.

B. Concealed, round and flat-oval, supply-air duct insulation shall be [**one of**] the following:

1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

C. Concealed, round and flat-oval, return-air duct insulation shall be [**one of**] the following:

1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.

2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- D. Concealed, round and flat-oval, outdoor-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- E. Concealed, rectangular, supply-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- F. Concealed, rectangular, return-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- G. Concealed, supply-air plenum insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- H. Concealed, return-air plenum insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

- I. Exposed, round and flat-oval, supply-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 3. Mineral-Fiber Pipe and Tank: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
- J. Exposed, round and flat-oval, return-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- K. Exposed, rectangular, supply-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- L. Exposed, rectangular, return-air duct insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- M. Exposed, supply-air plenum insulation shall be[**one of**] the following:
1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
 2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- N. Exposed, return-air plenum insulation shall be[**one of**] the following:

1. Mineral-Fiber Blanket: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> and [0.75-lb/cu. ft. (12-kg/cu. m)] [1.5-lb/cu. ft. (24-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] nominal density.
2. Mineral-Fiber Board: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

3.15 INDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.
- C. Ducts and Plenums, Concealed:
 1. None.
 2. [PVC] [PVC, Color-Coded by System]: [20 mils (0.5 mm)] [30 mils (0.8 mm)] thick.
 3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
 4. Painted Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] thick.
 5. Stainless Steel, [Type 304] [or] [Type 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 6. <Insert jacket type>.
- D. Ducts and Plenums, Exposed:
 1. None.
 2. [PVC] [PVC, Color-Coded by System]: [20 mils (0.5 mm)] [30 mils (0.8 mm)] thick.
 3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
 4. Painted Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] thick.
 5. Stainless Steel, [Type 304] [or] [Type 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 6. <Insert jacket type>.

3.16 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.
- C. Ducts and Plenums, Concealed:
1. None.
 2. **[PVC]** **[PVC, Color-Coded by System]**: **[20 mils (0.5 mm)]** **[30 mils (0.8 mm)]** thick.
 3. Aluminum, **[Smooth]** **[Corrugated]** **[Stucco Embossed]**: **[0.016 inch (0.41 mm)]** **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** **[0.032 inch (0.81 mm)]** **[0.040 inch (1.0 mm)]** thick.
 4. Painted Aluminum, **[Smooth]** **[Corrugated]** **[Stucco Embossed]**: **[0.016 inch (0.41 mm)]** **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** **[0.032 inch (0.81 mm)]** thick.
 5. Stainless Steel, **[Type 304]** **[or]** **[Type 316]**, **[Smooth 2B Finish]** **[Corrugated]** **[Stucco Embossed]**: **[0.010 inch (0.25 mm)]** **[0.016 inch (0.41 mm)]** **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** thick.
 6. **<Insert jacket type>**.
- D. Ducts and Plenums, Exposed, up to **48 Inches (1200 mm)** in Diameter or with Flat Surfaces up to **72 Inches (1800 mm)**:
1. Aluminum, **[Smooth]** **[Corrugated]** **[Stucco Embossed]**: **[0.016 inch (0.41 mm)]** **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** **[0.032 inch (0.81 mm)]** **[0.040 inch (1.0 mm)]** thick.
 2. Painted Aluminum, **[Smooth]** **[Corrugated]** **[Stucco Embossed]**: **[0.016 inch (0.41 mm)]** **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** **[0.032 inch (0.81 mm)]** thick.
 3. Stainless Steel, **[Type 304]** **[or]** **[Type 316]**, **[Smooth 2B Finish]** **[Corrugated]** **[Stucco Embossed]**: **[0.010 inch (0.25 mm)]** **[0.016 inch (0.41 mm)]** **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** thick.
 4. **<Insert jacket type>**.
- E. Ducts and Plenums, Exposed, Larger Than **48 Inches (1200 mm)** in Diameter or with Flat Surfaces Larger Than **72 Inches (1800 mm)**:
1. **[Painted]**Aluminum, **[Smooth]** **[Stucco Embossed]** with **[1-1/4-Inch- (32-mm-) Deep Corrugations]** **[2-1/2-Inch- (65-mm-) Deep Corrugations]** **[4-by-1-Inch (100-by-25-mm) Box Ribs]**: **[0.032 inch (0.81 mm)]** **[0.040 inch (1.0 mm)]** thick.
 2. Stainless Steel, **[Type 304]** **[or]** **[Type 316]**, **[Smooth]** **[Stucco Embossed]**, with **[1-1/4-Inch- (32-mm-) Deep Corrugations]** **[2-1/2-Inch- (65-mm-) Deep Corrugations]** **[4-by-1-Inch (100-by-25-mm) Box Ribs]**: **[0.020 inch (0.51 mm)]** **[0.024 inch (0.61 mm)]** thick.
 3. **<Insert jacket type>**.

3.17 R-VALUE SCHEDULE

Degree Days- Cool.		Degree Days- Heat.	
System Ducts:	R-Value:	System Ducts:	R-Value:
Below 500	3.3	Below 1500	3.3
500 to 1150	5.0	1500 to 4500	5.0
1151 to 2000	6.5	4501 to 7500	6.5
Above 2000	8.0	Above 7500	8.0

- A. The R-values shown in the following schedule and/or indicated on the drawings are "installed" values and, where materials performance can be affected by compression during installation, the Contractor shall make adjustments as required to achieve the R-values shown:

Ductwork Application:	Type:	Minimum R-Value:
*Ext. Cooling System Ducts	B**	8.0
*Ext. Heating System Ducts	B	6.5
Exhaust Ducts Within 10 ft of Exterior Openings	B	8.0
Plenums	A,B*	8.0
Ventilation Equip. Casings	A, B*	8.0
Supply and Return Ducts Inside Building Envelope or in Unconditioned Spaces with Temperature Differential > 15 Degrees F and < or = 40 Degrees F	A, B	3.3
Supply and Return Ducts Inside Building Envelope or in Unconditioned Spaces with Temperature Differential > 40 degrees F	A, B	5.0
Supply/Return Distribution Ducts in Conditioned Spaces	A, B*	2.0
Kitchen Grease Ducts	J	3"

1. *R-Values shown apply for both duct exterior and duct liner insulation applications.
2. **Or duct liner. Refer to Section 233113 "Metal Ducts" and Section 233116 "Non-Metal Ducts".

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230713

SECTION 230716 - HVAC EQUIPMENT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes insulating the following HVAC equipment that is not factory insulated:

1. Chillers.
2. Heat exchangers.
3. Converters.
4. Chilled-water pumps.
5. Condenser-water pumps.
6. Dual-service heating and cooling pumps.
7. Heating, hot-water pumps.
8. Heat-recovery pumps.
9. Steam condensate pumps.
10. Expansion/compression tanks.
11. Air separators.
12. Thermal storage tanks.
13. Deaerators.
14. Steam condensate tanks.
15. Steam flash tanks, flash separators, moisture separators, and blow-off tanks.
16. Piping system filtration unit housings.
17. Outdoor, aboveground, heated, fuel-oil storage tanks.
18. High-temperature engine exhaust system insulation.

- B. Related Sections:

1. Section 230713 "Duct Insulation."
2. Section 230719 "HVAC Piping Insulation."

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Submit product description, list of materials and thickness for equipment scheduled. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).

1. Include data substantiating that materials comply with requirements.
- B. Manufacturer's Installation Instructions: Indicate procedures for each product type, which ensure acceptable workmanship and installation standards will be achieved.
- C. LEED Submittals:
 1. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
 2. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
 2. Detail attachment and covering of heat tracing inside insulation.
 3. Detail removable insulation at equipment connections.
 4. Detail application of field-applied jackets.
 5. Detail application at linkages of control devices.
 6. Detail field application for each equipment type.
- E. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use. Sample sizes are as follows:
 1. Preformed Pipe Insulation Materials: 12 inches (300 mm) long by NPS 2 (DN 50).
 2. Sheet Form Insulation Materials: 12 inches (300 mm) square.
 3. Sheet Jacket Materials: 12 inches (300 mm) square.
 4. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Certificates confirming that all insulation, jacket, adhesives, mastics, sealers, etc., utilized in the fabrication of these systems shall meet NFPA for fire resistant ratings of a maximum of 25 flame spread and 50 smoke developed ratings, or more stringent requirements as required, and shall be approved by the insulation manufacturer for guaranteed performances when incorporated into their insulation system, unless a specific product is specified for a specific application, and is stated as an exception to this requirement.
- C. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of

insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

- D. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Insulation shall be applied by mechanics skilled in the work and regularly engaged in such occupation. All insulation shall be applied in strict accordance with manufacturer's recommendations and installation instructions as applicable. Unsightly or inadequate work will not be acceptable, and all such work shall be removed and replaced as necessary to achieve an acceptable installation.

- B. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

- C. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

- D. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by DEN Project Manager. Use materials indicated for the completed Work.

1. Equipment Mockups:
 - a. One chilled-water pump and one heating-hot-water pump.
 - b. One tank or vessel.
 - c. **<Add equipment>**.
2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
3. Notify DEN Project Manager [**seven**] **<Insert number>** days in advance of dates and times when mockups will be constructed.

4. Obtain DEN Project Manager's approval of mockups before starting insulation application.
5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless DEN Project Manager specifically approves such deviations in writing.
6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
7. Demolish and remove mockups when directed.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.
- B. Deliver materials to site in original factory packaging, labeled with manufacturer's density and thickness.
- C. Store insulation in original wrapping and protect from weather and construction traffic.
- D. Protect insulation against dirt, water, chemical, and mechanical damage.

1.8 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with equipment Installer for equipment insulation application.
- C. Coordinate installation and testing of heat tracing.

1.9 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Breeching Insulation Schedule" and "Equipment Insulation Schedule" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Calcium Silicate:
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Industrial Insulation Group (IIG); Thermo-12 Gold.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 - 2. Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
- G. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Pittsburgh Corning Corporation; Foamglas.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 - 2. Block Insulation: ASTM C 552, Type I.
 - 3. Special-Shaped Insulation: ASTM C 552, Type III.
 - 4. Board Insulation: ASTM C 552, Type IV.
 - 5. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
- H. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
 - 1. Products: Subject to compliance with requirements, provide one of the following:

- a. Aeroflex USA, Inc.; Aerocel.
 - b. Armacell LLC; AP Armaflex.
 - c. K-Flex USA; Insul-Sheet and K-FLEX LS.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
- I. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, **[Type I] [Type II with factory-applied vinyl jacket] [Type III with factory-applied FSK jacket] [Type III with factory-applied FSP jacket]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; SoftTouch Duct Wrap.
 - b. Johns Manville; Microlite.
 - c. Knauf Insulation; Friendly Feel Duct Wrap.
 - d. Manson Insulation Inc.; Alley Wrap.
 - e. Owens Corning; SOFTR All-Service Duct Wrap.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
- J. High-Temperature, Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type V, without factory-applied jacket.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Industrial Insulation Group (IIG); MinWool-1200 Flexible Batt.
 - b. Johns Manville; HTB 26 Spin-Glas.
 - c. Roxul Inc.; Roxul RW.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
- K. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. Provide insulation **[without factory-applied jacket] [with factory-applied ASJ] [with factory-applied FSK jacket]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; CertaPro Commercial Board.
 - b. Fibrex Insulations Inc.; FBX.
 - c. Johns Manville; 800 Series Spin-Glas.
 - d. Knauf Insulation; Insulation Board.
 - e. Manson Insulation Inc.; AK Board.
 - f. Owens Corning; Fiberglas 700 Series.
 - g. **<Insert manufacturer's name; product name or designation>**.
 - h. or approved equal.

- L. High-Temperature, Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type III, without factory-applied jacket.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Fibrex Insulations Inc.; FBX.Industrial Insulation Group (IIG); MinWool-1200 Industrial Board.
 - b. Rock Wool; Delta Board.
 - c. Roxul Inc.; RHT and RockBoard.
 - d. Thermafiber, Inc.; Thermafiber Industrial Felt.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
- M. Mineral-Fiber, Preformed Pipe Insulation:
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Fibrex Insulations Inc.; Coreplus 1200.
 - b. Johns Manville; Micro-Lok.
 - c. Knauf Insulation; 1000-Degree Pipe Insulation.
 - d. Manson Insulation Inc.; Alley-K.
 - e. Owens Corning; Fiberglas Pipe Insulation.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
 2. Type I, **850 Deg F** (454 Deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, **[without factory-applied jacket] [with factory-applied ASJ] [with factory-applied ASJ-SSL]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 3. Type II, **1200 Deg F** (649 Deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, **[without factory-applied jacket] [with factory-applied ASJ] [with factory-applied ASJ-SSL]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
- N. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied **[ASJ] [FSK jacket]** complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is **2.5 lb/cu. ft.** (40 kg/cu. m) or more. Thermal conductivity (k-value) at **100 deg F** (55 deg C) is **0.29 Btu x in./h x sq. ft. x deg F** (0.042 W/m x K) or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; CrimpWrap.
 - b. Johns Manville; MicroFlex.
 - c. Knauf Insulation; Pipe and Tank Insulation.

- d. Manson Insulation Inc.; AK Flex.
- e. Owens Corning; Fiberglas Pipe and Tank Insulation.
- f. **<Insert manufacturer's name; product name or designation>**.
- g. or approved equal.

O. Phenolic:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Kingspan Tarec Industrial Insulation NV; Koolphen K.
 - b. Resolco International BV; Insul-phen.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
2. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
3. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
4. Factory-Applied Jacket: **[None] [ASJ]**. Requirements are specified in "Factory-Applied Jackets" Article.

P. Polyisocyanurate: Unfaced, preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Trymer 2000 XP.
 - b. Duna USA Inc.; Corafoam.
 - c. Dyplast Products; ISO-25.
 - d. Elliott Company of Indianapolis; Elfoam.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Comply with ASTM C 591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed **0.19 Btu x in./h x sq. ft. x deg F** (0.027 W/m x K) at **75 deg F** (24 deg C) after 180 days of aging.
3. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thickness up to **1 inch** (25 mm) as tested by ASTM E 84.
4. Fabricate shapes according to ASTM C 450 and ASTM C 585.
5. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.

- a. Equipment Applications: **[None] [ASJ] [ASJ-SSL] [PVDC] [PVDC-SSL]**.

Q. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C 534 or ASTM C 1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Armacell LLC; Tubolit.

- b. Nomaco Insulation; IMCOLOCK, IMCOSHEET, NOMALOCK, and NOMAPLY.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
- R. Polystyrene: Rigid, extruded cellular polystyrene intended for use as thermal insulation. Comply with ASTM C 578, Type IV or Type XIII, except thermal conductivity (k-value) shall not exceed **0.26 Btu x in./h x sq. ft. x deg F** (0.038 W/m x K) after 180 days of aging. Fabricate shapes according to ASTM C 450 and ASTM C 585.
- 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Styrofoam.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.2 HIGH-TEMPERATURE ENGINE EXHAUST SYSTEM INSULATION

A. Mineral Fiber Insulation (Type A):

- 1. High temperature piping and silencers; **600 degrees F** (316 degrees C) to **1200 degrees F** (649 degrees C):
- 2. Insulation for piping shall be premolded, mandrel wound, non-fabricated. Board insulation, when required for other than cylindrical surfaces, shall consist of the same materials as the pipe insulation described by this article.
- 3. Insulation thickness shall be 2", consisting of at least two layers or a factory ship lapped system.
 - a. Composition: Basalt wool and organic binder that is non-combustible and asbestos free.
 - b. Nominal Density: The nominal density to be between 6 and 10 pound per cubic foot.
 - c. Maximum Thermal Conductivity: The thermal conductivity shall not exceed the following:

BTU in./h Sq. Ft. degrees F (W/m K)	Mean Temperature
0.42 (0.062)	400 degrees F (204 degrees C)
0.50 (0.072)	500 degrees F (260 degrees C)
0.59 (0.086)	600 degrees F (316 degrees C)

- d. Maximum non-fibrous (shot) content: The percentage content of non-fibrous material (shot) shall not exceed 20% by weight.
- e. Linear shrinkage: The linear shrinkage, when tested at 1200 °F (649 degrees C), shall be less than 1%.
- f. Stress corrosion: The material must not promote or contribute to the corrosion of austenitic stainless steel.
- g. Surface burning characteristics shall not exceed:

- 1) Flame Spread: 5.
- 2) Smoke Developed: 0.
- h. Subject to compliance with requirements, provide one of the following:
 - 1) Owens Corning Insulation - High Temperature Pipe Insulation 1200.
 - 2) Advanced Thermal Products, Inc. - High Temperature Flexible Insulation, Type E.
 - 3) or approved equal.
4. Insulation Jacket:
 - a. Aluminum Jacket: ASTM B 209.
 - 1) Minimum thickness: 0.025-inch sheet.
 - 2) Finish: Embossed.
 - 3) Joining: Longitudinal slip joints and 2-inch laps.
 - 4) Fittings: 0.016-inch thick die shaped fitting covers with factory attached protective liner.
 - 5) Metal jacket bands: 3/8 inch wide; .015-inch thick aluminum.
- B. Pre-formed Calcium Silicate Pipe Insulation (Type B):
 1. Hydrous calcium silicate; ASTM C 533; rigid white; asbestos free, formed as V-groove or molded radius block for application to piping and fittings:
 - a. 'K' value: ASTM C 177 and C 518; 0.44 at 300 degrees F.
 - b. Maximum service temperature: 1500 degrees F.
 - c. Maximum thermal conductivity: The thermal conductivity shall not exceed the following:

BTU in./h Sq. Ft. degrees F	Mean Temperature:
(W/m degrees C):	
0.43 (0.062)	400 degrees F (204 degrees C)
0.46 (0.066)	500 degrees F (260 degrees C)
0.50 (0.072)	600 degrees F (316 degrees C)
 - d. Density: 13 lb/cu ft; compressive strength (block) 200 PSI with 5% compression at 1-1/2" thickness.
 - e. Insulation thickness shall be 2", consisting of two layers with staggered joints.
 - f. Tie with 16 gage stainless steel wire loops with twisted ends, spaced 12 inches on center.
 2. Subject to compliance with requirements, provide products by one of the following:
 - a. Calsite Group.
 - b. Pabco.
 - c. or approved equal.

C. High-Temperature Blanket Insulation System (Type C):

1. High temperature thermal insulation shall be installed on all flexible connectors (bellows) exhaust silencers, and all hot exhaust system piping. Surfaces shall be insulated so as to ensure that outside surface temperatures will not exceed 250 degrees F.
2. Thermal blanket insulation shall be comprised of factory-cut and finished blanket units fabricated as three-ply assemblies comprised of the following:
 - a. Type 304 stainless steel wire mesh.
 - b. 2-inch (two layer) thickness of type "E" fiberglass insulation conforming to MIL-L-16411 and having the following properties:

- 1) Maximum thermal conductivity: The thermal conductivity shall not exceed the following:

BTU in./h Sq. Ft. degrees F

(W/m degrees C):

0.27

0.41

0.52

Mean Temperature:

300 degrees F

500 degrees F

700 degrees F

- 2) Average fiber diameter: 0.00035 in.
- 3) Fusion Temperature: No fusion or melting at 1300 degrees F.

c. Cold Face Materials:

- 1) Cold face of outer layer of insulating mat shall be a flexible, silicone impregnated fiberglass cloth (not less than 34 ounces per square yard) which is water and oil resistant, capable of withstanding temperatures of up to 500 degrees F, and conforming to Mil Spec MIL-Y-1140-C and MIL-J-24244. Silicone coated cloth is unacceptable.
- 2) Cold face of inner layer of insulating mat shall be silica fabric coated with a special fire-retardant silicone rubber compound, Lewco Style 600 or equal, with properties as follows:
 - a) Weight: 18 oz/sq.yd. +/- 10%.
 - b) Thickness: 0.030" +/- 10%.
 - c) Breaking Strength FED STD 191/5102: Warp - 560 lbs. min. avg; Fill - 350 lbs. min. avg.
 - d) Temperature Resistance: 1800 degrees F., continuous use.
- d. All blanket edges shall be machine stitched with type 304 stainless steel thread. Permanently mounted type 304 stainless steel hooks and/or type 304 stainless steel capstans shall be used as fasteners. The blankets shall be laced together with type 304 stainless steel tie wire, 0.032" in diameter. "Hog rings" are unacceptable for binding edges or securing blankets.
- e. The high temperature thermal blanket system shall be flexible and designed to enable removal and re-installation.

- 1) Subject to compliance with requirements, provide one of the following:
 - a) Advanced Thermal Products, Inc., Santa Ana, California.
 - b) or approved equal.

D. Accessories (Type A and Type B insulation systems only):

1. Covering for Flexible Manifold Connectors: Inorganic High Temperature Insulating Blanket, temperature limit 1300 degrees F conforming to Mil 1-23128, Grade A, Class 1, 2 inches thick, 4 lb. density with expanded metal jacket wired in place. 'K' value 0.80 at 1000 degrees F.
2. Insulating Cement: ASTM C 195; hydraulic setting mineral wool, suitable for temperatures up to 1600 degrees F.
3. Finishing Cement: ASTM C 449.

2.3 INSULATING CEMENTS

A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Super-Stik.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Thermokote V.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

C. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.4 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service

temperature range of 50 to 800 deg F (10 to 427 deg C).

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-97.
 - b. Eagle Bridges - Marathon Industries; 290.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 81-27.
 - d. Mon-Eco Industries, Inc.; 22-30.
 - e. Vimasco Corporation; 760.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F (minus 73 to plus 93 deg C).
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 81-84.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. Phenolic and Polyisocyanurate Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F (minus 59 to plus 149 deg C).
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-96.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 81-33.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.

2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- E. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Aeroflex USA, Inc.; Aero seal.
 - b. Armacell LLC; Armaflex 520 Adhesive.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-75.
 - d. K-Flex USA; R-373 Contact Adhesive.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- F. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- G. Polystyrene Adhesive: Solvent- or water-based, synthetic resin adhesive with a service temperature range of minus 20 to plus 140 deg F (29 to plus 60 deg C).

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-96.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.

- H. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-50.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.

 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

- I. PVC Jacket Adhesive: Compatible with PVC jacket.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Corning Corporation; 739, Dow Silicone.
 - b. Johns Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive.
 - c. P.I.C. Plastics, Inc.; Welding Adhesive.
 - d. Speedline Corporation; Polyco VP Adhesive.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.

 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.5 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
- For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. Vapor-Barrier Mastic: Water based; suitable for indoor and outdoor use on below ambient services.
- Products: Subject to compliance with requirements, provide one of the following:
 - Foster Brand, Specialty Construction Brands, Inc., a business of H .B. Fuller Company; 30-80/30-90.
 - Vimasco Corporation; 749.
 - <Insert manufacturer's name; product name or designation>**.
 - or approved equal.
 - Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, **0.013 perm** (0.009 metric perm) at **43-mil** (1.09-mm) dry film thickness.
 - Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
 - Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
 - Color: White.
- C. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below ambient services.
- Products: Subject to compliance with requirements, provide one of the following:
 - Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-30.
 - Eagle Bridges - Marathon Industries; 501.
 - Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-35.
 - Mon-Eco Industries, Inc.; 55-10.
 - <Insert manufacturer's name; product name or designation>**.
 - or approved equal.
 - Water-Vapor Permeance: ASTM F 1249, **0.05 perm** (0.03 metric perm) at **35-mil** (0.9-mm) dry film thickness.
 - Service Temperature Range: 0 to 180 deg F (Minus 18 to plus 82 deg C).
 - Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
 - Color: White.
- D. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below ambient services.
- Products: Subject to compliance with requirements, provide one of the following:

- a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Encacel.
 - b. Eagle Bridges - Marathon Industries; 570.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 60-95/60-96.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
2. Water-Vapor Permeance: ASTM F 1249, **0.05 perm** (0.033 metric perm) at **30-mil** (0.8-mm) dry film thickness.
 3. Service Temperature Range: Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C).
 4. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
 5. Color: White.
- E. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
 - b. Eagle Bridges - Marathon Industries; 550.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
 - d. Mon-Eco Industries, Inc.; 55-50.
 - e. Vimasco Corporation; WC-1/WC-5.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
 2. Water-Vapor Permeance: ASTM F 1249, **1.8 perms** (1.2 metric perms) at **0.0625-inch** (1.6-mm) dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
 4. Solids Content: 60 percent by volume and 66 percent by weight.
 5. Color: White.

2.6 LAGGING ADHESIVES

- A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.
1. For indoor applications, use lagging adhesives that have a VOC content of **<Insert value>** g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 2. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-50 AHV2.

- b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-36.
 - c. Vimasco Corporation; 713 and 714.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
3. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over equipment insulation.
 4. Service Temperature Range: 0 to plus 180 deg F (Minus 18 to plus 82 deg C).
 5. Color: White.

2.7 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass, Phenolic, and Polyisocyanurate Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-45.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. Pittsburgh Corning Corporation; Pittseal 444.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
2. Joint Sealants for Polystyrene Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-70.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-45.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
3. Materials shall be compatible with insulation materials, jackets, and substrates.
4. Permanently flexible, elastomeric sealant.
5. Service Temperature Range: Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C).
6. Color: White or gray.
7. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
8. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile

Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
5. Color: Aluminum.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.8 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
 2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
 3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
 4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
 5. PVDC Jacket for Indoor Applications: 4-mil- (0.10-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perm (0.013 metric perm) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - 2) **<Insert manufacturer's name; product name or designation>**.
 - 3) or approved equal.
 6. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perm (0.007 metric perm) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - 2) **<Insert manufacturer's name; product name or designation>**.
 - 3) or approved equal.
 7. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - 2) **<Insert manufacturer's name; product name or designation>**.
 - 3) or approved equal.

8. Vinyl Jacket: White vinyl with a permeance of **1.3 perms** (0.86 metric perm) when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.9 FIELD-APPLIED FABRIC-REINFORCING MESH

- A. Woven Glass-Fiber Fabric: Approximately **6 oz./sq. yd.** (203 g/sq. m) with a thread count of **5 strands by 5 strands/sq. in.** (2 strands by 2 strands/sq. mm) for covering equipment.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Chil-Glas No. 5.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
- B. Woven Polyester Fabric: Approximately **1 oz./sq. yd.** (34 g/sq. m) with a thread count of **10 strands by 10 strands/sq. in.** (4 strands by 4 strands/sq. mm), in a Leno weave, for equipment.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
 - b. Vimasco Corporation; Elastafab 894.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.

2.10 FIELD-APPLIED CLOTHS

- A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of **8 oz./sq. yd.** (271 g/sq. m).
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Alpha Associates, Inc.; Alpha-Maritex 84215 and 84217/9485RW, Luben 59.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.11 FIELD-APPLIED JACKETS

- A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.
- B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

- C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Johns Manville; Zeston.
 - b. P.I.C. Plastics, Inc.; FG Series.
 - c. Proto Corporation; LoSmoke.
 - d. Speedline Corporation; SmokeSafe.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. Adhesive: As recommended by jacket material manufacturer.
 3. Color: **[White] [Color-code jackets based on system. Color as selected by DEN Project Manager]**.
 4. Factory-fabricated tank heads and tank side panels.
- D. Metal Jacket:
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
 - b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
 - c. RPR Products, Inc.; Insul-Mate.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
 2. Aluminum Jacket: Comply with **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005, Temper H-14.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size]**.
 - b. Finish and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper] [3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.
 - d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.
 - e. Factory-Fabricated Fitting Covers:
 - 1) Same material, finish, and thickness as jacket.
 - 2) Preformed two-piece or gore, 45- and 90-degree, short- and long-radius elbows.
 - 3) Tee covers.
 - 4) Flange and union covers.
 - 5) End caps.

- 6) Beveled collars.
 - 7) Valve covers.
 - 8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.
 3. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size].**
 - b. Material, finish, and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper] [3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn].**
 - d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn].**
 - e. Factory-Fabricated Fitting Covers:
 - 1) Same material, finish, and thickness as jacket.
 - 2) Preformed two-piece or gore, 45- and 90-degree, short- and long-radius elbows.
 - 3) Tee covers.
 - 4) Flange and union covers.
 - 5) End caps.
 - 6) Beveled collars.
 - 7) Valve covers.
 - 8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.
- E. Self-Adhesive Outdoor Jacket: **60-mil- (1.5-mm-) thick**, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with **[white] [stucco-embossed]** aluminum-foil facing.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Polyguard Products, Inc.; Alumaguard 60.
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.
- F. PVDC Jacket for Indoor Applications: **4-mil- (0.10-mm-) thick**, white PVDC biaxially oriented barrier film with a permeance at **0.02 perm (0.013 metric perm)** when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The), Saran 540 Vapor Retarder Film.

- b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

- G. PVDC Jacket for Outdoor Applications: **6-mil-** (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at **0.01 perm** (0.007 metric perm) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The), Saran 560 Vapor Retarder Film.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

- H. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.12 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 428 AWF ASJ.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
 - c. Compac Corporation; 104 and 105.
 - d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 - 2. Width: **3 inches** (75 mm).
 - 3. Thickness: **11.5 mils** (0.29 mm).
 - 4. Adhesion: **90 ounces force/inch** (1.0 N/mm) in width.
 - 5. Elongation: 2 percent.
 - 6. Tensile Strength: **40 lbf/inch** (7.2 N/mm) in width.
 - 7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
 - 1. Products: Subject to compliance with requirements, provide one of the following:

- a. ABI, Ideal Tape Division; 491 AWF FSK.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
 - c. Compac Corporation; 110 and 111.
 - d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Width: **3 inches** (75 mm).
 3. Thickness: **6.5 mils** (0.16 mm).
 4. Adhesion: **90 ounces force/inch** (1.0 N/mm) in width.
 5. Elongation: 2 percent.
 6. Tensile Strength: **40 lbf/inch** (7.2 N/mm) in width.
 7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
- C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 370 White PVC tape.
 - b. Compac Corporation; 130.
 - c. Venture Tape; 1506 CW NS.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
 2. Width: **2 inches** (50 mm).
 3. Thickness: **6 mils** (0.15 mm).
 4. Adhesion: **64 ounces force/inch** (0.7 N/mm) in width.
 5. Elongation: 500 percent.
 6. Tensile Strength: **18 lbf/inch** (3.3 N/mm) in width.
- D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 488 AWF.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
 - c. Compac Corporation; 120.
 - d. Venture Tape; 3520 CW.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. Width: **2 inches** (50 mm).
 3. Thickness: **3.7 mils** (0.093 mm).
 4. Adhesion: **100 ounces force/inch** (1.1 N/mm) in width.
 5. Elongation: 5 percent.
 6. Tensile Strength: **34 lbf/inch** (6.2 N/mm) in width.
- E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. Width: **3 inches** (75 mm).
 3. Film Thickness: **4 mils** (0.10 mm).
 4. Adhesive Thickness: **1.5 mils** (0.04 mm).
 5. Elongation at Break: 145 percent.
 6. Tensile Strength: **55 lbf/inch** (10.1 N/mm) in width.
- F. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 560 Vapor Retarder Tape.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. Width: **3 inches** (75 mm).
 3. Film Thickness: **6 mils** (0.15 mm).
 4. Adhesive Thickness: **1.5 mils** (0.04 mm).
 5. Elongation at Break: 145 percent.
 6. Tensile Strength: **55 lbf/inch** (10.1 N/mm) in width.

2.13 SECUREMENTS

A. Bands:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ITW Insulation Systems; Gerrard Strapping and Seals.
 - b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, [**Type 304**] [**or**] [**Type 316**]; **0.015 inch** (0.38 mm) thick, [**1/2 inch** (13 mm)] [**3/4 inch** (19 mm)] wide with [**wing seal**] [**or**] [**closed seal**].
3. Aluminum: **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, **0.020 inch** (0.51 mm) thick, [**1/2 inch** (13 mm)] [**3/4 inch** (19 mm)] wide with [**wing seal**] [**or**] [**closed seal**].
4. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed

for capacitor-discharge welding, [0.106-inch- (2.6-mm-)] [0.135-inch- (3.5-mm-)] diameter shank, length to suit depth of insulation indicated.

- a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; CWP-1.
 - 2) GEMCO; CD.
 - 3) Midwest Fasteners, Inc.; CD.
 - 4) Nelson Stud Welding; TPA, TPC, and TPS.
 - 5) **<Insert manufacturer's name; product name or designation>**.
 - 6) or approved equal.
2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [0.106-inch- (2.6-mm-)] [0.135-inch- (3.5-mm-)] diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; CHP-1.
 - 2) GEMCO; Cupped Head Weld Pin.
 - 3) Midwest Fasteners, Inc.; Cupped Head.
 - 4) Nelson Stud Welding; CHP.
 - 5) **<Insert manufacturer's name; product name or designation>**.
 - 6) or approved equal.
 3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; Tactoo Perforated Base Insul-Hangers.
 - 2) GEMCO; Perforated Base.
 - 3) Midwest Fasteners, Inc.; Spindle.
 - 4) **<Insert manufacturer's name; product name or designation>**.
 - 5) or approved equal.
 - b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.
 - c. Spindle: [**Copper- or zinc-coated, low-carbon steel**] [**Aluminum**] [**Stainless steel**], fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.
 - d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) GEMCO; Nylon Hangers.
 - 2) Midwest Fasteners, Inc.; Nylon Insulation Hangers.
 - 3) **<Insert manufacturer's name; product name or designation>**.
 - 4) or approved equal.
 - b. Baseplate: Perforated, nylon sheet, **0.030 inch** (0.76 mm) thick by **1-1/2 inches** (38 mm) in diameter.
 - c. Spindle: Nylon, **0.106-inch-** (2.6-mm-) diameter shank, length to suit depth of insulation indicated, up to **2-1/2 inches** (63 mm).
 - d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.
5. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; Tactoo Self-Adhering Insul-Hangers, Series.
 - 2) GEMCO; Peel & Press.
 - 3) Midwest Fasteners, Inc.; Self Stick.
 - 4) **<Insert manufacturer's name; product name or designation>**.
 - 5) or approved equal.
 - b. Baseplate: Galvanized carbon-steel sheet, **0.030 inch** (0.76 mm) thick by **2 inches** (50 mm) square.
 - c. Spindle: [**Copper- or zinc-coated, low-carbon steel**] [**Aluminum**] [**Stainless steel**], fully annealed, **0.106-inch-** (2.6-mm-) diameter shank, length to suit depth of insulation indicated.
 - d. Adhesive-backed base with a peel-off protective cover.
6. Insulation-Retaining Washers: Self-locking washers formed from **0.016-inch-** (0.41-mm-) thick, [**galvanized-steel**] [**aluminum**] [**stainless-steel**] sheet, with beveled edge sized as required to hold insulation securely in place but not less than **1-1/2 inches** (38 mm) in diameter.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; RC-150.
 - 2) GEMCO; R-150.

- 3) Midwest Fasteners, Inc.; WA-150.
 - 4) Nelson Stud Welding; Speed Clips.
 - 5) **<Insert manufacturer's name; product name or designation>**.
 - 6) or approved equal.
- b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.
7. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from **0.016-inch** (0.41-mm-) thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than **1-1/2 inches** (38 mm) in diameter.
- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- 1) GEMCO.
 - 2) Midwest Fasteners, Inc.
 - 3) **<Insert manufacturer's name>**.
 - 4) or approved equal.
- C. Staples: Outward-clinching insulation staples, nominal **3/4-inch** (19-mm-) wide, stainless steel or Monel.
- D. Wire: [**0.080-inch** (2.0-mm) **nickel-copper alloy**] [**0.062-inch** (1.6-mm) **soft-annealed, stainless steel**] [**0.062-inch** (1.6-mm) **soft-annealed, galvanized steel**].
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- a. C & F Wire.
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
- 2.14 CORNER ANGLES
- A. PVC Corner Angles: [**30 mils** (0.8 mm)] **<Insert dimension>** thick, minimum **1 by 1 inch** (25 by 25 mm), PVC according to ASTM D 1784, Class 16354-C. White or color-coded to match adjacent surface.
- B. Aluminum Corner Angles: [**0.040 inch** (1.0 mm)] **<Insert dimension>** thick, minimum **1 by 1 inch** (25 by 25 mm), aluminum according to **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14.
- C. Stainless-Steel Corner Angles: [**0.024 inch** (0.61 mm)] **<Insert dimension>** thick, minimum **1 by 1 inch** (25 by 25 mm), stainless steel according to ASTM A 167 or ASTM A 240/A 240M, [**Type 304**] [**or**] [**Type 316**].

PART 3 - EXECUTION

3.1 ENVIRONMENTAL REQUIREMENTS

- A. Maintain ambient temperatures and conditions required by manufacturers of adhesive and insulation.
- B. Maintain temperature during and after installation for minimum period of 24 hours.

3.2 EXAMINATION

- A. Verify that equipment has been tested before applying insulation materials.
- B. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 - 1. Verify that systems and equipment to be insulated have been tested and are free of defects.
 - 2. Verify that surfaces to be insulated are clean and dry.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
 - 1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer **5 mils** (0.127 mm) thick and an epoxy finish **5 mils** (0.127 mm) thick if operating in a temperature range between **140 and 300 deg F** (60 and 149 deg C). Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 - 2. Carbon Steel: Coat carbon steel operating at a service temperature between **32 and 300 deg F** (0 and 149 deg C) with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.4 GENERAL INSTALLATION REQUIREMENTS

- A. Install materials in accordance with manufacturer's instructions and N.I.C.A. standards.

- B. Do not insulate factory insulated equipment.
- C. On exposed equipment, locate insulation and cover seams in least visible locations.
- D. Apply insulation as close as possible to equipment by grooving, scoring, and beveling insulation. Secure insulation to equipment with studs, pins, clips, adhesive, wires, or bands.
- E. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment.
- F. Fill joints, cracks, seams, and depressions with bedding compound to form smooth surface. On cold equipment, use vapor barrier cement.
- G. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of equipment as specified in insulation system schedules.
- H. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- I. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- J. Install multiple layers of insulation with longitudinal and end seams staggered.
- K. Keep insulation materials dry during application and finishing.
- L. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- M. Install insulation with least number of joints practical.
- N. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 - 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 - 4. Cover inserts with jacket material matching adjacent insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- O. Insulated dual temperature equipment or cold equipment containing fluids below ambient temperature:
 - 1. Provide vapor barrier jackets, factory applied or field applied.

2. Finish with glass cloth and vapor barrier adhesive.
 3. Insulate entire system.
 4. Where staples are used to secure insulation covering requiring vapor barrier, the staples shall be sealed with a vapor barrier mastic.
- P. For insulated equipment containing fluids above ambient temperature:
1. Provide standard jackets, with or without vapor barrier, factory applied or field applied.
 2. Finish with glass cloth and adhesive.
 3. For hot equipment containing fluids 140 degrees F or less, do not insulate flanges and unions, but bevel and seal ends of insulation.
 4. For hot equipment containing fluids over 140 degrees F, insulate flanges and unions with removable sections and jackets.
- Q. Inserts and Shields:
1. Application: Piping 1-1/2 inches diameter or larger.
 2. Shields: Galvanized steel between hangers and inserts.
 3. Insert location: Between support shield and equipment and under the finish jacket.
 4. Insert configuration: Minimum 6 inches long, of same thickness and contour as adjoining insulation; may be factory fabricated.
 5. Insert material: ASTM C640 cork, hydrous calcium silicate insulation, or other heavy density insulating material suitable for the planned temperature range.
- R. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- S. Install insulation with factory-applied jackets as follows:
1. Draw jacket tight and smooth.
 2. Cover circumferential joints with 3-inch- (75-mm-) wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches (100 mm) o.c.
 3. Overlap jacket longitudinal seams at least 1-1/2 inches (38 mm). Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at [2 inches (50 mm)] [4 inches (100 mm)] o.c.
 - a. For below ambient services, apply vapor-barrier mastic over staples.
 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints.
- T. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- U. Finish installation with systems at operating conditions. Repair joint separations and

cracking due to thermal movement.

- V. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least **4 inches (100 mm)** beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
- W. For above ambient services, do not install insulation to the following:
 - 1. Vibration-control devices.
 - 2. Testing agency labels and stamps.
 - 3. Nameplates and data plates.
 - 4. Manholes.
 - 5. Handholes.
 - 6. Cleanouts.
- X. Finish insulation at supports, protrusions, and interruptions.
- Y. For equipment in mechanical equipment rooms or in finished spaces, finish with PVC jacket and fitting covers.
- Z. For exterior applications, provide vapor barrier jacket or finish with glass mesh reinforced vapor barrier cement. Cover with aluminum jacket with seams located on bottom side of horizontal equipment.
- AA. Cover glass fiber, cellular glass, and cellular foam insulation with metal mesh and finish with heavy coat of insulating cement.
- BB. Install insulation for equipment requiring access for maintenance, repair, or cleaning, in such a manner that it can be easily removed and replaced without damage.
- CC. Do not insulate over nameplate or ASME stamps. Bevel and seal insulation around such.

3.5 INSTALLATION OF EQUIPMENT, TANK, AND VESSEL INSULATION

- A. Mineral-Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.
 - 1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for **[100] [50] <Insert number>** percent coverage of tank and vessel surfaces.
 - 2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
 - 3. Protect exposed corners with secured corner angles.
 - 4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:
 - a. Do not weld anchor pins to ASME-labeled pressure vessels.
 - b. Select insulation hangers and adhesive that are compatible with service

- temperature and with substrate.
- c. On tanks and vessels, maximum anchor-pin spacing is **3 inches (75 mm)** from insulation end joints, and **16 inches (400 mm)** o.c. in both directions.
 - d. Do not overcompress insulation during installation.
 - e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
 - f. Impale insulation over anchor pins and attach speed washers.
 - g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
5. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.
 6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately **6 inches (150 mm)** from each end. Install wire or cable between two circumferential girdles **12 inches (300 mm)** o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of **48 inches (1200 mm)** o.c. Use this network for securing insulation with tie wire or bands.
 7. Stagger joints between insulation layers at least **3 inches (75 mm)**.
 8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.
 9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.
 10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.
- B. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.
1. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.
 2. Seal longitudinal seams and end joints.
- C. Insulation Installation on Pumps:
1. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on **6-inch (150-mm)** centers, starting at corners. Install **3/8-inch- (10-mm-)** diameter fasteners with wing nuts. Alternatively, secure the box sections together using a latching mechanism.
 2. Fabricate boxes from [**galvanized steel**] [**aluminum**] [**stainless steel**], at least [**0.040 inch (1.0 mm)**] [**0.050 inch (1.3 mm)**] [**0.060 inch (1.6 mm)**] thick.
 3. For below ambient services, install a vapor barrier at seams, joints, and

penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

3.6 INSTALLATION OF CALCIUM SILICATE INSULATION

A. Insulation Installation on Boiler Breechings:

1. Secure single-layer insulation with stainless-steel bands at **12-inch** (300-mm) intervals and tighten bands without deforming insulation material.
2. Install two-layer insulation with joints tightly butted and staggered at least **3 inches** (75 mm). Secure inner layer with wire spaced at **12-inch** (300-mm) intervals. Secure outer layer with stainless-steel bands at **12-inch** (300-mm) intervals.
3. On exposed applications without metal jacket, finish insulation surface with a skim coat of mineral-fiber, hydraulic-setting cement. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth. Overlap edges at least **1 inch** (25 mm). Apply finish coat of lagging adhesive over glass cloth. Thin finish coat to achieve smooth, uniform finish.

3.7 INSTALLATION OF PHENOLIC INSULATION

- A. Secure single-layer insulation with stainless-steel bands at **12-inch** (300-mm) intervals and tighten bands without deforming insulation materials.
- B. Install two-layer insulation with joints tightly butted and staggered at least **3 inches** (75 mm). Secure inner layer with **0.062-inch** (1.6-mm) wire spaced at **12-inch** (300-mm) intervals. Secure outer layer with stainless-steel bands at **12-inch** (300-mm) intervals.

3.8 FIELD-APPLIED JACKET INSTALLATION

- A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.
 1. Draw jacket smooth and tight to surface with **2-inch** (50-mm) overlap at seams and joints.
 2. Embed glass cloth between two **0.062-inch-** (1.6-mm-) thick coats of lagging adhesive.
 3. Completely encapsulate insulation with coating, leaving no exposed insulation.
- B. Where FSK jackets are indicated, install as follows:
 1. Draw jacket material smooth and tight.
 2. Install lap or joint strips with same material as jacket.
 3. Secure jacket to insulation with manufacturer's recommended adhesive.
 4. Install jacket with **1-1/2-inch** (38-mm) laps at longitudinal seams and **3-inch-** (75-mm-) wide joint strips at end joints.
 5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

- C. Where PVC jackets are indicated, install with **1-inch (25-mm)** overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.
 - 1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.
- D. Where metal jackets are indicated, install with **2-inch (50-mm)** overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands **12 inches (300 mm)** o.c. and at end joints.
- E. Where PVDC jackets are indicated, install as follows:
 - 1. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of **33-1/2 inches (850 mm)** or less. **33-1/2-inch- (850-mm-)** circumference limit allows for **2-inch- (50-mm-)** overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
 - 2. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

3.9 INSTALLATION OF HIGH-TEMPERATURE ENGINE EXHAUST INSULATION

- A. Recommended industry standards, similar to those listed in the MICA manual, are to be followed.
 - 1. National Commercial and Industrial Insulation Standards, produced by Midwest Insulation Contractors Association.
- B. All insulation, jacket, adhesives, mastics, sealers, etc., utilized in the fabrication of these systems shall meet NFPA for fire resistant ratings (maximum of 25 flame spread and 50 smoke developed ratings) and shall be approved by the insulation manufacturer for guaranteed performances when incorporated into their insulation system, unless a specific product is specified for a specific application, and is stated as an exception to this requirement. Certificates to this effect shall be submitted along with Contractor's submittal data for this section of the Specifications. No material may be used that, when tested by the ASTM E84-89 test method, is found to melt, drip or delaminate to such a degree that the continuity of the flame front is destroyed, thereby resulting in an artificially low flame spread rating.
- C. The handling and installation of all insulation materials shall be performed in strict accordance with the manufacturer's recommendations.
- D. All high temperature piping, silencers, and exhaust system accessories shall be insulated as indicated on the Drawings, as specified herein, and as required for a

complete system. In each case, the insulation shall be equal to that specified and materials applied and finished as described in these Specifications.

- E. Type A and B Insulation Systems: All surfaces to be insulated shall be clean and dry before applying the insulation. All sections of molded pipe covering shall be firmly butted together. Where an insulation covering is applied, it shall lap the adjoining section of insulation by at least three inches (3"). Where insulation terminates, it shall be neatly beveled and finished.
- F. Type A Insulation:
1. Provide an insert, not less than 6 inches long, of same thickness and contour as adjoining insulation, between support shield and piping, but under the finish jacket, on piping 2 inches diameter or larger, to prevent insulation from being crushed at support points. Inserts shall be calcium silicate or other heavy density insulating material suitable for the planned temperature range. Factory fabricated inserts may be used. Inserts shall also be provided (on both sides) where vertical piping supports are installed.
 2. Double-layer installation:
 - a. Piping runs: Insulation shall be installed in two layers, each in thickness of one-half of the total thickness specified. Outer layer shall be installed to provide staggered joints relative to longitudinal and transverse joints of inner layer.
 - b. Pipe fittings: For piping offsets and elbows, prepare two-layer installation of mitered sections of piping insulation, exercising care to ensure snug fit between miter-cut sections. As specified for piping runs, outer layer segments shall overlap joints of inner layer segments to provide staggered joints.
 - c. Apply insulation cement to joints in layers of insulation.
 3. Jacket: Cover completed insulation system with aluminum jacket with seams located on bottom side of horizontal piping. Insulate fittings and joints with insulation of like material and thickness as adjoining pipe, and finish with glass mesh reinforced vapor barrier cement.
 4. Engine exhaust silencer:
 - a. Insulate cylindrical surfaces with pre-molded insulation, applied as described for piping.
 - b. For other surfaces, install high temperature board insulation on flat or curved surfaces by attaching with weld pins or studs, finishing with metal mesh and insulating cement, then one layer of glass cloth coated with mastic.
 - 1) Pins with speed washers or studs with nuts shall be installed on 16" (400mm) centers and not more than 4" (100mm) from the edge of the insulation.
 5. Flexible piping connectors: For flexible piping connectors, provide 2-inch high temperature blanket insulation as described in Part 2 of this Section. Provide

segments of enlarged Type A pipe insulation to fit over flanges of flexible connection, finished as specified for piping insulation.

G. Type B Insulation:

1. Insulate all interior sections of piping with rigid hydrous calcium silicate (thickness as indicated) molded sectional pipe insulation secured in place with stainless steel wire 12" on centers. Install piping insulation as a two-layer system.
 - a. Apply insulation cement to joints in layers of insulation.
2. Cover with 1" hexagonal mesh galvanized steel poultry netting secured in place, followed by application of two layers of insulating cement, finished smooth. Finish with one layer of glass cloth, coat with mastic.
3. Engine exhaust silencer:
 - a. Insulate cylindrical surfaces with 2" (50mm) thickness of pre-formed insulation, applied as described for piping.
 - b. Insulate other surfaces with 2" (50mm) thick rigid hydrous calcium silicate (Type HCS) molded block insulation, mitered, tightly butted with joints staggered, and filled with insulating cement. Tie with 16 gage stainless steel wire or 1/2" x 0.015" galvanized steel bands, 12" on centers. Cover with 1" hexagonal mesh galvanized steel poultry netting secured in place, followed by application of two layers of insulating cement, finished smooth. Finish with one layer of glass cloth, coat with mastic.
4. Flexible piping connectors: For flexible piping connectors, provide 2-inch high temperature blanket insulation as described in Part 2 of this section. Provide segments of enlarged Type B pipe insulation to fit over flanges of flexible connection, finished as specified for piping insulation.

H. Type C Insulation:

1. Dimensional data: Contractor shall provide insulation system manufacturer with detailed piping assembly drawings, showing dimensions, along with locations and dimensions of flanges, piping hangers, or supporting brackets and all accessory items as required to enable factory fabrication of blanket sections which will correctly fit assembled piping, silencers, and accessory components of exhaust systems. No field alterations to blanket assemblies will be allowed; for any changes necessitated by altered conditions or Contractor's failure to provide correct information to the manufacturer, modified blanket units must be prepared by the manufacturer for Contractor's installation.
2. Protection of insulation at piping supports:
 - a. At pipe supports, provide thermal wrapping of support surfaces, which will bear weight of piping, using same materials as applied blanket insulation. Obtain specific instructions from blanket insulation manufacturer for methods and procedures to be applied.
 - b. Notch blanket insulation as appropriate to accommodate area of insulation-wrapped piping support, and carefully position wrapped hanger

with notch to provide for a gap-free engagement of pipe support with insulated piping system.

3.10 FINISHES

- A. Equipment Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
 - 1. Flat Acrylic Finish: [**Two**] <Insert number> finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- C. Color: Final color as selected by DEN Project Manager. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless-steel jackets.

3.11 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections: Inspect field-insulated equipment, randomly selected by DEN Project Manager, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to [**one**] <Insert number> location(s) for each type of equipment defined in the "Equipment Insulation Schedule" Article. For large equipment, remove only a portion adequate to determine compliance.
- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.12 BREECHING INSULATION SCHEDULE

- A. Round, exposed breeching and connector insulation shall be [**one of**] the following:
 - 1. Calcium Silicate: **4 inches** (100 mm) thick.
 - 2. High-Temperature Mineral-Fiber Blanket: **3 inches** (75 mm) thick and **3-lb/cu. ft.** (48-kg/cu. m) nominal density.
 - 3. High-Temperature Mineral-Fiber Board: **3 inches** (75 mm) thick and [**3-lb/cu. ft.**

(48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

- B. Round, concealed breeching and connector insulation shall be [**one of**] the following:
1. Calcium Silicate: 4 inches (100 mm) thick.
 2. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
 3. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- C. Rectangular, exposed breeching and connector insulation shall be [**one of**] the following:
1. Calcium Silicate: 4 inches (100 mm) thick.
 2. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
 3. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- D. Rectangular, concealed breeching and connector insulation shall be [**one of**] the following:
1. Calcium Silicate: 4 inches (100 mm) thick.
 2. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
 3. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.

3.13 EQUIPMENT INSULATION SCHEDULE

- A. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.
- B. Insulate indoor and outdoor equipment that is not factory insulated.
- C. Chillers: Insulate cold surfaces on chillers, including, but not limited to, evaporator bundles, [condenser bundles,] [heat-recovery bundles,] suction piping, compressor inlets, tube sheets, water boxes, and nozzles with [**one of**] the following:
1. Cellular Glass: [2 inches (50 mm)] <insert dimension> thick.
 2. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1 inch (25 mm)] <Insert dimension> thick.
 5. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
 6. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 7. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.

- D. Heat-exchanger (water-to-water for cooling service) insulation shall be **[one of]** the following:
1. Cellular Glass: **[2 inches (50 mm)]** <Insert dimension> thick.
 2. Flexible Elastomeric: **[1 inch (25 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[1 inch (25 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[1 inch (25 mm)]** <Insert dimension> thick.
 5. Phenolic: **[1 inch (25 mm)]** <Insert dimension> thick.
 6. Polyisocyanurate: **[1 inch (25 mm)]** <Insert dimension> thick.
 7. Polyolefin: **[1 inch (25 mm)]** <Insert dimension> thick.
- E. Heat-exchanger (water-to-water for heating service) insulation shall be **[one of]** the following:
1. Calcium Silicate: **[3 inches (75 mm)]** <Insert dimension> thick.
 2. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[2 inches (50 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[2 inches (50 mm)]** <Insert dimension> thick.
- F. Steam-to-hot-water converter insulation shall be **[one of]** the following:
1. Calcium Silicate: **[3 inches (75 mm)]** <Insert dimension> thick.
 2. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[2 inches (50 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[2 inches (50 mm)]** <Insert dimension> thick.
- G. Hot-water-to-steam converter insulation shall be **[one of]** the following:
1. Calcium Silicate: **[3 inches (75 mm)]** <Insert dimension> thick.
 2. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[2 inches (50 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[2 inches (50 mm)]** <Insert dimension> thick.
- H. Chilled-water pump insulation shall be **[one of]** the following:
1. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 2. Mineral-Fiber Board: **[2 inches (50 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 3. Phenolic: **[2 inches (50 mm)]** <Insert dimension> thick.
- I. Condenser-water pump insulation shall be **[one of]** the following:

1. Cellular Glass: [2 inches (50 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 3. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
- J. Dual-service heating and cooling pump insulation shall be [one of] the following:
1. Cellular Glass: [3 inches (75 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Board: [2 inches (50 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 3. Phenolic: [2 inches (50 mm)] <Insert dimension> thick.
 4. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
- K. Heating-hot-water pump insulation shall be [one of] the following:
1. Calcium Silicate: [3 inches (75 mm)] <Insert dimension> thick.
 2. Cellular Glass: [3 inches (75 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [2 inches (50 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
- L. Heat-recovery pump insulation shall be [one of] the following:
1. Cellular Glass: [2 inches (50 mm)] <Insert dimension> thick.
 2. Mineral-Fiber Board: [2 inches (50 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 3. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
- M. Steam condensate pump and boiler feedwater pump insulation shall be [one of] the following:
1. Calcium Silicate: [3 inches (75 mm)] <Insert dimension> thick.
 2. Cellular Glass: [3 inches (75 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [2 inches (50 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [2 inches (50 mm)] <Insert dimension> thick.
- N. Chilled-water expansion/compression tank insulation shall be [one of] the following:
1. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 2. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1 inch (25 mm)] <Insert dimension> thick.
 5. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.

6. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 7. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- O. Condenser-water expansion/compression tank insulation shall be [one of] the following:
1. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 2. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1 inch (25 mm)] <Insert dimension> thick.
 5. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
 6. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 7. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- P. Dual-service heating and cooling expansion/compression tank insulation shall be [one of] the following:
1. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 2. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1 inch (25 mm)] <Insert dimension> thick.
 5. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
 6. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 7. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.
- Q. Heating-hot-water expansion/compression tank insulation shall be [one of] the following:
1. Calcium Silicate: [2 inches (50 mm)] <Insert dimension> thick.
 2. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1 inch (25 mm)] <Insert dimension> thick.
- R. Heat-recovery expansion/compression tank insulation shall be [one of] the following:
1. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 2. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 3. Mineral-Fiber Board: [1 inch (25 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
 4. Mineral-Fiber Pipe and Tank: [1 inch (25 mm)] <Insert dimension> thick.
 5. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
 6. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 7. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.

- S. Chilled-water air-separator insulation shall be **[one of]** the following:
1. Cellular Glass: **[2 inches (50 mm)]** <Insert dimension> thick.
 2. Flexible Elastomeric: **[1 inch (25 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[1 inch (25 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[1 inch (25 mm)]** <Insert dimension> thick.
 5. Phenolic: **[1 inch (25 mm)]** <Insert dimension> thick.
 6. Polyisocyanurate: **[1 inch (25 mm)]** <Insert dimension> thick.
 7. Polyolefin: **[1 inch (25 mm)]** <Insert dimension> thick.
- T. Condenser-water air-separator insulation shall be **[one of]** the following:
1. Cellular Glass: **[2 inches (50 mm)]** <Insert dimension> thick.
 2. Flexible Elastomeric: **[1 inch (25 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[1 inch (25 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[1 inch (25 mm)]** <Insert dimension> thick.
 5. Phenolic: **[1 inch (25 mm)]** <Insert dimension> thick.
 6. Polyisocyanurate: **[1 inch (25 mm)]** <Insert dimension> thick.
 7. Polyolefin: **[1 inch (25 mm)]** <Insert dimension> thick.
- U. Dual-service heating and cooling air-separator insulation shall be **[one of]** the following:
1. Cellular Glass: **[2 inches (50 mm)]** <Insert dimension> thick.
 2. Flexible Elastomeric: **[1 inch (25 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[1 inch (25 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[1 inch (25 mm)]** <Insert dimension> thick.
 5. Phenolic: **[1 inch (25 mm)]** <Insert dimension> thick.
 6. Polyisocyanurate: **[1 inch (25 mm)]** <Insert dimension> thick.
 7. Polyolefin: **[1 inch (25 mm)]** <Insert dimension> thick.
- V. Heating-hot-water air-separator insulation shall be **[one of]** the following:
1. Calcium Silicate: **[3 inches (75 mm)]** <Insert dimension> thick.
 2. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 3. Mineral-Fiber Board: **[2 inches (50 mm)]** <Insert dimension> thick and **[2-lb/cu. ft. (32-kg/cu. m)]** **[3-lb/cu. ft. (48-kg/cu. m)]** **[6-lb/cu. ft. (96-kg/cu. m)]** nominal density.
 4. Mineral-Fiber Pipe and Tank: **[2 inches (50 mm)]** <Insert dimension> thick.
- W. Heat-recovery air-separator insulation shall be **[one of]** the following:
1. Cellular Glass: **[2 inches (50 mm)]** <Insert dimension> thick.
 2. Flexible Elastomeric: **[1 inch (25 mm)]** <Insert dimension> thick.

3. Mineral-Fiber Board: [**1 inch (25 mm)**] <Insert dimension> thick and [**2-lb/cu. ft. (32-kg/cu. m)**] [**3-lb/cu. ft. (48-kg/cu. m)**] [**6-lb/cu. ft. (96-kg/cu. m)**] nominal density.
 4. Mineral-Fiber Pipe and Tank: [**1 inch (25 mm)**] <Insert dimension> thick.
 5. Phenolic: [**1 inch (25 mm)**] <Insert dimension> thick.
 6. Polyisocyanurate: [**1 inch (25 mm)**] <Insert dimension> thick.
 7. Polyolefin: [**1 inch (25 mm)**] <Insert dimension> thick.
- X. Thermal storage tank (brine, water, ice) insulation shall be[**one of**] the following:
1. Cellular Glass: [**4 inches (100 mm)**] <Insert dimension> thick.
 2. Mineral-Fiber Board: [**3 inches (75 mm)**] <Insert dimension> thick and [**2-lb/cu. ft. (32-kg/cu. m)**] [**3-lb/cu. ft. (48-kg/cu. m)**] [**6-lb/cu. ft. (96-kg/cu. m)**] nominal density.
 3. Mineral-Fiber Pipe and Tank: [**3 inches (75 mm)**] <Insert dimension> thick.
 4. Phenolic: [**3 inches (75 mm)**] <Insert dimension> thick.
 5. Polyisocyanurate (Outdoor Application Only): [**3 inches (75 mm)**] <Insert dimension> thick.
 6. Polystyrene (Outdoor Application Only): [**3 inches (75 mm)**] <Insert dimension> thick.
- Y. Deaerator insulation shall be[**one of**] the following:
1. Calcium Silicate: [**3 inches (75 mm)**] <Insert dimension> thick.
 2. Cellular Glass: [**3 inches (75 mm)**] <Insert dimension> thick.
 3. Mineral-Fiber Board: [**2 inches (50 mm)**] <Insert dimension> thick and [**2-lb/cu. ft. (32-kg/cu. m)**] [**3-lb/cu. ft. (48-kg/cu. m)**] [**6-lb/cu. ft. (96-kg/cu. m)**] nominal density.
 4. Mineral-Fiber Pipe and Tank: [**2 inches (50 mm)**] <Insert dimension> thick.
- Z. Steam condensate tank and receiver insulation shall be[**one of**] the following:
1. Calcium Silicate: [**3 inches (75 mm)**] <Insert dimension> thick.
 2. Cellular Glass: [**3 inches (75 mm)**] <Insert dimension> thick.
 3. Mineral-Fiber Board: [**2 inches (50 mm)**] <Insert dimension> thick and [**2-lb/cu. ft. (32-kg/cu. m)**] [**3-lb/cu. ft. (48-kg/cu. m)**] [**6-lb/cu. ft. (96-kg/cu. m)**] nominal density.
 4. Mineral-Fiber Pipe and Tank: [**2 inches (50 mm)**] <Insert dimension> thick.
- AA. Steam flash-tank, flash-separator, moisture-separator, and blow-off-tank insulation shall be[**one of**] the following:
1. Calcium Silicate: [**3 inches (75 mm)**] <Insert dimension> thick.
 2. Cellular Glass: [**3 inches (75 mm)**] <Insert dimension> thick.
 3. Mineral-Fiber Board: [**2 inches (50 mm)**] <Insert dimension> thick and [**2-lb/cu. ft. (32-kg/cu. m)**] [**3-lb/cu. ft. (48-kg/cu. m)**] [**6-lb/cu. ft. (96-kg/cu. m)**] nominal density.
 4. Mineral-Fiber Pipe and Tank: [**2 inches (50 mm)**] <Insert dimension> thick.
- BB. Piping system filter-housing insulation shall be[**one of**] the following:

1. Cellular Glass: [3 inches (75 mm)] <Insert dimension> thick.
2. Mineral-Fiber Board: [2 inches (50 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
3. Mineral-Fiber Pipe and Tank: [2 inches (50 mm)] <Insert dimension> thick.

CC. Outdoor, aboveground, heated, fuel-oil storage tank insulation shall be [one of] the following:

1. Cellular Glass: [3 inches (75 mm)] <Insert dimension> thick.
2. Mineral-Fiber Board: [2 inches (50 mm)] <Insert dimension> thick and [2-lb/cu. ft. (32-kg/cu. m)] [3-lb/cu. ft. (48-kg/cu. m)] [6-lb/cu. ft. (96-kg/cu. m)] nominal density.
3. Mineral-Fiber Pipe and Tank: [2 inches (50 mm)] <Insert dimension> thick.
4. Polyisocyanurate: [1-1/2 inches (38 mm)] <Insert dimension> thick.

3.14 INDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Equipment, Concealed:

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils (0.5 mm)] [30 mils (0.8 mm)] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
4. Painted Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] thick.
5. Stainless Steel, [Type 304] [or] [Type 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
6. <Insert jacket type>.

D. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):

1. None.
2. [PVC] [PVC, Color-Coded by System]: [20 mils (0.5 mm)] [30 mils (0.8 mm)] thick.
3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
4. Painted Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch

- (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] thick.
5. Stainless Steel, [Type 304] [or] [Type 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 6. <Insert jacket type>.
- E. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):
1. None.
 2. [Painted]Aluminum, [Smooth] [Stucco Embossed] with [1-1/4-Inch- (32-mm-) Deep Corrugations] [2-1/2-Inch- (65-mm-) Deep Corrugations] [4-by-1-Inch (100-by-25-mm) Box Ribs]: [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
 3. Stainless Steel, [Type 304] [or] [Type 316], [Smooth] [Stucco Embossed], with [1-1/4-Inch- (32-mm-) Deep Corrugations] [2-1/2-Inch- (65-mm-) Deep Corrugations] [4-by-1-Inch (100-by-25-mm) Box Ribs]: [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 4. <Insert jacket type>.
- 3.15 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE
- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.
- C. Equipment, Concealed:
1. None.
 2. [PVC] [PVC, Color-Coded by System]: [20 mils (0.5 mm)] [30 mils (0.8 mm)] thick.
 3. Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
 4. Painted Aluminum, [Smooth] [Corrugated] [Stucco Embossed]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] thick.
 5. Stainless Steel, [Type 304] [or] [Type 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 6. <Insert jacket type>.
- D. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):
1. [Painted]Aluminum, [Smooth] [Corrugated] [Stucco Embossed] [with Z-Shaped Locking Seam]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.

2. Stainless Steel, [Type 304] [or] [Type 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed] [with Z-Shaped Locking Seam]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 3. <Insert jacket type>.
- E. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):
1. [Painted]Aluminum, [Smooth] [Stucco Embossed] with [1-1/4-Inch- (32-mm-) Deep Corrugations] [2-1/2-Inch- (65-mm-) Deep Corrugations] [4-by-1-Inch (100-by-25-mm) Box Ribs]: [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
 2. Stainless Steel, [Type 304] [or] [Type 316], [Smooth] [Stucco Embossed], with [1-1/4-Inch- (32-mm-) Deep Corrugations] [2-1/2-Inch- (65-mm-) Deep Corrugations] [4-by-1-Inch (100-by-25-mm) Box Ribs]: [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 3. <Insert jacket type>.
- F. High-Temperature Engine Exhaust System Insulation:
1. As specified in Part 2 of this Section.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230716

SECTION 230719 - HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes insulating the following HVAC piping systems:
1. Condensate drain piping, **[indoors] [and] [outdoors]**.
 2. Chilled-water and brine piping, **[indoors] [and] [outdoors]**.
 3. Condenser-water piping, **[indoors when used for waterside economizer or for condensate control] [and] [outdoors]**.
 4. Heating hot-water piping, **[indoors] [and] [outdoors]**.
 5. Steam and steam condensate piping, **[indoors] [and] [outdoors]**.
 6. Refrigerant suction and hot-gas piping, **[indoors] [and] [outdoors]**.
 7. Dual-service heating and cooling piping, **[indoors] [and] [outdoors]**.
 8. Heat-recovery piping, **[indoors] [and] [outdoors]**.
 9. Heated fuel-oil piping, **[indoors] [and] [outdoors]**.
- B. Related Sections:
1. Section 230713 "Duct Insulation."
 2. Section 230716 "HVAC Equipment Insulation" for HVAC equipment insulation and high-temperature engine exhaust insulation.
 3. Section 232113.13 "Underground Hydronic Piping" for loose-fill pipe insulation in underground piping outside the building.
 4. Section 336313 "Underground Steam and Condensate Distribution Piping" for loose-fill pipe insulation in underground piping outside the building.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Submit product description, list of materials and thickness for each service, and locations. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any) for each type of product indicated.
1. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
2. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail attachment and covering of heat tracing inside insulation.
3. Detail insulation application at pipe expansion joints for each type of insulation.
4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
5. Detail removable insulation at piping specialties.
6. Detail application of field-applied jackets.
7. Detail application at linkages of control devices.

D. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use.

1. Preformed Pipe Insulation Materials: 12 inches (300 mm) long by NPS 2 (DN 50).
2. Sheet Form Insulation Materials: 12 inches (300 mm) square.
3. Jacket Materials for Pipe: 12 inches (300 mm) long by NPS 2 (DN 50).
4. Sheet Jacket Materials: 12 inches (300 mm) square.
5. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
- C. Installer Certificates: Signed by the Contractor certifying that installers comply with requirements.
- D. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
 2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.
- C. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by DEN Project Manager. Use materials indicated for the completed Work.
1. Piping Mockups:
 - a. One 10-foot (3-m) section of NPS 2 (DN 50) straight pipe.
 - b. One each of a 90-degree threaded, welded, and flanged elbow.
 - c. One each of a threaded, welded, and flanged tee fitting.
 - d. One NPS 2 (DN 50) or smaller valve, and one NPS 2-1/2 (DN 65) or larger valve.
 - e. Four support hangers including hanger shield and insert.
 - f. One threaded strainer and one flanged strainer with removable portion of insulation.
 - g. One threaded reducer and one welded reducer.
 - h. One pressure temperature tap.
 - i. One mechanical coupling.
 2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
 3. Notify DEN Project Manager seven (7) days in advance of dates and times when mockups will be constructed.
 4. Obtain DEN Project Manager's approval of mockups before starting insulation application.
 5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless DEN Project Manager specifically approves such deviations in writing.

6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
7. Demolish and remove mockups when directed.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.
- B. Deliver materials to site in original factory packaging, labeled with manufacturer's identification, including product density and thickness.
- C. Store insulation in original wrapping and protect from weather and construction traffic.
- D. Protect insulation against dirt, water, chemical, and mechanical damage.

1.8 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.
- C. Coordinate installation and testing of heat tracing.

1.9 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," "Outdoor, Aboveground Piping Insulation Schedule," and "Outdoor, Underground Piping Insulation Schedule" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Calcium Silicate:
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Industrial Insulation Group (IIG); Thermo-12 Gold.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. Preformed Pipe Sections: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
 3. Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
 4. Prefabricated Fitting Covers: Comply with ASTM C 450 and ASTM C 585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.
- G. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Pittsburgh Corning Corporation; Foamglas.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. Block Insulation: ASTM C 552, Type I.
 3. Special-Shaped Insulation: ASTM C 552, Type III.
 4. Board Insulation: ASTM C 552, Type IV.
 5. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.

6. Preformed Pipe Insulation with Factory-Applied **[ASJ]** **[ASJ-SSL]**: Comply with ASTM C 552, Type II, Class 2.
 7. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
- H. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Aeroflex USA, Inc.; Aerocel.
 - b. Armacell LLC; AP Armaflex.
 - c. K-Flex USA; Insul-Lock, Insul-Tube, and K-FLEX LS.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
- I. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type [I] **[II with factory-applied vinyl jacket]** **[III with factory-applied FSK jacket]** **[III with factory-applied FSP jacket]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; SoftTouch Duct Wrap.
 - b. Johns Manville; Microlite.
 - c. Knauf Insulation; Friendly Feel Duct Wrap.
 - d. Manson Insulation Inc.; Alley Wrap.
 - e. Owens Corning; SOFTR All-Service Duct Wrap.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
- J. Mineral-Fiber, Preformed Pipe Insulation:
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Fibrex Insulations Inc.; Coreplus 1200.
 - b. Johns Manville; Micro-Lok.
 - c. Knauf Insulation; 1000-Degree Pipe Insulation.
 - d. Manson Insulation Inc.; Alley-K.
 - e. Owens Corning; Fiberglas Pipe Insulation.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
 2. Type I, **850 deg F** (454 deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, **[without factory-applied jacket]** **[with factory-applied ASJ]** **[with factory-applied ASJ-SSL]**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 3. Type II, **1200 deg F** (649 deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, **[without**

factory-applied jacket] [with factory-applied ASJ] [with factory-applied ASJ-SSL]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

- K. Mineral-Fiber, Pipe Insulation Wicking System: Preformed pipe insulation complying with ASTM C 547, Type I, Grade A, with absorbent cloth factory-applied to the entire inside surface of preformed pipe insulation and extended through the longitudinal joint to outside surface of insulation under insulation jacket. Factory apply a white, polymer, vapor-retarder jacket with self-sealing adhesive tape seam and evaporation holes running continuously along the longitudinal seam, exposing the absorbent cloth.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Knauf Insulation; Permawick Pipe Insulation.
 - b. Owens Corning; VaporWick Pipe Insulation.
 - c. **<Insert manufacturer's name; product name or designation>.**
 - d. or approved equal.

- L. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied **[ASJ] [FSK jacket]** complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is **2.5 lb/cu. ft. (40 kg/cu. m)** or more. Thermal conductivity (k-value) at **100 deg F (55 deg C)** is **0.29 Btu x in./h x sq. ft. x deg F (0.042 W/m x K)** or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; CrimpWrap.
 - b. Johns Manville; MicroFlex.
 - c. Knauf Insulation; Pipe and Tank Insulation.
 - d. Manson Insulation Inc.; AK Flex.
 - e. Owens Corning; Fiberglas Pipe and Tank Insulation.
 - f. **<Insert manufacturer's name; product name or designation>.**
 - g. or approved equal.

- M. Phenolic:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Kingspan Tarec Industrial Insulation NV; Koolphen K.
 - b. Resolco International BV; Insul-phen.
 - c. **<Insert manufacturer's name; product name or designation>.**
 - d. or approved equal.
2. Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type III, Grade 1.
3. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
4. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

5. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.
 - a. Preformed Pipe Insulation: **[None] [ASJ]**.

- N. Polyisocyanurate: Unfaced, preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Trymer 2000 XP.
 - b. Duna USA Inc.; Corafoam.
 - c. Dyplast Products; ISO-25.
 - d. Elliott Company of Indianapolis; Elfoam.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.

 2. Comply with ASTM C 591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed **0.19 Btu x in./h x sq. ft. x deg F** (0.027 W/m x K) at **75 deg F** (24 deg C) after 180 days of aging.
 3. Flame-spread index shall be 25 or less, and smoke-developed index shall be 50 or less for thickness up to **1 inch** (25 mm) as tested by ASTM E 84.
 4. Fabricate shapes according to ASTM C 450 and ASTM C 585.
 5. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.
 - a. Pipe Applications: **[None] [ASJ] [ASJ-SSL] [PVDC] [PVDC-SSL]**.

- O. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C 534 or ASTM C 1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Armacell LLC; Tubolit.
 - b. Nomaco Insulation; IMCOLOCK, IMCOSHEET, NOMALOCK, and NOMAPLY.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.

- P. Polystyrene: Rigid, extruded cellular polystyrene intended for use as thermal insulation. Comply with ASTM C 578, Type IV or Type XIII, except thermal conductivity (k-value) shall not exceed **0.26 Btu x in./h x sq. ft. x deg F** (0.038 W/m x K) after 180 days of aging. Fabricate shapes according to ASTM C 450 and ASTM C 585.
 1. Products: Subject to compliance with requirements, **provide one of the following**:
 - a. Dow Chemical Company (The); Styrofoam.
 - b. **<Insert manufacturer's name; product name or designation>**.

- c. or approved equal.

2.2 INSULATING CEMENTS

A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Super-Stik.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.

1. Products: Subject to compliance with requirements, **provide one of the following:**
 - a. Ramco Insulation, Inc.; Thermokote V.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

C. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.3 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F (10 to 427 deg C).

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-97.
 - b. Eagle Bridges - Marathon Industries; 290.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 81-27.
 - d. Mon-Eco Industries, Inc.; 22-30.
 - e. Vimasco Corporation; 760.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.

2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F (minus 73 to plus 93 deg C).
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 81-84.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. Phenolic and Polyisocyanurate Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F (minus 59 to plus 149 deg C).
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-96.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 81-33.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- E. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Aeroflex USA, Inc.; Aero seal.

- b. Armacell LLC; Armaflex 520 Adhesive.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-75.
 - d. K-Flex USA; R-373 Contact Adhesive.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- F. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- G. Polystyrene Adhesive: Solvent- or water-based, synthetic resin adhesive with a service temperature range of minus 20 to plus 140 deg F (29 to plus 60 deg C).
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-96.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
- H. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
 1. Products: Subject to compliance with requirements, provide one of the following:

- a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-50.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- I. PVC Jacket Adhesive: Compatible with PVC jacket.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Corning Corporation; 739, Dow Silicone.
 - b. Johns Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive.
 - c. P.I.C. Plastics, Inc.; Welding Adhesive.
 - d. Speedline Corporation; Polyco VP Adhesive.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- 2.4 MASTICS
- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.

- b. Vimasco Corporation; 749.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
 2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, **0.013 perm** (0.009 metric perm) at **43-mil** (1.09-mm) dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
 4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
 5. Color: White.
- C. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below-ambient services.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-30.
 - b. Eagle Bridges - Marathon Industries; 501.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-35.
 - d. Mon-Eco Industries, Inc.; 55-10.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. Water-Vapor Permeance: ASTM F 1249, **0.05 perm** (0.03 metric perm) at **35-mil** (0.9-mm) dry film thickness.
 3. Service Temperature Range: 0 to 180 deg F (Minus 18 to plus 82 deg C).
 4. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
 5. Color: White.
- D. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below-ambient services.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Encacel.
 - b. Eagle Bridges - Marathon Industries; 570.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 60-95/60-96.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
 2. Water-Vapor Permeance: ASTM F 1249, **0.05 perm** (0.033 metric perm) at **30-mil** (0.8-mm) dry film thickness.
 3. Service Temperature Range: Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C).
 4. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
 5. Color: White.

- E. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
 - b. Eagle Bridges - Marathon Industries; 550.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
 - d. Mon-Eco Industries, Inc.; 55-50.
 - e. Vimasco Corporation; WC-1/WC-5.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
 2. Water-Vapor Permeance: ASTM F 1249, **1.8 perms** (1.2 metric perms) at **0.0625-inch** (1.6-mm) dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
 4. Solids Content: 60 percent by volume and 66 percent by weight.
 5. Color: White.

2.5 LAGGING ADHESIVES

- A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.
1. For indoor applications, use lagging adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 2. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-50 AHV2.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-36.
 - c. Vimasco Corporation; 713 and 714.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
 3. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
 4. Service Temperature Range: 0 to plus 180 deg F (Minus 18 to plus 82 deg C).
 5. Color: White.

2.6 SEALANTS

- A. Joint Sealants:
1. Joint Sealants for Cellular-Glass, Phenolic, and Polyisocyanurate Products:

Subject to compliance with requirements, provide one of the following:

- a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-45.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. Pittsburgh Corning Corporation; Pittseal 444.
 - f. **<Insert manufacturer's name; product name or designation>**.
 - g. or approved equal.
2. Joint Sealants for Polystyrene Products: Subject to compliance with requirements, provide one of the following:
- a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-70.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-45.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
3. Materials shall be compatible with insulation materials, jackets, and substrates.
4. Permanently flexible, elastomeric sealant.
5. Service Temperature Range: Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C).
6. Color: White or gray.
7. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
8. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. Eagle Bridges - Marathon Industries; 405.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.
 - d. Mon-Eco Industries, Inc.; 44-05.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Materials shall be compatible with insulation materials, jackets, and substrates.

3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
5. Color: Aluminum.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.7 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. PVDC Jacket for Indoor Applications: **4-mil- (0.10-mm-)** thick, white PVDC biaxially oriented barrier film with a permeance at **0.02 perm (0.013 metric perm)** when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.

- a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - 2) **<Insert manufacturer's name; product name or designation>**.
 - 3) or approved equal.
6. PVDC Jacket for Outdoor Applications: **6-mil-** (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at **0.01 perm** (0.007 metric perm) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - 2) **<Insert manufacturer's name; product name or designation>**.
 - 3) or approved equal.
7. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - 2) **<Insert manufacturer's name; product name or designation>**.
 - 3) or approved equal.
8. Vinyl Jacket: White vinyl with a permeance of **1.3 perms** (0.86 metric perms) when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

- A. Woven Glass-Fiber Fabric: Approximately **2 oz./sq. yd.** (68 g/sq. m) with a thread count of **10 strands by 10 strands/sq. in.** (4 strands by 4 strands/sq. mm) for covering pipe and pipe fittings.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Chil-Glas Number 10.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
- B. Woven Polyester Fabric: Approximately **1 oz./sq. yd.** (34 g/sq. m) with a thread count of

10 strands by 10 strands/sq. in. (4 strands by 4 strands/sq. mm), in a Leno weave, for pipe.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
 - b. Vimasco Corporation; Elastafab 894.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.

2.9 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd. (271 g/sq. m).

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Alpha Associates, Inc.; Alpha-Maritex 84215 and 84217/9485RW, Luben 59.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.10 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Johns Manville; Zeston.
 - b. P.I.C. Plastics, Inc.; FG Series.
 - c. Proto Corporation; LoSmoke.
 - d. Speedline Corporation; SmokeSafe.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Adhesive: As recommended by jacket material manufacturer.
3. Color: **[White] [Color-code jackets based on system. Color as selected by DEN Project Manager].**
4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.

- a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

D. Metal Jacket:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
 - b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
 - c. RPR Products, Inc.; Insul-Mate.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
2. Aluminum Jacket: Comply with **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005, Temper H-14.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size]**.
 - b. Finish and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper] [3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.
 - d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn]**.
 - e. Factory-Fabricated Fitting Covers:
 - 1) Same material, finish, and thickness as jacket.
 - 2) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
 - 3) Tee covers.
 - 4) Flange and union covers.
 - 5) End caps.
 - 6) Beveled collars.
 - 7) Valve covers.
 - 8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.
3. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size]**.
 - b. Material, finish, and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper] [3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick**

- polysurlyn].**
- d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper] [2.5-mil- (0.063-mm-) thick polysurlyn].**
- e. Factory-Fabricated Fitting Covers:
- 1) Same material, finish, and thickness as jacket.
 - 2) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
 - 3) Tee covers.
 - 4) Flange and union covers.
 - 5) End caps.
 - 6) Beveled collars.
 - 7) Valve covers.
 - 8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.
- E. Underground Direct-Buried Jacket: **125-mil- (3.2-mm-) thick vapor barrier and waterproofing membrane consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.**
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Pittsburgh Corning Corporation; Pittwrap.
 - b. Polyguard Products, Inc.; Insulrap No Torch 125.
 - c. **<Insert manufacturer's name; product name or designation>.**
 - d. or approved equal.
- F. Self-Adhesive Outdoor Jacket: **60-mil- (1.5-mm-) thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with [white] [stucco-embossed] aluminum-foil facing.**
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Polyguard Products, Inc.; Alumaguard 60.
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.
- G. PVDC Jacket for Indoor Applications: **4-mil- (0.10-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms (0.013 metric perms) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.**
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film.
 - b. **<Insert manufacturer's name; product name or designation>.**
 - c. or approved equal.

- H. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perms (0.007 metric perms) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 560 Vapor Retarder Film.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
- I. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.

2.11 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 428 AWF ASJ.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
 - c. Compac Corporation; 104 and 105.
 - d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. Width: 3 inches (75 mm).
 3. Thickness: 11.5 mils (0.29 mm).
 4. Adhesion: 90 ounces force/inch (1.0 N/mm) in width.
 5. Elongation: 2 percent.
 6. Tensile Strength: 40 lbf/inch (7.2 N/mm) in width.
 7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 491 AWF FSK.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
 - c. Compac Corporation; 110 and 111.

- d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
2. Width: **3 inches** (75 mm).
 3. Thickness: **6.5 mils** (0.16 mm).
 4. Adhesion: **90 ounces force/inch** (1.0 N/mm) in width.
 5. Elongation: 2 percent.
 6. Tensile Strength: **40 lbf/inch** (7.2 N/mm) in width.
 7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
- C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 370 White PVC tape.
 - b. Compac Corporation; 130.
 - c. Venture Tape; 1506 CW NS.
 - d. **<Insert manufacturer's name; product name or designation>**.
 - e. or approved equal.
 2. Width: **2 inches** (50 mm).
 3. Thickness: **6 mils** (0.15 mm).
 4. Adhesion: **64 ounces force/inch** (0.7 N/mm) in width.
 5. Elongation: 500 percent.
 6. Tensile Strength: **18 lbf/inch** (3.3 N/mm) in width.
- D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 488 AWF.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
 - c. Compac Corporation; 120.
 - d. Venture Tape; 3520 CW.
 - e. **<Insert manufacturer's name; product name or designation>**.
 - f. or approved equal.
 2. Width: **2 inches** (50 mm).
 3. Thickness: **3.7 mils** (0.093 mm).
 4. Adhesion: **100 ounces force/inch** (1.1 N/mm) in width.
 5. Elongation: 5 percent.
 6. Tensile Strength: **34 lbf/inch** (6.2 N/mm) in width.
- E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, provide one of the following:

- a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
2. Width: **3 inches** (75 mm).
 3. Film Thickness: **4 mils** (0.10 mm).
 4. Adhesive Thickness: **1.5 mils** (0.04 mm).
 5. Elongation at Break: 145 percent.
 6. Tensile Strength: **55 lbf/inch** (10.1 N/mm) in width.
- F. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Chemical Company (The); Saran 560 Vapor Retarder Tape.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - c. or approved equal.
 2. Width: **3 inches** (75 mm).
 3. Film Thickness: **6 mils** (0.15 mm).
 4. Adhesive Thickness: **1.5 mils** (0.04 mm).
 5. Elongation at Break: 145 percent.
 6. Tensile Strength: **55 lbf/inch** (10.1 N/mm) in width.

2.12 SECUREMENTS

- A. Bands:
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ITW Insulation Systems; Gerrard Strapping and Seals.
 - b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
 - c. **<Insert manufacturer's name; product name or designation>**.
 - d. or approved equal.
 2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, [**Type 304**] [**or**] [**Type 316**]; **0.015 inch** (0.38 mm) thick, [**1/2 inch** (13 mm)] [**3/4 inch** (19 mm)] wide with [**wing seal**] [**or**] [**closed seal**].
 3. Aluminum: **ASTM B 209** (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, **0.020 inch** (0.51 mm) thick, [**1/2 inch** (13 mm)] [**3/4 inch** (19 mm)] wide with [**wing seal**] [**or**] [**closed seal**].
 4. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.
- B. Staples: Outward-clinching insulation staples, nominal **3/4-inch-** (19-mm-) wide, stainless steel or Monel.
- C. Wire: [**0.080-inch** (2.0-mm) **nickel-copper alloy**] [**0.062-inch** (1.6-mm) **soft-annealed**,

stainless steel] [0.062-inch (1.6-mm) soft-annealed, galvanized steel].

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. C & F Wire.
 - b. <Insert manufacturer's name>.
 - c. or approved equal.

PART 3 - EXECUTION

3.1 ENVIRONMENTAL REQUIREMENTS

- A. Maintain ambient temperatures and conditions required by manufacturers of adhesives, mastics, and insulation cements.
- B. Maintain temperature during and after installation for minimum period of 24 hours.

3.2 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 1. Verify that systems to be insulated have been tested and are free of defects.
 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
 1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer **5 mils** (0.127 mm) thick and an epoxy finish **5 mils** (0.127 mm) thick if operating in a temperature range between **140 and 300 deg F** (60 and 149 deg C). Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 2. Carbon Steel: Coat carbon steel operating at a service temperature between **32 and 300 deg F** (0 and 149 deg C) with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the trade installing heat tracing. Comply with

requirements for heat tracing that apply to insulation.

- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.4 GENERAL INSTALLATION REQUIREMENTS

- A. Apply insulation materials, accessories, and finishes according to the manufacturer's written instructions; with smooth, straight, and even surfaces; free of voids throughout the length of piping, including fittings, valves, and specialties.
- B. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.
- C. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.
- D. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- E. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- F. Install multiple layers of insulation with longitudinal and end seams staggered.
- G. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
- H. Seal joints and seams with vapor-retarder mastic on insulation indicated to receive a vapor retarder.
- I. Keep insulation materials dry during application and finishing.
- J. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- K. Install insulation with least number of joints practical.
- L. Apply insulation over fittings, valves, and specialties, with continuous thermal and vapor-retarder integrity, unless otherwise indicated. Refer to special instructions for applying insulation over fittings, valves, and specialties.
- M. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs at least **12 inches (300 mm)** from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to

- structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- N. Insulation Terminations: For insulation application where vapor retarders are indicated, taper insulation ends. Seal tapered ends with a compound recommended by the insulation material manufacturer to maintain vapor retarder.
- O. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- P. Install insulation with factory-applied jackets as follows:
1. Draw jacket tight and smooth.
 2. Circumferential joints: Cover circumferential joints with **3-inch- (75-mm-)** wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced **4 inches (100 mm)** o.c.
 3. Longitudinal seams: Overlap jacket longitudinal seams at least **1-1/2 inches (38 mm)**. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at [**2 inches (50 mm)**] [**4 inches (100 mm)**] o.c.
 - a. For below-ambient services, apply vapor-barrier mastic over staples.
 - b. Exception: Do not staple longitudinal laps on insulation having a vapor retarder.
 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.
- Q. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- R. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- S. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least **4 inches (100 mm)** beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
- T. For above-ambient services, do not install insulation to the following:
1. Vibration-control devices.
 2. Testing agency labels and stamps.

3. Nameplates and data plates.
4. Manholes.
5. Handholes.
6. Cleanouts.

3.5 PENETRATIONS

- A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside roof flashing at least **2 inches** (50 mm) below top of roof flashing.
 4. Seal jacket to roof flashing with flashing sealant.
- B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.
- C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least **2 inches** (50 mm).
 4. Seal jacket to wall flashing with flashing sealant.
- D. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.
1. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.
- F. Insulation Installation at Floor Penetrations:
1. Pipe: Install insulation continuously through floor penetrations.
 2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.6 GENERAL PIPE INSULATION INSTALLATION

- A. Install materials in accordance with manufacturer's instructions and N.I.C.A. standards.
- B. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.
- C. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:
 - 1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
 - 2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
 - 3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
 - 4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
 - 5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
 - 6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
 - 7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
 - 8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.
 - 9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.

- D. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.
- E. Install removable insulation covers at locations indicated. Installation shall conform to the following:
1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
 2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
 3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical centerline of valve body.
 4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least **2 inches (50 mm)** over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
 5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.7 INSTALLATION OF CALCIUM SILICATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure single-layer insulation with stainless-steel bands at **12-inch (300-mm)** intervals and tighten bands without deforming insulation materials.
2. Install two-layer insulation with joints tightly butted and staggered at least **3 inches (75 mm)**. Secure inner layer with wire spaced at **12-inch (300-mm)** intervals. Secure outer layer with stainless-steel bands at **12-inch (300-mm)** intervals.
3. Apply a skim coat of mineral-fiber, hydraulic-setting cement to insulation surface. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth or tape. Overlap edges at least **1 inch (25 mm)**. Apply finish coat of lagging adhesive over glass cloth or tape. Thin finish coat to achieve smooth, uniform finish.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus

- twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.
 4. Finish flange insulation same as pipe insulation.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.
3. Finish fittings insulation same as pipe insulation.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install mitered segments of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
2. Install insulation to flanges as specified for flange insulation application.
3. Finish valve and specialty insulation same as pipe insulation.

3.8 INSTALLATION OF CELLULAR-GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient services, secure laps with outward-clinched staples at **6 inches (150 mm)** o.c.
4. For insulation with factory-applied jackets on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least **1 inch (25 mm)**, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of cellular-glass insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.9 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of

air to surface being insulated.

3.10 INSTALLATION OF MINERAL-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at **6 inches (150 mm)** o.c.
4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least **1 inch (25 mm)**, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.11 INSTALLATION OF PHENOLIC INSULATION

A. General Installation Requirements:

1. Secure single-layer insulation with stainless-steel bands at **12-inch (300-mm)** intervals and tighten bands without deforming insulation materials.
2. Install 2-layer insulation with joints tightly butted and staggered at least **3 inches (75 mm)**. Secure inner layer with **0.062-inch (1.6-mm)** wire spaced at **12-inch (300-mm)** intervals. Secure outer layer with stainless-steel bands at **12-inch (300-mm)** intervals.

B. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient services, secure laps with outward-clinched staples at **6 inches (150 mm)** o.c.
4. For insulation with factory-applied jackets with vapor retarders on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

C. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.

D. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.

E. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.12 INSTALLATION OF POLYISOCYANURATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with tape or bands and tighten without deforming insulation materials. Orient longitudinal joints between half sections in 3- and 9-o'clock positions on the pipe.

2. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive or tape as recommended by insulation material manufacturer and seal with vapor-barrier mastic.
3. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, same thickness of adjacent pipe insulation, not to exceed **1-1/2-inch (38-mm)** thickness.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyisocyanurate block insulation of same thickness as pipe insulation.

C. Insulation Installation on Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of polyisocyanurate insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.13 INSTALLATION OF POLYOLEFIN INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Seal split-tube longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyolefin sheet insulation of same thickness as pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of polyolefin pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install cut sections of polyolefin pipe and sheet insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.14 INSTALLATION OF POLYSTYRENE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation with tape or bands and tighten bands without deforming insulation materials. Orient longitudinal joints between half sections in 3- and 9-o'clock positions on the pipe.
2. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive or tape as recommended by insulation material manufacturer and seal with vapor-barrier mastic.
3. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, and make thickness same as adjacent pipe insulation, not to exceed 1-1/2-inch (38-mm).
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polystyrene block insulation of same thickness as pipe insulation.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed section of polystyrene insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation

- without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.15 FIELD-APPLIED JACKET INSTALLATION

- A. Indoor, Concealed Applications: Insulated pipes conveying fluids above ambient temperature shall have standard jackets, with vapor barrier, factory-applied or field-applied. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass cloth and adhesive. PVC jackets may be used if in accordance with specified flame spread and smoke developed limitations.
- B. Indoor, Concealed Applications: Insulated dual-temperature pipes or pipes conveying fluids below ambient temperature shall have vapor barrier jackets, factory-applied or field-applied. Insulate fittings, joints, and valves with molded insulation of like material and thickness as adjacent pipe, and finish with glass cloth and vapor barrier adhesive.
- C. Indoor, Exposed Applications: For pipe exposed in mechanical equipment rooms or in finished spaces, insulate as for concealed applications. Finish with reinforced white kraft and aluminum foil laminates. **[Do not use PVC jackets.]**
- D. Exterior Applications: Provide vapor barrier jackets. Cover with aluminum jacket with seams located on bottom side of horizontal piping. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass mesh reinforced vapor barrier cement.
- E. Buried Piping: Provide factory fabricated assembly with inner all-purpose service jacket with self-sealing lap, and asphalt impregnated open mesh glass fabric, with one mil thick aluminum foil sandwiched between three layers of bituminous compound; outer surface faced with a polyester film.
- F. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.
 1. Draw jacket smooth and tight to surface with **2-inch (50-mm)** overlap at seams and joints.
 2. Embed glass cloth between two **0.062-inch- (1.6-mm-)** thick coats of lagging adhesive.
 3. Completely encapsulate insulation with coating, leaving no exposed insulation.
- G. Where FSK jackets are indicated, install as follows:
 1. Draw jacket material smooth and tight.
 2. Install lap or joint strips with same material as jacket.
 3. Secure jacket to insulation with manufacturer's recommended adhesive.
 4. Install jacket with **1-1/2-inch (38-mm)** laps at longitudinal seams and **3-inch- (75-mm-)** wide joint strips at end joints.
 5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

- H. Where PVC jackets are indicated, install with **1-inch (25-mm)** overlap at longitudinal seams and end joints; for horizontal applications. Seal with manufacturer's recommended adhesive.
1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.
- I. Where metal jackets are indicated, install with **2-inch (50-mm)** overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands **12 inches (300 mm)** o.c. and at end joints.
- J. Where PVDC jackets are indicated, install as follows:
1. Apply three separate wraps of filament tape per insulation section to secure pipe insulation to pipe prior to installation of PVDC jacket.
 2. Wrap factory-presizes jackets around individual pipe insulation sections with one end overlapping the previously installed sheet. Install presized jacket with an approximate overlap at butt joint of **2 inches (50 mm)** over the previous section. Adhere lap seal using adhesive or SSL, and then apply 1-1/4 circumferences of appropriate PVDC tape around overlapped butt joint.
 3. Continuous jacket can be spiral-wrapped around a length of pipe insulation. Apply adhesive or PVDC tape at overlapped spiral edge. When electing to use adhesives, refer to manufacturer's written instructions for application of adhesives along this spiral edge to maintain a permanent bond.
 4. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of **33-1/2 inches (850 mm)** or less. The **33-1/2-inch- (850-mm-)** circumference limit allows for **2-inch- (50-mm-)** overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
 5. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

3.16 FINISHES

- A. Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
1. Flat Acrylic Finish: [**Two**] **<Insert number>** finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

- C. Color: Final color as selected by DEN Project Manager. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless-steel jackets.

3.17 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:
 - 1. Inspect pipe, fittings, strainers, and valves, randomly selected by DEN Project Manager, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to **[three] <Insert number>** locations of straight pipe, **[three] <Insert number>** locations of threaded fittings, **[three] <Insert number>** locations of welded fittings, **[two] <Insert number>** locations of threaded strainers, **[two] <Insert number>** locations of welded strainers, **[three] <Insert number>** locations of threaded valves, and **[three] <Insert number>** locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.
- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.18 PIPING INSULATION SCHEDULE, GENERAL

- A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.
- B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
 - 1. Drainage piping located in crawl spaces.
 - 2. Underground piping.
 - 3. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.19 INDOOR PIPING INSULATION SCHEDULE

- A. Condensate and Equipment Drain Water below **60 Deg F (16 Deg C)**:
 - 1. All Pipe Sizes: Insulation shall be **[one of]** the following:
 - a. Cellular Glass: **[1-1/2 inches (38 mm)] <Insert dimension>** thick.
 - b. Flexible Elastomeric: **[3/4 inch (19 mm)] [1 inch (25 mm)] <Insert**

dimension> thick.

- c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1/2 inch (13 mm)**] [**1 inch (25 mm)**] <Insert dimension> thick.
- d. Phenolic: [**1 inch (25 mm)**] <Insert dimension> thick.
- e. Polyisocyanurate: [**1 inch (25 mm)**] <Insert dimension> thick.
- f. Polyolefin: [**3/4 inch (19 mm)**] [**1 inch (25 mm)**] <Insert dimension> thick.

B. Chilled Water and Brine, 40 Deg F (5 Deg C) and below:

- 1. [**NPS 3 (DN 80)**] <Insert pipe size> and Smaller: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] <Insert dimension> thick.
 - b. Mineral-Fiber, [**Preformed Pipe, Type I**] [or] [**Pipe Insulation Wicking System**]: [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] <Insert dimension> thick.
 - c. Phenolic: [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] [**3 inches (75 mm)**] <Insert dimension> thick.
 - d. Polyisocyanurate: [**1 inch (25 mm)**] <Insert dimension> thick.
- 2. [**NPS 4 (DN 100) to NPS 12 (DN 300)**] <Insert pipe size range>: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] [**3 inches (75 mm)**] <Insert dimension> thick.
 - b. Mineral-Fiber, [**Preformed Pipe, Type I**] [or] [**Pipe Insulation Wicking System**]: [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] <Insert dimension> thick.
 - c. Phenolic: [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] [**3 inches (75 mm)**] <Insert dimension> thick.
 - d. Polyisocyanurate: [**1 inch (25 mm)**] <Insert dimension> thick.
- 3. [**NPS 14 (DN 350)**] <Insert pipe size> and Larger: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**2 inches (50 mm)**] [**3 inches (75 mm)**] <Insert dimension> thick.
 - b. Mineral-Fiber, [**Preformed Pipe, Type I**,] [**Pipe and Tank Insulation**,] [or] [**Pipe Insulation Wicking System**]: [**2 inches (50 mm)**] [**3 inches (75 mm)**] <Insert dimension> thick.
 - c. Phenolic: [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] [**3 inches (75 mm)**] <Insert dimension> thick.

C. Chilled Water and Brine, above 40 Deg F (5 Deg C):

- 1. [**NPS 12 (DN 300)**] <Insert pipe size> and Smaller: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**1-1/2 inches (38 mm)**] [**2 inches (50 mm)**] <Insert

the following:

- a. Cellular Glass: [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension> thick.
 - b. Mineral-Fiber, Preformed Pipe, Type I: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension> thick.
 - c. Phenolic: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - d. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
2. [NPS 14 (DN 350)] <Insert pipe size> and Larger: Insulation shall be [one of] the following:
- a. Cellular Glass: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - b. Mineral-Fiber, [Preformed Pipe, Type I] [or] [Pipe and Tank Insulation]: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - c. Phenolic: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.

F. Heating-Hot-Water Supply and Return, above 200 Deg F (93 Deg C):

1. [NPS 3/4 (DN 20)] <Insert pipe size> and Smaller: Insulation shall be [one of] the following:
 - a. Calcium Silicate: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - b. Cellular Glass: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe, Type I or II: [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension> thick.
2. [NPS 1 (DN 25)] <Insert pipe size> and Larger: Insulation shall be [one of] the following:
 - a. Calcium Silicate: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
 - b. Cellular Glass: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe, Type I or II: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.

G. Steam and Steam Condensate, 350 Deg F (177 Deg C) and Below:

1. [NPS 3/4 (DN 20)] <Insert pipe size> and Smaller: Insulation shall be [one of] the following:
 - a. Calcium Silicate: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.

- b. Cellular Glass: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe, Type I or II: [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension> thick.
 2. [NPS 1 (DN 25)] <Insert pipe size> and Larger: Insulation shall be [one of] the following:
 - a. Calcium Silicate: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
 - b. Cellular Glass: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, [Preformed Pipe, Type I or II] [or] [Pipe and Tank Insulation]: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
- H. Steam and Steam Condensate, above 350 Deg F (177 Deg C):
 1. [NPS 3/4 (DN 20)] <Insert pipe size> and Smaller: Insulation shall be [one of] the following:
 - a. Calcium Silicate: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - b. Cellular Glass: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe, Type I or II: [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension> thick.
 2. [NPS 1 (DN 25)] <Insert pipe size> and Larger: Insulation shall be [one of] the following:
 - a. Calcium Silicate: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
 - b. Cellular Glass: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, [Preformed Pipe, Type I or II] [or] [Pipe and Tank Insulation]: [3 inches (75 mm)] [4 inches (100 mm)] <Insert dimension> thick.
- I. Refrigerant Suction and Hot-Gas Piping:
 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 - b. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [1 inch (25 mm)] <Insert dimension> thick.
 - d. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
 - e. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 - f. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.

J. Refrigerant Suction and Hot-Gas Flexible Tubing:

1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 - b. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.

K. Dual-Service Heating and Cooling, 40 to 200 Deg F (5 to 93 Deg C):

1. [NPS 12 (DN 300)] <Insert pipe size> and Smaller: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension> thick.
 - b. Mineral-Fiber, Preformed Pipe, Type I: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension> thick.
 - c. Phenolic: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - d. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
2. [NPS 14 (DN 350)] <Insert pipe size> and Larger: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - b. Mineral-Fiber, [Preformed Pipe, Type I] [or] [Pipe and Tank Insulation]: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.
 - c. Phenolic: [1-1/2 inches (38 mm)] [2 inches (50 mm)] [3 inches (75 mm)] <Insert dimension> thick.

L. Heat-Recovery Piping:

1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [1-1/2 inches (38 mm)] <Insert dimension> thick.
 - b. Flexible Elastomeric: [1 inch (25 mm)] <Insert dimension> thick.
 - c. Mineral-Fiber, [Preformed Pipe Insulation, Type I] [or] [Pipe and Tank Insulation]: [1 inch (25 mm)] <Insert dimension> thick.
 - d. Phenolic: [1 inch (25 mm)] <Insert dimension> thick.
 - e. Polyisocyanurate: [1 inch (25 mm)] <Insert dimension> thick.
 - f. Polyolefin: [1 inch (25 mm)] <Insert dimension> thick.

3.20 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. Chilled Water and Brine:

1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [3 inches (75 mm)] <Insert dimension> thick.

- b. Flexible Elastomeric: **[3 inches (75 mm)]** <Insert dimension> thick.
- c. Mineral-Fiber, Preformed Pipe Insulation, Type I: **[3 inches (75 mm)]** <Insert dimension> thick.
- d. Phenolic: **[2 inches (50 mm)]** <Insert dimension> thick.
- e. Polyisocyanurate: **[2 inches (50 mm)]** <Insert dimension> thick.
- f. Polyolefin: **[3 inches (75 mm)]** <Insert dimension> thick.
- g. Polystyrene: **[2 inches (50 mm)]** <Insert dimension> thick.

B. Condenser-Water Supply and Return:

- 1. All Pipe Sizes: Insulation shall be **[one of]** the following:
 - a. Cellular Glass: **[2 inches (50 mm)]** <Insert dimension> thick.
 - b. Flexible Elastomeric: **[2 inches (50 mm)]** <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I: **[2 inches (50 mm)]** <Insert dimension> thick.
 - d. Phenolic: **[2 inches (50 mm)]** <Insert dimension> thick.
 - e. Polyisocyanurate: **[2 inches (50 mm)]** <Insert dimension> thick.
 - f. Polyolefin: **[2 inches (50 mm)]** <Insert dimension> thick.
 - g. Polystyrene: **[2 inches (50 mm)]** <Insert dimension> thick.

C. Heating-Hot-Water Supply and Return, **200 Deg F (93 Deg C)** and Below:

- 1. All Pipe Sizes: Insulation shall be **[one of]** the following:
 - a. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 - b. Mineral-Fiber, Preformed Pipe Insulation, Type I: **[2 inches (50 mm)]** <Insert dimension> thick.
 - c. Phenolic: **[2 inches (50 mm)]** <Insert dimension> thick.
 - d. Polyisocyanurate: **[2 inches (50 mm)]** <Insert dimension> thick.

D. Heating-Hot-Water Supply and Return, above **200 Deg F (93 Deg C)**:

- 1. All Pipe Sizes: Insulation shall be **[one of]** the following:
 - a. Calcium Silicate: **[3 inches (75 mm)]** <Insert dimension> thick.
 - b. Cellular Glass: **[3 inches (75 mm)]** <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I or II: **[2 inches (50 mm)]** <Insert dimension> thick.

E. Steam and Steam Condensate, **350 Deg F (177 Deg C)** and Below:

- 1. All Pipe Sizes: Insulation shall be **[one of]** the following:
 - a. Calcium Silicate: **[4 inches (100 mm)]** <Insert dimension> thick.
 - b. Cellular Glass: **[4 inches (100 mm)]** <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I or II: **[3 inches (75 mm)]** <Insert dimension> thick.

F. Steam and Steam Condensate, above **350 Deg F (177 Deg C)**:

1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Calcium Silicate: [**5 inches (125 mm)**] <Insert dimension> thick.
 - b. Cellular Glass: [**5 inches (125 mm)**] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I or II: [**4 inches (100 mm)**] <Insert dimension> thick.

- G. Refrigerant Suction and Hot-Gas Piping:
 1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**2 inches (50 mm)**] <Insert dimension> thick.
 - b. Flexible Elastomeric: [**2 inches (50 mm)**] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches (50 mm)**] <Insert dimension> thick.
 - d. Phenolic: [**2 inches (50 mm)**] <Insert dimension> thick.
 - e. Polyisocyanurate: [**2 inches (50 mm)**] <Insert dimension> thick.
 - f. Polyolefin: [**2 inches (50 mm)**] <Insert dimension> thick.
 - g. Polystyrene: [**2 inches (50 mm)**] <Insert dimension> thick.

- H. Refrigerant Suction and Hot-Gas Flexible Tubing:
 1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Flexible Elastomeric: [**2 inches (50 mm)**] <Insert dimension> thick.
 - b. Polyolefin: [**2 inches (50 mm)**] <Insert dimension> thick.

- I. Heat-Recovery Piping:
 1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**2 inches (50 mm)**] <Insert dimension> thick.
 - b. Flexible Elastomeric: [**2 inches (50 mm)**] <Insert dimension> thick.
 - c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches (50 mm)**] <Insert dimension> thick.
 - d. Phenolic: [**2 inches (50 mm)**] <Insert dimension> thick.
 - e. Polyisocyanurate: [**2 inches (50 mm)**] <Insert dimension> thick.
 - f. Polyolefin: [**2 inches (50 mm)**] <Insert dimension> thick.
 - g. Polystyrene: [**2 inches (50 mm)**] <Insert dimension> thick.

- J. Dual-Service Heating and Cooling:
 1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**3 inches (75 mm)**] <Insert dimension> thick.
 - b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches (50 mm)**] <Insert dimension> thick.
 - c. Phenolic: [**2 inches (50 mm)**] <Insert dimension> thick.
 - d. Polyisocyanurate: [**2 inches (50 mm)**] <Insert dimension> thick.

K. Fuel Oil Piping, Heated:

1. All Pipe Sizes: Insulation shall be[**one of**] the following:
 - a. Cellular Glass: [**2 inches (50 mm)**] <Insert dimension> thick.
 - b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches (50 mm)**] <Insert dimension> thick.

3.21 OUTDOOR, UNDERGROUND PIPING INSULATION SCHEDULE

- A. Loose-fill insulation, for belowground piping, is specified in Section 232113.13 "Underground Hydronic Piping" and Section 336313 "Underground Steam and Condensate Distribution Piping."
- B. Chilled Water, All Sizes: Cellular glass, [**2 inches (50 mm)**] <Insert dimension> thick.
- C. Condenser-Water Supply and Return, All Sizes: Cellular glass, [**2 inches (50 mm)**] <Insert dimension> thick.
- D. Heating-Hot-Water Supply and Return, All Sizes, **200 Deg F (93 Deg C)** and Below: Cellular glass, [**3 inches (75 mm)**] <Insert dimension> thick.
- E. Heating-Hot-Water Supply and Return, All Sizes, above **200 Deg F (93 Deg C)**:
 1. Calcium Silicate: [**3 inches (75 mm)**] <Insert dimension> thick.
 2. Cellular Glass: [**3 inches (75 mm)**] <Insert dimension> thick.
- F. Steam and Steam Condensate, All Sizes, **350 Deg F (177 Deg C)** and Below:
 1. Calcium Silicate: [**4 inches (100 mm)**] <Insert dimension> thick.
 2. Cellular Glass: [**4 inches (100 mm)**] <Insert dimension> thick.
- G. Steam and Steam Condensate, All Sizes, above **350 Deg F (177 Deg C)**:
 1. Calcium Silicate: [**5 inches (125 mm)**] <Insert dimension> thick.
 2. Cellular Glass: [**5 inches (125 mm)**] <Insert dimension> thick.
- H. Dual-Service Heating and Cooling, All Sizes, **40 to 200 Deg F (4 to 93 Deg C)**: Cellular glass, [**3 inches (75 mm)**] <Insert dimension> thick.
- I. Fuel Oil Piping, All Sizes, Heated: Cellular glass, [**2 inches (50 mm)**] <Insert dimension> thick.

3.22 INDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Concealed:

1. None.
2. **[PVC]** [**PVC, Color-Coded by System**]: [**20 mils (0.5 mm)**] [**30 mils (0.8 mm)**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] [**0.032 inch (0.81 mm)**] [**0.040 inch (1.0 mm)**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] [**0.032 inch (0.81 mm)**] thick.
5. Stainless Steel, [**Type 304**] [or] [**Type 316**], [**Smooth 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch (0.25 mm)**] [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] thick.
6. <Insert jacket type>.

D. Piping, Exposed:

1. None.
2. **[PVC]** [**PVC, Color-Coded by System**]: [**20 mils (0.5 mm)**] [**30 mils (0.8 mm)**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] [**0.032 inch (0.81 mm)**] [**0.040 inch (1.0 mm)**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] [**0.032 inch (0.81 mm)**] thick.
5. Stainless Steel, [**Type 304**] [or] [**Type 316**], [**Smooth 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch (0.25 mm)**] [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] thick.
6. <Insert jacket type>.

3.23 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.
- C. Piping, Concealed:

1. None.
2. **[PVC]** [**PVC, Color-Coded by System**]: [**20 mils (0.5 mm)**] [**30 mils (0.8 mm)**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] [**0.032 inch (0.81 mm)**] [**0.040 inch (1.0 mm)**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch (0.41 mm)**] [**0.020 inch (0.51 mm)**] [**0.024 inch (0.61 mm)**] [**0.032 inch (0.81 mm)**]

- thick.
5. Stainless Steel, Type [304] [316] [304 or 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
 6. <Insert jacket type>.

D. Piping, Exposed:

1. PVC: [20 mils (0.5 mm)] [30 mils (0.8 mm)] [40 mils (1.0 mm)] thick.
2. [Painted]Aluminum, [Smooth] [Corrugated] [Stucco Embossed] [with Z-Shaped Locking Seam]: [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] [0.032 inch (0.81 mm)] [0.040 inch (1.0 mm)] thick.
3. Stainless Steel, Type [304] [316] [304 or 316], [Smooth 2B Finish] [Corrugated] [Stucco Embossed] [with Z-Shaped Locking Seam]: [0.010 inch (0.25 mm)] [0.016 inch (0.41 mm)] [0.020 inch (0.51 mm)] [0.024 inch (0.61 mm)] thick.
4. <Insert jacket type>.

3.24 UNDERGROUND, FIELD-INSTALLED INSULATION JACKET

- A. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230719

SECTION 230800 - COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes commissioning process requirements for HVAC&R systems, assemblies, and equipment.
- B. The purpose of this effort is to bring the project mechanical systems to a state of dynamic operation in accordance with the contract documents by verifying the operation of individual components, subsystems and systems.
- C. The Owner will retain the services of an independent commissioning agent (CA) separate from the work of this Contract. As herein specified the DEN Project Manager and CA shall develop detailed commissioning procedures, equipment checkout procedures and data forms for recording compliance with contract documents, performance and punch list deficiencies, and will assist in developing schedules for checkout and Owner acceptance, at a future date during the construction phase.
- D. The Division 23 Mechanical Contractor and the General Contractor shall include as part of the Work of this Contract, labor and material to provide manpower, equipment, tools, ladders, instruments, etc., necessary to accomplish the work and labor and material for execution, monitoring and printing data forms necessary to verify and record system observations.
- E. The Test and Balance Contractors shall include as part of the work of this contract, labor, and material to provide manpower, equipment, tools, ladders, instruments, etc. necessary to execute and accomplish the work.
- F. At the completion of the start-up, operations performance test and test and balance, the Contractor shall conduct a 72-hour dynamic mode demonstration of the systems in the presence of the DEN Project Manager and CA.
- G. Related Sections:
 - 1. Section 019113 "General Commissioning Requirements" for general commissioning process requirements.
- H. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

- I. Commissioned Equipment:
 - 1. Air Conditioning Units.
 - 2. Dry cooler Units, glycol pumps, and components.
 - 3. Packaged Rooftop Unit.
 - 4. Exhaust Fans (power Roof Ventilators).

- J. Commissioned Systems:
 - 1. Air Conditioning Units.
 - 2. Dry Cooler Units and glycol system.
 - 3. Packaged Roof Top Unit.
 - 4. Power Roof Ventilators (Exhaust Fans).

1.3 DEFINITIONS

- A. Commissioning Plan: A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the commissioning process.
- B. CA: Commissioning Authority.
- C. HVAC&R: Heating, Ventilating, Air Conditioning, and Refrigeration.
- D. Systems, Subsystems, Equipment, and Components: Where these terms are used together or separately, they shall mean "as-built" systems, subsystems, equipment, and components.

1.4 INFORMATIONAL SUBMITTALS

- A. Certificates of readiness.
- B. Certificates of completion of installation, prestart, and startup activities.

1.5 ALLOWANCES

- A. Labor, instrumentation, tools, and equipment costs for technicians for the performance of commissioning testing are covered by the "Schedule of Allowances" Article in Section 012100 "Allowances."

1.6 UNIT PRICES

- A. Commissioning testing allowance may be adjusted up or down by the "List of Unit Prices" Article in Section 012200 "Unit Prices" when actual man-hours are computed at the end of commissioning testing.

1.7 CONTRACTOR'S RESPONSIBILITIES

- A. Perform commissioning tests at the direction of the CA.
- B. Attend construction phase controls coordination meeting.
- C. Attend testing, adjusting, and balancing review and coordination meeting.
- D. Participate in HVAC&R systems, assemblies, equipment, and component maintenance orientation and inspection as directed by the CA.
- E. Provide information requested by the CA for final commissioning documentation.
- F. Provide measuring instruments and logging devices to record test data, and provide data acquisition equipment to record data for the complete range of testing for the required test period.

1.8 COMMISSIONING AGENT'S REQUIREMENTS AND RESPONSIBILITIES

- A. This Article covers the Scope of Work for the Commissioning Agent (CA) who will be hired by the Owner.
- B. Description of the Work:
 - 1. The Commissioning Agent shall oversee the commissioning of the HVAC systems as described in this Section. The CA shall prepare pre-commissioning and functional performance test checklists to be used by the Contractor. Prepare and publish a commissioning plan. Witness startup and operational tests of equipment and systems. Perform observations of the mechanical systems throughout construction and prepare the final commissioning document.
 - 2. The CA shall have authority to direct and schedule testing. The CA shall have no authority to direct changes to the systems.
- C. Commissioning Plan:
 - 1. The CA shall prepare a plan listing the parties involved with their responsibility, scope, definitions, safety concerns, design criteria, attendance schedules, commissioning schedules, and commissioning manual requirements.
- D. Commissioning Forms:
 - 1. Review 100% of CDs. Provide written summary of how each commissioned item of equipment should operate; include calculations verifying scheduled capacity.
 - 2. The CA shall develop forms similar to that in this Section for the Contractors use during the commissioning process. The forms shall become part of the final commissioning manual. Forms shall be provided for each piece of commissioned equipment and system. Any deviations from the design shall be noted and approved by the DEN Project Manager prior to acceptance. Each form shall be signed by the Contractor, CA, and DEN Project Manager prior to acceptance of a system or piece of equipment.

E. Commissioned Equipment:

1. All air-conditioning units as scheduled.
2. All split systems as scheduled.
3. All fans as scheduled.

F. Commissioned Systems:

1. All HVAC systems including the glycol system.

G. Project Observations:

1. The CA shall perform observations of construction progress for the equipment and systems to be commissioned twice a month at a minimum and more as required to keep pace with construction. The CA shall note progress and any deviations of the construction documents shall be brought to attention of the Contractor and DEN Project Manager for resolution. The CA will have no authority to direct changes or corrections to the system. Observation reports shall be published to the DEN Project Manager and Contractor and shall be part of the final commissioning manual.

H. Operational and Start-Up Tests:

1. The CA shall witness start-up tests and collect documentation of the tests. The CA shall notify the DEN Project Manager and Contractor of any deviations from the contract documents. Any deviations shall be corrected or accepted by the DEN Project Manager prior to acceptance.
2. After the Contractor has submitted in writing that the systems are completed, the CA shall schedule and direct operational tests of the systems. These tests shall be as described in this Section. The results shall be documented and made part of the commissioning manual. Any deviations from the design shall be brought to the attention of the DEN Project Manager and Contractor. Any deviations shall be corrected or accepted by the DEN Project Manager prior to acceptance.

I. Commissioning Manual:

1. The CA shall prepare the final commissioning manual. The manual shall provide a complete history of the commissioning process and shall include:
 - a. Design and Energy Codes.
 - b. Commissioning Plan.
 - c. Completed Commissioning Forms.
 - d. Completed Observation Reports.
 - e. Completed Start-up Reports.
 - f. System Operational Tests.
 - g. Final sequence of operation to be achieved.
 - h. Summary of building operation as commissioned, noting deviations from design.
 - i. Design Criteria (extended from Design Documents by CA).
 - j. Written summary of normal startup and operating procedures for each

- commissioned item of equipment.
- k. The manual shall be a three ring binder with tabs for each section. Provide five (5) copies.

1.9 COMMISSIONING DOCUMENTATION

- A. Provide the following information to the CA for inclusion in the commissioning plan:
1. Plan for delivery and review of submittals, systems manuals, and other documents and reports.
 2. Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.
 3. Process and schedule for completing construction checklists and manufacturer's prestart and startup checklists for HVAC&R systems, assemblies, equipment, and components to be verified and tested.
 4. Certificate of completion certifying that installation, prestart checks, and startup procedures have been completed.
 5. Certificate of readiness certifying that HVAC&R systems, subsystems, equipment, and associated controls are ready for testing.
 6. Test and inspection reports and certificates.
 7. Corrective action documents.
 8. Verification of testing, adjusting, and balancing reports.

PART 2 - PRODUCTS

2.1 MATERIALS, LABOR, INSTRUMENTS, TOOLS, LADDERS AND APPARATUS

- A. The Contractor shall provide all materials, labor, instruments, tools, ladders, and apparatus necessary to start-up, perform operating performance test and systems conditioning.
- B. The Contractor shall be responsible for maintaining the commissioning documentation until final acceptance of the Project. The checklists in appendix one are samples for bidding purposes. Final checklists will be produced by the CA and provided prior to beginning commissioning. The commissioning documentation shall be kept current by the Contractor and shall be available for inspection at all times. At the time of acceptance of the Project, the Contractor shall surrender three (3) completed copies of the commissioning documentation to the DEN Project Manager.

PART 3 - EXECUTION

3.1 TESTING PREPARATION

- A. Before request for contract compliance inspection and system commissioning all equipment, components, and systems shall be started-up, adjusted, calibrated; set, test and check all electric disconnect, fuses, circuit breakers, valves, dampers,

temperatures and pressures of all systems for proper operation and performance. After completion of the start-up and operating performance test, the Contractor will notify the Owner in writing that the system is ready for commissioning.

B. Information, date, etc. from start-up and operating performance test may be utilized, as appropriate, to execute preliminary commissioning documentation, however, certification of equipment and systems for the preliminary commissioning phase shall be completed in accordance with the following Article of this section of the specifications.

1. Start-up and operating performance test documentation shall include the following:

a. Rooftop Air Handling Unit Systems:

- 1) Coil entering and leaving air temperature.
- 2) Coil entering and leaving water temperature.
- 3) Space temperatures at thermostats or sensors.
- 4) Total fan air CFM.
- 5) Selected airflow readings at major branch ducts and grilles.
- 6) Fan speed.
- 7) Fan total static pressure.

b. Air Conditioning Unit Systems:

- 1) Coil entering and leaving air temperature.
- 2) Space temperatures at thermostats or sensors.
- 3) Total fan air CFM.
- 4) Selected airflow readings at major branch ducts and grilles.
- 5) Fan speed.
- 6) Fan total static pressure.

c. Exhaust Fans:

- 1) Total fan CFM.
- 2) Fan speed.
- 3) Fan total static pressure.

d. Electric Motors:

- 1) Full load amperes and voltage.
- 2) Starter heater size and rated amperage range for heater installed.
- 3) Measure running current, after adjustment of system to deliver rated performance.

e. Controls:

- 1) Operational setting of controllers and instruments.
- 2) Positioning and function of valves and dampers.
- 3) Interlock and operation of systems (HVAC and Fire).

f. Glycol System:

- 1) Compressor safety and operating controls.
- 2) Capacity reduction controls.
- 3) Low ambient controls.
- 4) Condenser fan operation.

- C. Certify that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.
- D. Certify that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.
- E. Certify that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.
- F. Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
- G. Inspect and verify the position of each device and interlock identified on checklists.
- H. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.
- I. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the CA.

3.2 TESTING AND BALANCING VERIFICATION

- A. Prior to performance of testing and balancing Work, provide copies of reports, sample forms, checklists, and certificates to the CA.
- B. Notify the CA at least [10] <Insert number> days in advance of testing and balancing Work, and provide access for the CA to witness testing and balancing Work.
- C. Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems at the direction of the CA.
 1. The CA will notify testing and balancing [Contractor] [Subcontractor] [10] <Insert number> days in advance of the date of field verification. Notice will not include data points to be verified.
 2. The testing and balancing [Contractor] [Subcontractor] shall use the same instruments (by model and serial number) that were used when original data were collected.
 3. Failure of an item includes, other than sound, a deviation of more than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a

deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.

4. Remedy the deficiency and notify the CA so verification of failed portions can be performed.

3.3 SYSTEM COMMISSIONING

- A. All systems, components, equipment, etc., furnished as part of this Contract shall be subjected to system commissioning as hereinafter specified. All systems, components, equipment, etc., commissioned In this section of the Specifications shall be evaluated based on the sequences of control/operation, performance characteristics, and equipment schedules, etc., as specified in other sections of the Specifications and as shown on the Contract drawings. Systems, components, equipment, etc., that do not have specified operating sequence, etc., shall be operated and evaluated based on their use and function for this project.
- B. Commissioning Documentation: The Contractor shall maintain the commissioning documentation in 3-ring binders. The commissioning documentation shall be organized by system when practicable. All pages shall be numbered and a table of contents page shall be provided. The commissioning documentation shall include, but not be limited to, the following:
 1. Design Criteria provided by the A/E.
 2. Approved Test and Balance Report for the system or component being commissioned, provided by Test and Balance Contractor.
 3. Approved submittals for all equipment to be commissioned, provided by Mechanical Contractor.
 4. All approved shop drawings of equipment to be commissioned. Shop drawings shall be full size sheets folded as required to fit in binders. Provided by Mechanical Contractor.
 5. All pre-commissioning checklists initialized by indicated personnel organized by system and subsystem.
 6. All functional performance test checklist initialized by indicated personnel organized by systems and subsystems.
 7. Three copies of the Operation and Maintenance Manuals specified in other sections of these specifications shall be reviewed by the CA for completeness and for applicability. The manuals shall be incorporated in the Commissioning Documentation prior to the commencement of the training required in other sections of the specifications. Preparation of Operation and Maintenance Manuals shall be as specified in other sections of these specifications.
- C. Shop Drawings and As-Built Drawings and Specifications shall be assembled by the Contractor after completion of the pre-commissioning phase and turned over to the DEN Project Manager. Changes as a result of subsequent Commissioning procedures will be incorporated (as required) at the conclusion of final Commissioning.
- D. Commissioning Schedule:
 1. Phase 1 - Preliminary Commissioning: All shop drawings, including but not

- limited to, equipment, controls, test and balance reports, and operation and maintenance manuals, shall be submitted and approved by the CA. In addition, all pre-commissioning checklists shall be completed and initialed by all parties.
2. Phase 2 - Functional Performance Testing: Functional Performance Testing shall be performed as indicated on the Functional Performance Test Checklists. Functional Performance Testing shall not begin until Phase 1 of the commissioning process is complete. Owner's operation and maintenance personnel shall observe the function performance testing. The Contractor may perform initial system familiarization and training of Owner's operating and maintenance personnel required under other sections of the Specification during the functional performance testing.
 3. Functional Performance Test Notification: The Contractor shall notify the CA two (2) weeks before functional performance testing is to begin.
 4. Phase 3 - System training and operating instructions shall be conducted by the Contractor as indicated in the specifications of each item of equipment. The Contractor shall be responsible for specified training and operating instructions being observed by the CA

E. Pre-Commissioning Checklists:

1. Pre-Commissioning Checklists shall be developed by the CA and shall be executed and certified prior to the commencement of functional performance testing. The indicated initial is required in each location for all items, except where an "X" is shown indicating an initial is not required. See initials legend below for required initials. The pre-commissioning checklist will not be accepted as complete until all items have been initialed signifying this portion of the project is ready for Functional Performance Testing. The Contractor shall provide the CA with the completed Pre-Commissioning Checklists for his review and initials. The CA shall be the last person to initial each checklist item. The Contractor shall submit for approval a list of all contractor and subcontractor representatives responsible for the completion of the pre-commissioning checklist phase of the project. This list of representatives shall be submitted two (2) weeks prior to commencement of any pre-commissioning activities of any systems or equipment. Representatives may be replaced only after written approval from the CA.
2. Initials Legend:
 - a. Construction Manager.
 - b. Mechanical Contractor's representative.
 - c. Electrical Contractor' s representative.
 - d. Commissioning Agent.
 - e. Balancing Contractor's representative.
 - f. Controls Contractor's representative.
3. Blank Example Pre-Commissioning Checklists are in Appendix, located at the end of this Section of the specifications. A separate Pre-Commissioning checklist shall be provided for each system and piece of HVAC equipment to be Commissioned.

F. Functional Performance Test Checklist:

1. Functional performance testing shall be performed by the Contractor as directed by the CA and observed by a commissioning team consisting of the individuals indicated on the Functional Performance Test Checklists. The Contractor shall submit in writing a list of all contractor and subcontractor representatives responsible for the functional performance testing phase of the project. This list of representatives shall be submitted two (2) weeks prior to the commencement of functional performance testing of systems and equipment. All representatives shall remain on the commissioning team throughout functional performance testing. Substitutions will not be permitted. Functional performance test checklists shall be completed in the presence of all commissioning team personnel at the time of the functional performance test.
2. Upon failure of completion of a functional performance test checklist, the Contractor shall provide a written report to the CA listing the deficiencies causing the failure and remedies to correct all deficiencies. After the Contractor has corrected all deficiencies, the entire functional performance test checklist for the item of equipment shall be repeated. If possible, corrections can be accomplished during the functional performance testing of equipment in other non-related systems. In any case, no system will be accepted until all equipment items in the system have complete functional performance test checklists thereby demonstrating satisfactory performance.
3. Failure to complete 2 functional performance test checklists constitutes failure of Phase 2 of the HVAC Commissioning process. The Contractor shall provide a written report to the CA listing the deficiencies causing all failures and remedies to correct all deficiencies. After correction of all deficiencies, Phase 2 of the HVAC Commissioning process shall be repeated in its entirety. The Contractor shall give the CA two (2) weeks notice before repeat functional performance testing is scheduled. Should the first or one subsequent functional performance test fail, the Owner reserves the right to obtain compensation from the Contractor for fees and expenses incurred in conjunction with having to perform more than two (2) functional performance tests.
4. Blank examples functional performance test checklists are in the Appendix 2 located at the end of this section of the specifications. A separate Functional Performance Checklist shall be provided for each system and piece of equipment to be Commissioned.

3.4 DEMONSTRATION TEST

- A. After completion of system start-up, operating performance test and commissioning, but before Owner acceptance, the Contractor shall conduct a 72 hour dynamic mode demonstration of the systems provided under this Contract. The intent of the 72 hour dynamic test is to verify that the mechanical and electrical equipment will respond as designed to meet the changes that may occur under varying indoor/outdoor conditions including seasonal variations and occupancy loads.
- B. A detailed procedure and sequence of events shall be developed by the Contractor and submitted to the Owner and CA for review and approval. Procedures and sequence of events should contain as a minimum the following activities:
 1. Hours 1-4: Bring all systems on line for standard operations and parameters.

2. Hours 5-28: Operate all systems under normal parameters and verify proper operation.
 3. Hours 29-52: Validation of systems operation through indoor/outdoor changes to include heating, cooling, ventilation, humidity control, domestic and control systems.
 4. Hours 69-72: Return of systems to normal operation.
- C. Systems and their associated equipment which are to be included in the dynamic test are all systems and components furnished under this Contract and as a minimum will include, but are not limited to the following:
1. Pressurization Air Handling Systems.
 2. Air Handling Systems.
 3. Chilled Water Systems.
 4. Domestic Water Systems.
 5. Fan Coil Systems.
 6. Pumping Systems.
 7. Exhaust Systems.
 8. Air Filtration Systems.
 9. Building Management and Control Systems.
- D. Contractor shall notify the Owner and CA in writing that the Project is completed and ready for the demonstration test. Schedule for test will then be established and documented. Initiation of the 72 hours dynamic test will not occur until all systems are balanced, operational, and incorporated into the building management and control system. Should the demonstration test fail for any reason, the problems shall be corrected and another demonstration test conducted. Should the first or one subsequent demonstration test fail, the Owner reserves the right to obtain compensation from the Contractor for fees and expenses incurred in conjunction with having to witness more than two (2) 72 hour demonstration tests.
- E. The attendees of each 72 hour demonstration test shall include representative from the following organizations:
1. General Contractor.
 2. Mechanical Contractor.
 3. Electrical Contractor.
 4. Test and Balance Contractor.
 5. Building Management and Control System Contractor.
 6. DEN Project Manager of Record.
 7. Mechanical Engineer.
 8. Electrical Engineer.
 9. Commissioning Agent.
- F. Minor problems are anticipated and the necessary personnel required to correct problems and adjust systems need to be available to insure continuation of the dynamic testing process. If major problems are encountered, at the discretion of the Owner and CA, the testing will be terminated and rescheduled.
- G. The Contractor shall notify any external organizations, which would include but not be

limited to Fire Department which are not directly involved in the testing, but might be affected due to interface to insure that alarms do not occur.

- H. During the demonstration test, all systems shall operate in the "hands-off" automatic mode in accordance with the requirements of the Contract Documents. Changes in operating modes required to simulate load shifting, seasonal changeover, emergency modes, etc., will be accomplished by changing set points and equipment operating status at the BMS central control console as required to observe capacity control and monitoring. Provide a readout of space temperature at each thermostat building relative humidity, building pressurization, chilled water supply and return temperatures and chiller capacity.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 230800

SECTION 230900 - INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls.
- B. Related Sections include the following:
 - 1. Section 230519 "Meters and Gages for HVAC Piping" for measuring equipment that relates to this Section.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to this Section.

1.3 DEFINITIONS

- A. DDC: Direct digital control.
- B. I/O: Input/output.
- C. LonWorks: A control network technology platform for designing and implementing interoperable control devices and networks.
- D. MS/TP: Master slave/token passing.
- E. PC: Personal computer.
- F. PID: Proportional plus integral plus derivative.
- G. RTD: Resistance temperature detector.

1.4 SYSTEM PERFORMANCE

- A. Comply with the following performance requirements:

1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.
2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.
4. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
7. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
 - a. Water Temperature: Plus or minus 1 deg F (0.5 deg C).
 - b. Water Flow: Plus or minus 5 percent of full scale.
 - c. Water Pressure: Plus or minus 2 percent of full scale.
 - d. Space Temperature: Plus or minus 1 deg F (0.5 deg C).
 - e. Ducted Air Temperature: Plus or minus 1 deg F (0.5 deg C).
 - f. Outside Air Temperature: Plus or minus 2 deg F (1.0 deg C).
 - g. Dew Point Temperature: Plus or minus 3 deg F (1.5 deg C).
 - h. Temperature Differential: Plus or minus 0.25 deg F (0.15 deg C).
 - i. Relative Humidity: Plus or minus 5 percent.
 - j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
 - k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
 - l. Airflow (Terminal): Plus or minus 10 percent of full scale.
 - m. Air Pressure (Space): Plus or minus 0.01-inch wg (2.5 Pa).
 - n. Air Pressure (Ducts): Plus or minus 0.1-inch wg (25 Pa).
 - o. Carbon Monoxide: Plus or minus 5 percent of reading.
 - p. Carbon Dioxide: Plus or minus 50 ppm.
 - q. Electrical: Plus or minus 5 percent of reading.

1.5 SEQUENCE OF OPERATION

1.6 ACTION SUBMITTALS

- A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
 1. DDC System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors,

- actuators, valves, relays/switches, control panels, and operator interface equipment.
2. Control System Software: Include technical data for operating system software, operator interface, color graphics, and other third-party applications.
 3. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
1. Bill of materials of equipment indicating quantity, manufacturer, and model number.
 2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
 3. Wiring Diagrams: Power, signal, and control wiring.
 4. Details of control panel faces, including controls, instruments, and labeling.
 5. Written description of sequence of operation.
 6. Schedule of dampers including size, leakage, and flow characteristics.
 7. Schedule of valves including flow characteristics.
 8. DDC System Hardware:
 - a. Wiring diagrams for control units with termination numbers.
 - b. Schematic diagrams and floor plans for field sensors and control hardware.
 - c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
 9. Control System Software: List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, and operator notations.
 10. Controlled Systems:
 - a. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
 - b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
 - c. Written description of sequence of operation including schematic diagram.
 - d. Points list.
- C. Samples for Initial Selection: For each color required, of each type of thermostat[**or sensor**] cover with factory-applied color finishes.
- D. Samples for Verification: For each color required, of each type of thermostat[**or sensor**] cover.

1.7 INFORMATIONAL SUBMITTALS

- A. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with ASHRAE 135.
- B. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with LonWorks.
- C. Qualification Data: For **[Installer]** **[and]** **[manufacturer]**.
- D. Software Upgrade Kit: For Owner to use in modifying software to suit future systems revisions or monitoring and control revisions.
- E. Field quality-control test reports.

1.8 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - 1. Maintenance instructions and lists of spare parts for each type of control device and compressed air station.
 - 2. Interconnection wiring diagrams with identified and numbered system components and devices.
 - 3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
 - 4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
 - 5. Calibration records and list of set points.
- B. Software and Firmware Operational Documentation: Include the following:
 - 1. Software operating and upgrade manuals.
 - 2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
 - 3. Device address list.
 - 4. Printout of software application and graphic screens.
 - 5. Software license required by and installed for DDC workstations and control systems.

1.9 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Replacement Materials: One replacement diaphragm or relay mechanism for each unique [pneumatic damper motor] [valve motor] [controller] [thermostat] [positioning relay].
2. Maintenance Materials: [One] <Insert number required> thermostat adjusting key(s).
3. Maintenance Materials: One pneumatic thermostat test kit.

1.10 QUALITY ASSURANCE

- A. Installer Qualifications: Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this Project.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Comply with ASHRAE 135 for DDC system components.

1.11 DELIVERY, STORAGE, AND HANDLING

- A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.
- B. System Software: Update to latest version of software at Project completion.

1.12 COORDINATION

- A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.
- B. Coordinate equipment with Section 281600 "Intrusion Detection" to achieve compatibility with equipment that interfaces with that system and with building master clock.
- C. Coordinate equipment with Section 281300 "Access Control" to achieve compatibility with equipment that interfaces with that system.
- D. Coordinate equipment with Section 275313 "Clock Systems" to achieve compatibility with equipment that interfaces with that system.
- E. Coordinate equipment with Section 284619 "PLC Electronic Detention Monitoring and Control Systems" to achieve compatibility with equipment that interfaces with that system.

- F. Coordinate equipment with Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls" to achieve compatibility with equipment that interfaces with that system.
- G. Coordinate equipment with Section 283111 "Digital, Addressable Fire-Alarm System" and Section 283112 "Zoned (DC Loop) Fire-Alarm System" to achieve compatibility with equipment that interfaces with that system.
- H. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.
- I. Coordinate equipment with Section 260913 "Electrical Power Monitoring and Control" to achieve compatibility of communication interfaces.
- J. Coordinate equipment with Section 262416 "Panelboards" to achieve compatibility with starter coils and annunciation devices.
- K. Coordinate equipment with Section 262419 "Motor-Control Centers" to achieve compatibility with motor starters and annunciation devices.
- L. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 033000 "Cast-in-Place Concrete."

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
 - 1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.
 - 2. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2 CONTROL SYSTEM

- A. **[Available]**Manufacturers:
 - 1. [Alerton Inc.](#)
 - 2. [American Auto-Matrix.](#)
 - 3. [Andover Controls Corporation.](#)
 - 4. [Automated Logic Corporation.](#)
 - 5. [Carel.](#)
 - 6. [Delta Controls Inc.](#)
 - 7. [EDA Controls Corp.](#)

8. [Electronic Systems USA, Inc.](#)
 9. [Functional Devices Inc.](#)
 10. [Heat-Timer Corporation.](#)
 11. [Honeywell International Inc.: Home & Building Control.](#)
 12. [Impact Energy Controls Corp.](#)
 13. [Invensys Building Systems.](#)
 14. [Johnson Controls, Inc.: Controls Group.](#)
 15. [KMC Controls/Kreuter Manufacturing Company.](#)
 16. [Luwa USA, Inc.: Textile Air Engineering.](#)
 17. [MAMAC Systems, Inc.](#)
 18. [McQuay International.](#)
 19. [Pneuline Controls.](#)
 20. [Sauter Controls Corporation.](#)
 21. [Siemens Building Technologies, Inc.](#)
 22. [Solidyne Corp.](#)
 23. [Spence Engineering Company, Inc.](#)
 24. [Staefa Control System Inc.; Siemens Building Technologies, Inc.](#)
 25. [TAC Americas, INC.](#)
 26. [TCS/Basys Controls.](#)
 27. [tekmar Control Systems, Inc.](#)
 28. [Teletrol Systems Incorporated.](#)
 29. [Temco Controls Ltd. USA.](#)
 30. [Tour & Andersson Control, Inc.](#)
 31. [Trane; Worldwide Applied Systems Group](#)
 32. [Triangle MicroSystems, Inc.](#)
 33. [Voltec, Inc.](#)
 34. **<Insert manufacturer's name.>**
- B. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories to control mechanical systems.
- C. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on token-passing network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.
- D. Control system shall include the following:
1. Building intrusion detection system specified in Section 281600 "Intrusion Detection."
 2. Building clock control system specified in Section 275313 "Clock Systems."
 3. Building lighting control system specified in Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls."
 4. Fire alarm system specified in Section 283111 "Digital, Addressable Fire-Alarm System" and Section 283112 "Zoned (DC Loop) Fire-Alarm System."

2.3 DDC EQUIPMENT

- A. Operator Workstation: **[One]** **[Two]** **<Insert number>** PC-based microcomputer(s) with minimum configuration as follows:
1. Motherboard: With 8 integrated USB 2.0 ports, integrated Intel Pro 10/100 (Ethernet), integrated audio, bios, and hardware monitoring.
 2. Processor: **[Intel Pentium 4]** **<Insert name>**, **<Insert clock speed>** MHz.
 3. Random-Access Memory: **[512]** **<Insert number>** MB.
 4. Graphics: Video adapter, minimum **[1280 x 1024]** **[1600 x 1200]** **<Insert value>** pixels, **[64]** **<Insert number>**-MB video memory, with TV out.
 5. Monitor: **[17 inches (430 mm)]** **[19 inches (480 mm)]** **<Insert size>**, LCD color.
 6. Keyboard: QWERTY, 105 keys in ergonomic shape.
 7. Floppy-Disk Drive: 1.44 MB.
 8. Hard-Disk Drive: **[80 GB]** **<Insert capacity>**.
 9. CD-ROM Read/Write Drive: **[48x24x48]** **<Insert value>**.
 10. Mouse: Three button, optical.
 11. Uninterruptible Power Supply: **[2]** **<Insert capacity>** kVa.
 12. Operating System: **[Microsoft Windows XP Professional]** **<Insert system name>** with high-speed Internet access.
 - a. ASHRAE 135 Compliance: Workstation shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
 - b. LonWorks Compliance: Control units shall use LonTalk protocol and communicate using EIA/CEA 709.1 datalink/physical layer protocol.
 13. Printer: Black-and-white, laser-jet type as follows:
 - a. Print Head: **[1200 x 1200]** **<Insert value>** dpi resolution.
 - b. Paper Handling: Minimum of **[250]** **<Insert number>** sheet trays.
 - c. Print Speed: Minimum of **[120]** **<Insert number>** characters per second.
 14. Printer: Color, ink-jet type as follows:
 - a. Print Head: **[4800 x 1200]** **<Insert value>** dpi optimized color resolution.
 - b. Paper Handling: Minimum of **[100]** **<Insert number>** sheets.
 - c. Print Speed: Minimum of **[17]** **<Insert number>** ppm in black and **[12]** **<Insert number>** ppm in color.
 15. Application Software:
 - a. I/O capability from operator station.
 - b. System security for each operator via software password and access levels.
 - c. Automatic system diagnostics; monitor system and report failures.
 - d. Database creation and support.
 - e. Automatic and manual database save and restore.
 - f. Dynamic color graphic displays with up to **[10]** **<Insert number>** screen displays at once.

- g. Custom graphics generation and graphics library of HVAC equipment and symbols.
- h. Alarm processing, messages, and reactions.
- i. Trend logs retrievable in spreadsheets and database programs.
- j. Alarm and event processing.
- k. Object and property status and control.
- l. Automatic restart of field equipment on restoration of power.
- m. Data collection, reports, and logs. Include standard reports for the following:
 - 1) Current values of all objects.
 - 2) Current alarm summary.
 - 3) Disabled objects.
 - 4) Alarm lockout objects.
 - 5) Logs.
- n. Custom report development.
- o. Utility and weather reports.
- p. Workstation application editors for controllers and schedules.
- q. Maintenance management.

16. Custom Application Software:

- a. English language oriented.
- b. Full-screen character editor/programming environment.
- c. Allow development of independently executing program modules with debugging/simulation capability.
- d. Support conditional statements.
- e. Support floating-point arithmetic with mathematic functions.
- f. Contains predefined time variables.

B. Diagnostic Terminal Unit: Portable notebook-style, PC-based microcomputer terminal capable of accessing system data by connecting to system network with minimum configuration as follows:

1. System: With one integrated USB 2.0 port, integrated Intel Pro 10/100 (Ethernet), integrated audio, bios, and hardware monitoring.
2. Processor: [**Intel Pentium 4**] <Insert name>, <Insert clock speed> MHz.
3. Random-Access Memory: [**128**] <Insert number> MB.
4. Graphics: Video adapter, minimum [**800 x 600**] [**1024 x 768**] <Insert value> pixels, [**64**] <Insert number>-MB video memory.
5. Monitor: [**17 inches** (430 mm)] [**19 inches** (480 mm)] <Insert size>, LCD color.
6. Keyboard: QWERTY 105 keys in ergonomic shape.
7. Floppy-Disk Drive: 1.44 MB.
8. Hard-Disk Drive: [**800 MB**] <Insert capacity>.
9. CD-ROM Read/Write Drive: [**48x24x48**] <Insert value>.
10. Pointing Device: Touch pad or other internal device.

C. Control Units: Modular, comprising processor board with programmable, nonvolatile, random-access memory; local operator access and display panel; integral interface equipment; and backup power source.

1. Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation or diagnostic terminal unit.
 2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
 - a. Global communications.
 - b. Discrete/digital, analog, and pulse I/O.
 - c. Monitoring, controlling, or addressing data points.
 - d. Software applications, scheduling, and alarm processing.
 - e. Testing and developing control algorithms without disrupting field hardware and controlled environment.
 3. Standard Application Programs:
 - a. Electric Control Programs: Demand limiting, duty cycling, automatic time scheduling, start/stop time optimization, night setback/setup, on-off control with differential sequencing, staggered start, antishort cycling, PID control, DDC with fine tuning, and trend logging.
 - b. HVAC Control Programs: Optimal run time, supply-air reset, and enthalpy switchover.
 - c. Chiller Control Programs: Control function of condenser-water reset, chilled-water reset, and equipment sequencing.
 - d. Programming Application Features: Include trend point; alarm processing and messaging; weekly, monthly, and annual scheduling; energy calculations; run-time totalization; and security access.
 - e. Remote communications.
 - f. Maintenance management.
 - g. Units of Measure: Inch-pound and SI (metric).
 4. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.
 5. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
 6. LonWorks Compliance: Control units shall use LonTalk protocol and communicate using EIA/CEA 709.1 datalink/physical layer protocol.
- D. Local Control Units: Modular, comprising processor board with electronically programmable, nonvolatile, read-only memory; and backup power source.
1. Units monitor or control each I/O point, process information, and download from or upload to operator workstation or diagnostic terminal unit.
 2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
 - a. Global communications.
 - b. Discrete/digital, analog, and pulse I/O.
 - c. Monitoring, controlling, or addressing data points.

3. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.
 4. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
 5. LonWorks Compliance: Control units shall use LonTalk protocol and communicate using EIA/CEA 709.1 datalink/physical layer protocol.
- E. I/O Interface: Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.
1. Binary Inputs: Allow monitoring of on-off signals without external power.
 2. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
 3. Analog Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20 mA), or resistance signals.
 4. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation[**with three-position (on-off-auto) override switches and status lights**].
 5. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA)[**with status lights, two-position (auto-manual) switch, and manually adjustable potentiometer**].
 6. Tri-State Outputs: Provide two coordinated binary outputs for control of three-point, floating-type electronic actuators.
 7. Universal I/Os: Provide software selectable binary or analog outputs.
- F. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:
1. Output ripple of 5.0 mV maximum peak to peak.
 2. Combined 1 percent line and load regulation with 100-mic.sec. response time for 50 percent load changes.
 3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.
- G. Power Line Filtering: Internal or external transient voltage and surge suppression for workstations or controllers with the following:
1. Minimum dielectric strength of 1000 V.
 2. Maximum response time of 10 nanoseconds.
 3. Minimum transverse-mode noise attenuation of 65 dB.
 4. Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

2.4 UNITARY CONTROLLERS

- A. Unitized, capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.

1. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip or card connected with ribbon cable; memory with bios; and [72] <Insert number>-hour battery backup.
2. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms. **[Perform scheduling with real-time clock.]** Perform automatic system diagnostics; monitor system and report failures.
3. ASHRAE 135 Compliance: Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
4. LonWorks Compliance: Communicate using EIA/CEA 709.1 datalink/physical layer protocol using LonTalk protocol.
5. Enclosure: Dustproof rated for operation at 32 to 120 deg F (0 to 50 deg C).
6. Enclosure: Waterproof rated for operation at 40 to 150 deg F (5 to 65 deg C).

2.5 ALARM PANELS

- A. Unitized cabinet with suitable brackets for wall or floor mounting. Fabricate of 0.06-inch- (1.5-mm-) thick, furniture-quality steel or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with manufacturer's standard shop-painted finish. **[Provide common keying for all panels.]**
- B. Indicating light for each alarm point, single horn, acknowledge switch, and test switch, mounted on hinged cover.
 1. Alarm Condition: Indicating light flashes and horn sounds.
 2. Acknowledge Switch: Horn is silent and indicating light is steady.
 3. Second Alarm: Horn sounds and indicating light is steady.
 4. Alarm Condition Cleared: System is reset and indicating light is extinguished.
 5. Contacts in alarm panel allow remote monitoring by independent alarm company.

2.6 ANALOG CONTROLLERS

- A. Step Controllers: 6- or 10-stage type, with heavy-duty switching rated to handle loads and operated by electric motor.
- B. Electric, Outdoor-Reset Controllers: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range, adjustable set point, scale range minus 10 to plus 70 deg F (minus 23 to plus 21 deg C), and single- or double-pole contacts.
- C. Electronic Controllers: Wheatstone-bridge-amplifier type, in steel enclosure with provision for remote-resistance readjustment. Identify adjustments on controllers, including proportional band and authority.

1. Single controllers can be integral with control motor if provided with accessible control readjustment potentiometer.
- D. Fan-Speed Controllers: Solid-state model providing field-adjustable proportional control of motor speed from maximum to minimum of 55 percent and on-off action below minimum fan speed. Controller shall briefly apply full voltage, when motor is started, to rapidly bring motor up to minimum speed. Equip with filtered circuit to eliminate radio interference.
- E. Receiver Controllers: Single- or multiple-input models with control-point adjustment, direct or reverse acting with mechanical set-point adjustment with locking device, proportional band adjustment, authority adjustment, and proportional control mode.
 1. Remote-control-point adjustment shall be plus or minus 20 percent of sensor span, input signal of 3 to 13 psig (21 to 90 kPa).
 2. Proportional band shall extend from 2 to 20 percent for 5 psig (35 kPa).
 3. Authority shall be 20 to 200 percent.
 4. Air-supply pressure of 18 psig (124 kPa), input signal of 3 to 15 psig (21 to 103 kPa), and output signal of zero to supply pressure.
 5. Gages: [1-1/2 inches (38 mm)] [2-1/2 inches (64 mm)] [3-1/2 inches (89 mm)] in diameter, 2.5 percent wide-scale accuracy, and range to match transmitter input or output pressure.

2.7 TIME CLOCKS

- A. **[Available]Manufacturers:**
 1. [ATC-Diversified Electronics.](#)
 2. [Grasslin Controls Corporation.](#)
 3. [Paragon Electric Co., Inc.](#)
 4. [Precision Multiple Controls, Inc.](#)
 5. [SSAC Inc.; ABB USA.](#)
 6. [TCS/Basys Controls.](#)
 7. [Theben AG - Lumilite Control Technology, Inc.](#)
 8. [Time Mark Corporation.](#)
 9. **<Insert manufacturer's name.>**
- B. Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
- C. Solid-state, programmable time control with [4] [8] **<Insert number>** separate programs each with up to 100 on-off operations; 1-second resolution; lithium battery backup; keyboard interface and manual override; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; system fault alarm; and communications package allowing networking of time controls and programming from PC.

2.8 ELECTRONIC SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Thermistor Temperature Sensors and Transmitters:

1. **[Available]Manufacturers:**

- a. [BEC Controls Corporation.](#)
- b. [Ebtron, Inc.](#)
- c. [Heat-Timer Corporation.](#)
- d. [I.T.M. Instruments Inc.](#)
- e. [MAMAC Systems, Inc.](#)
- f. [RDF Corporation.](#)
- g. **<Insert manufacturer's name.>**

2. Accuracy: Plus or minus [0.5 deg F (0.3 deg C)] [0.36 deg F (0.2 deg C)] at calibration point.

3. Wire: Twisted, shielded-pair cable.

4. Insertion Elements in Ducts: Single point, [8 inches (200 mm)] [18 inches (460 mm)] long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft. (0.84 sq. m).

5. Averaging Elements in Ducts: [36 inches (915 mm) long, flexible] [72 inches (1830 mm) long, flexible] [18 inches (460 mm) long, rigid]; use where prone to temperature stratification or where ducts are larger than 10 sq. ft. (1 sq. m).

6. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 2-1/2 inches (64 mm).

7. Room Sensor Cover Construction: Manufacturer's standard locking covers.

- a. Set-Point Adjustment: [Concealed] [Exposed].
- b. Set-Point Indication: [Concealed] [Keyed] [Exposed].
- c. Thermometer: [Concealed] [Exposed] [Red-reading glass] [Spiral bimetal].
- d. Color: **<Insert color from manufacturer's full range.>**
- e. Orientation: [Vertical] [Horizontal].

8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.

9. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.

C. RTDs and Transmitters:

1. **[Available]Manufacturers:**

- a. [BEC Controls Corporation.](#)
- b. [MAMAC Systems, Inc.](#)
- c. [RDF Corporation.](#)
- d. **<Insert manufacturer's name.>**

2. Accuracy: Plus or minus 0.2 percent at calibration point.
 3. Wire: Twisted, shielded-pair cable.
 4. Insertion Elements in Ducts: Single point, [8 inches (200 mm)] [18 inches (460 mm)] long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft. (0.84 sq. m).
 5. Averaging Elements in Ducts: [18 inches (460 mm) long, rigid] [24 inches (610 mm) long, rigid] [48 inches (1200 mm) long, rigid] [24 feet (7.3 m) long, flexible]; use where prone to temperature stratification or where ducts are larger than 9 sq. ft. (0.84 sq. m); length as required.
 6. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches (64 mm).
 7. Room Sensor Cover Construction: Manufacturer's standard locking covers.
 - a. Set-Point Adjustment: [Concealed] [Exposed].
 - b. Set-Point Indication: [Concealed] [Keyed] [Exposed].
 - c. Thermometer: [Concealed] [Exposed] [Red-reading glass] [Spiral bimetal].
 - d. Color: <Insert color from manufacturer's full range.>
 - e. Orientation: [Vertical] [Horizontal].
 8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
 9. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
- D. Humidity Sensors: Bulk polymer sensor element.
1. [Available]Manufacturers:
 - a. [BEC Controls Corporation.](#)
 - b. [General Eastern Instruments.](#)
 - c. [MAMAC Systems, Inc.](#)
 - d. [ROTRONIC Instrument Corp.](#)
 - e. [TCS/Basys Controls.](#)
 - f. [Vaisala.](#)
 - g. <Insert manufacturer's name.>
 2. Accuracy: [5] [2] percent full range with linear output.
 3. Room Sensor Range: 20 to 80 percent relative humidity.
 4. Room Sensor Cover Construction: Manufacturer's standard locking covers.
 - a. Set-Point Adjustment: [Concealed] [Exposed].
 - b. Set-Point Indication: [Concealed] [Keyed] [Exposed].
 - c. Thermometer: [Concealed] [Exposed] [Red-reading glass] [Spiral bimetal].
 - d. Color: <Insert color from manufacturer's full range.>
 - e. Orientation: [Vertical] [Horizontal].
 5. Duct Sensor: 20 to 80 percent relative humidity range with element guard and mounting plate.

6. Outside-Air Sensor: 20 to 80 percent relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of [32 to 120 deg F (0 to 50 deg C)] [minus 22 to plus 185 deg F (minus 30 to plus 85 deg C)] [minus 40 to plus 170 deg F (minus 40 to plus 76 deg C)].
 7. Duct and Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.
- E. Pressure Transmitters/Transducers:
1. **[Available]Manufacturers:**
 - a. [BEC Controls Corporation.](#)
 - b. [General Eastern Instruments.](#)
 - c. [MAMAC Systems, Inc.](#)
 - d. [ROTRONIC Instrument Corp.](#)
 - e. [TCS/Basys Controls.](#)
 - f. [Vaisala.](#)
 - g. <Insert manufacturer's name.>
 2. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
 - a. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
 - b. Output: 4 to 20 mA.
 - c. Building Static-Pressure Range: 0- to 0.25-inch wg (0 to 62 Pa).
 - d. Duct Static-Pressure Range: 0- to 5-inch wg (0 to 1240 Pa).
 3. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig (1034-kPa) operating pressure; linear output 4 to 20 mA.
 4. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig (1034-kPa) operating pressure and tested to 300-psig (2070-kPa); linear output 4 to 20 mA.
 5. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.
 6. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4 to 20 mA.
- F. Room Sensor Cover Construction: Manufacturer's standard locking covers.
1. Set-Point Adjustment: **[Concealed] [Exposed]**.
 2. Set-Point Indication: **[Concealed] [Keyed] [Exposed]**.
 3. Thermometer: **[Concealed] [Exposed] [Red-reading glass] [Spiral bimetal]**.
 4. Color: <Insert color from manufacturer's full range.>
 5. Orientation: **[Vertical] [Horizontal]**.
- G. Room sensor accessories include the following:
1. Insulating Bases: For sensors located on exterior walls.

2. Guards: [**Locking; heavy-duty, transparent plastic; mounted on separate base**] [**Metal wire, tamperproof**] [**Locking, solid metal, ventilated**].
3. Adjusting Key: As required for calibration and cover screws.

2.9 PNEUMATIC SENSORS

A. Pneumatic Transmitters: Vibration and corrosion resistant.

1. Space-Temperature Sensors: Linear-output type, **50 to 100 deg F** (10 to 38 deg C) range, with blank locking covers matching room thermostats.
2. Room Return-Air Temperature Sensors: Linear-output type with bimetal sensing element and corrosion-proof construction, **50 to 100 deg F** (10 to 38 deg C) range, designed to be mounted in light troffers.
3. Duct-Mounted or Immersion-Type Temperature Sensors: Range as required for **3- to 15-psig** (21- to 103-kPa) output signal.
4. Temperature Transmitters: Rigid-stem type with bimetal sensing elements unless averaging is required, **3- to 15-psig** (21- to 103-kPa) output signal.
 - a. Averaging-Element Sensors: Single- or multiple-unit capillary elements.
 - b. Tamperproof Sensors: Corrosion-resistant construction, suitable for mounting on vibrating surface with exposed capillary protected with temperature-compensated armor or protective tubing.
 - c. Pipe-Mounted Temperature-Sensing Elements: Rod-and-tube type; with separable wells filled with heat-conductive compound.
 - d. Outdoors: Provide bulb shield with mounting bracket.
5. Space and Duct Humidity Transmitters: One pipe, directly proportional, with minimum sensing span of 20 to 80 percent relative humidity for **3- to 15-psig** (21- to 103-kPa) output signal, corrosion resistant and temperature compensated, and with factory-calibrated adjustment.
 - a. Space Mounting: With covers to match thermostats.
6. Differential-Pressure Transmitters: One pipe, direct acting for gas, liquid, or steam service; pressure sensor and transmitter of linear-output type; with range of **0 to 50 psig** (0 to 344 kPa), and **3- to 15-psig** (21- to 103-kPa) output signal.
7. Differential-Air-Pressure Transmitters: One pipe, direct acting, double bell; unidirectional with suitable range for expected input; and temperature compensated.
 - a. Accuracy: 5 percent of full range and 2 percent of full scale at midrange.
 - b. Output Signal: **3 to 15 psig** (21 to 103 kPa).

B. Digital-to-Pneumatic Transducers: Convert plus or minus 12-V dc pulse-width-modulation outputs, or continuous proportional current or voltage to **0 to 20 psig** (0 to 140 kPa).

1. [**Available**] [Manufacturers](#):

- a. [BEC Controls Corporation](#).
- b. [MAMAC Systems, Inc.](#)
- c. **<Insert manufacturer's name.>**

- C. Pneumatic Valve/Damper Position Indicator: Potentiometer mounted in enclosure with adjustable crank-arm assembly connected to damper to transmit 0 to 100 percent valve/damper travel.

2.10 STATUS SENSORS

- A. Status Inputs for Fans: Differential-pressure switch with pilot-duty rating and with adjustable range of 0- to 5-inch wg (0 to 1240 Pa).
- B. Status Inputs for Pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig (55 to 414 kPa), piped across pump.
- C. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.
- D. Voltage Transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.
- E. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.
- F. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.
- G. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
- H. Water-Flow Switches: Bellows-actuated mercury or snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.

1. **[Available]Manufacturers:**
 - a. [BEC Controls Corporation](#).
 - b. [I.T.M. Instruments Inc.](#)
 - c. **<Insert manufacturer's name.>**

2.11 GAS DETECTION EQUIPMENT

- A. **[Available]Manufacturers:**

1. [B. W. Technologies.](#)
2. [CEA Instruments, Inc.](#)
3. [Ebtron, Inc.](#)
4. [Gems Sensors Inc.](#)
5. [Greystone Energy Systems Inc.](#)
6. [Honeywell International Inc.; Home & Building Control.](#)
7. [INTEC Controls, Inc.](#)
8. [I.T.M. Instruments Inc.](#)
9. [MSA Canada Inc.](#)
10. [QEL/Quatrosense Environmental Limited.](#)
11. [Sauter Controls Corporation.](#)
12. [Sensidyne, Inc.](#)
13. [TSI Incorporated.](#)
14. [Vaisala.](#)
15. [Vulcain Inc.](#)
16. **<Insert manufacturer's name.>**

- B. Carbon Monoxide Detectors: Single or multichannel, dual-level detectors using solid-state plug-in sensors with a 3-year minimum life; suitable over a temperature range of **32 to 104 deg F** (0 to 40 deg C); with 2 factory-calibrated alarm levels at **[50 and 100] [35 and 200]** ppm.
- C. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of **23 to 130 deg F** (minus 5 to plus 55 deg C) and calibrated for 0 to 2 percent, with continuous or averaged reading, 4- to 20-mA output;, for wall mounting.
- D. Oxygen Sensor and Transmitter: Single detectors using solid-state zircon cell sensing; suitable over a temperature range of **minus 32 to plus 1100 deg F** (0 to 593 deg C) and calibrated for 0 to 5 percent, with continuous or averaged reading, 4- to 20-mA output; for wall mounting.
- E. Occupancy Sensor: Passive infrared, with time delay, daylight sensor lockout, sensitivity control, and 180-degree field of view with vertical sensing adjustment; for flush mounting.

2.12 FLOW MEASURING STATIONS

- A. Duct Airflow Station: Combination of air straightener and multiport, self-averaging pitot tube station.
1. **[Available]Manufacturers:**
 - a. [Air Monitor Corporation.](#)
 - b. [Wetmaster Co., Ltd.](#)
 - c. **<Insert manufacturer's name.>**
 2. Casing: Galvanized-steel frame.

3. Flow Straightener: Aluminum honeycomb, 3/4-inch (20-mm) parallel cell, 3 inches (75 mm) deep.
4. Sensing Manifold: Copper manifold with bullet-nosed static pressure sensors positioned on equal area basis.

2.13 THERMOSTATS

A. [Available]Manufacturers:

1. [Erie Controls.](#)
2. [Danfoss Inc.; Air-Conditioning and Refrigeration Div.](#)
3. [Heat-Timer Corporation.](#)
4. [Sauter Controls Corporation.](#)
5. [tekmar Control Systems, Inc.](#)
6. [Theben AG - Lumilite Control Technology, Inc.](#)
7. <Insert manufacturer's name.>

B. Combination Thermostat and Fan Switches: Line-voltage thermostat with push-button or lever-operated fan switch.

1. Label switches ["**FAN ON-OFF**"] ["**FAN HIGH-LOW-OFF**"] ["**FAN HIGH-MED-LOW-OFF**"].
2. Mount on single electric switch box.

C. Electric, solid-state, microcomputer-based room thermostat with remote sensor.

1. Automatic switching from heating to cooling.
2. Preferential rate control to minimize overshoot and deviation from set point.
3. Set up for four separate temperatures per day.
4. Instant override of set point for continuous or timed period from 1 hour to 31 days.
5. Short-cycle protection.
6. Programming based on [**weekday, Saturday, and Sunday**] [**every day of week**].
7. Selection features include degree F or degree C display, 12- or 24-hour clock, keyboard disable, remote sensor, and fan on-auto.
8. Battery replacement without program loss.
9. Thermostat display features include the following:
 - a. Time of day.
 - b. Actual room temperature.
 - c. Programmed temperature.
 - d. Programmed time.
 - e. Duration of timed override.
 - f. Day of week.
 - g. System mode indications include "heating," "off," "fan auto," and "fan on."

D. Low-Voltage, On-Off Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed set-point

adjustment, 55 to 85 deg F (13 to 30 deg C) set-point range, and 2 deg F (1 deg C) maximum differential.

- E. Line-Voltage, On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch or equivalent solid-state type, with heat anticipator; listed for electrical rating; with concealed set-point adjustment, 55 to 85 deg F (13 to 30 deg C) set-point range, and 2 deg F (1 deg C) maximum differential.
1. Electric Heating Thermostats: Equip with off position on dial wired to break ungrounded conductors.
 2. Selector Switch: Integral, manual on-off-auto.
- F. Remote-Bulb Thermostats: On-off or modulating type, liquid filled to compensate for changes in ambient temperature; with copper capillary and bulb, unless otherwise indicated.
1. Bulbs in water lines with separate wells of same material as bulb.
 2. Bulbs in air ducts with flanges and shields.
 3. Averaging Elements: Copper tubing with either single- or multiple-unit elements, extended to cover full width of duct or unit; adequately supported.
 4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
 5. On-Off Thermostat: With precision snap switches and with electrical ratings required by application.
 6. Modulating Thermostats: Construct so complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.
- G. Fire-Protection Thermostats: Listed and labeled by an NRTL acceptable to authorities having jurisdiction; with fixed or adjustable settings to operate at not less than 75 deg F (24 deg C) above normal maximum operating temperature, and the following:
1. Reset: Manual.
 2. Reset: Automatic, with control circuit arranged to require manual reset at central control panel; with pilot light and reset switch on panel labeled to indicate operation.
- H. Pneumatic Room Thermostats: **[One] [Two] [Three]** pipe(s), fully proportional with adjustable throttling range and tamperproof locking settings, direct or reverse acting as required. Factory calibrated at 2.5 psig/deg F (17.2 kPa/deg C).
1. Factory Calibration: 2.5 psig/deg F (17.2 kPa/deg C).
 2. Range: 45 to 85 deg F (7 to 30 deg C).
 3. Sensitivity Adjustment Range: 1 to 4 psig/deg F (7 to 27.6 kPa/deg C).
 4. Dual-Temperature Thermostats: Automatic changeover from normal setting to lower setting for unoccupied cycles, with manual-reset lever to permit return to normal temperatures during unoccupied cycles, with automatic reset to normal during next cycle of operation.
 5. Limits: Field adjustable, to limit setting cooling set point below 75 deg F (24 deg C), and heating set point above 75 deg F (24 deg C).

6. Room Thermostat Cover Construction: Manufacturer's standard locking covers.
 - a. Set-Point Adjustment: [**Concealed**] [**Exposed**].
 - b. Set-Point Indication: [**Concealed**] [**Keyed**] [**Exposed**].
 - c. Thermometer: [**Concealed**] [**Exposed**] [**Red-reading glass**] [**Spiral bimetal**].
 - d. Color: <Insert color from manufacturer's full range.>
 - e. Orientation: [**Vertical**] [**Horizontal**].
 7. Room thermostat accessories include the following:
 - a. Insulating Bases: For thermostats located on exterior walls.
 - b. Thermostat Guards: [**Locking; heavy-duty, transparent plastic; mounted on separate base**] [**Metal wire, tamperproof**] [**Locking, solid metal, ventilated**].
 - c. Adjusting Key: As required for calibration and cover screws.
 - d. Aspirating Boxes: For flush-mounted aspirating thermostats.
 - e. Set-Point Adjustment: 1/2-inch- (13-mm-) diameter, adjustment knob.
 - I. Immersion Thermostat: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range and adjustable set point.
 - J. Airstream Thermostats: Two-pipe, fully proportional, single-temperature type; with adjustable set point in middle of range, adjustable throttling range, plug-in test fitting or permanent pressure gage, remote bulb, bimetal rod and tube, or averaging element.
 - K. Electric, Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- [**or automatic-**] reset switch that trips if temperature sensed across any 12 inches (300 mm) of bulb length is equal to or below set point.
 1. Bulb Length: Minimum 20 feet (6 m).
 2. Quantity: One thermostat for every 20 sq. ft. (2 sq. m) of coil surface.
 - L. Electric, High-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- [**or automatic-**] reset switch that trips if temperature sensed across any 12 inches (300 mm) of bulb length is equal to or above set point.
 1. Bulb Length: Minimum 20 feet (6 m).
 2. Quantity: One thermostat for every 20 sq. ft. (2 sq. m) of coil surface.
 - M. Heating/Cooling Valve-Top Thermostats: Proportional acting for proportional flow, with molded-rubber diaphragm, remote-bulb liquid-filled element, direct and reverse acting at minimum shutoff pressure of 25 psig (172 kPa), and cast housing with position indicator and adjusting knob.
- 2.14 HUMIDISTATS
- A. [**Available**] [Manufacturers](#):
 1. [MAMAC Systems, Inc.](#)

2. [ROTRONIC Instrument Corp.](#)
3. **<Insert manufacturer's name.>**

- B. Pneumatic Room Humidistats: Wall-mounting, proportioning type with adjustable throttling range, **[20 to 90] [55 to 95] [25 to 65]** percent operating range, and cover matching room thermostat cover.
- C. Duct-Mounting Humidistats: Electric insertion, 2-position type with adjustable, 2 percent throttling range, 20 to 80 percent operating range, and single- or double-pole contacts.
- D. Pneumatic Duct-Mounting Humidistats: Proportioning type with adjustable throttling range, **[20 to 90] [55 to 95] [25 to 65]** percent operating range, in galvanized-steel duct box.

2.15 ACTUATORS

- A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
1. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
 3. Nonspring-Return Motors for Valves Larger Than **NPS 2-1/2 (DN 65)**: Size for running torque of **150 in. x lbf (16.9 N x m)** and breakaway torque of **300 in. x lbf (33.9 N x m)**.
 4. Spring-Return Motors for Valves Larger Than **NPS 2-1/2 (DN 65)**: Size for running and breakaway torque of **150 in. x lbf (16.9 N x m)**.
 5. Nonspring-Return Motors for Dampers Larger Than **25 Sq. Ft. (2.3 sq. m)**: Size for running torque of **150 in. x lbf (16.9 N x m)** and breakaway torque of **300 in. x lbf (33.9 N x m)**.
 6. Spring-Return Motors for Dampers Larger Than **25 Sq. Ft. (2.3 sq. m)**: Size for running and breakaway torque of **150 in. x lbf (16.9 N x m)**.
- B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
1. **[Available]Manufacturers:**
 - a. [Belimo Aircontrols \(USA\), Inc.](#)
 - b. **<Insert manufacturer's name.>**
 2. Valves: Size for torque required for valve close off at maximum pump differential pressure.
 3. Dampers: Size for running torque calculated as follows:

- a. Parallel-Blade Damper with Edge Seals: **7 inch-lb/sq. ft.** (86.8 kg-cm/sq. m) of damper.
 - b. Opposed-Blade Damper with Edge Seals: **5 inch-lb/sq. ft.** (62 kg-cm/sq. m) of damper.
 - c. Parallel-Blade Damper without Edge Seals: **4 inch-lb/sq. ft.** (49.6 kg-cm/sq. m) of damper.
 - d. Opposed-Blade Damper without Edge Seals: **3 inch-lb/sq. ft.** (37.2 kg-cm/sq. m) of damper.
 - e. Dampers with **2- to 3-Inch wg** (500 to 750 Pa) of Pressure Drop or Face Velocities of **1000 to 2500 fpm** (5 to 13 m/s): Increase running torque by 1.5.
 - f. Dampers with **3- to 4-Inch wg** (750 to 1000 Pa) of Pressure Drop or Face Velocities of **2500 to 3000 fpm** (13 to 15 m/s): Increase running torque by 2.0.
4. Coupling: V-bolt and V-shaped, toothed cradle.
 5. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
 6. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
 7. Power Requirements (Two-Position Spring Return): **[24] [120] [230]-V ac.**
 8. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
 9. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
 10. Temperature Rating: **[Minus 22 to plus 122 deg F (Minus 30 to plus 50 deg C)] [40 to 104 deg F (5 to 40 deg C)].**
 11. Temperature Rating (Smoke Dampers): **Minus 22 to plus 250 deg F (Minus 30 to plus 121 deg C).**
 12. Run Time: **[12 seconds open, 5 seconds closed] [30 seconds] [60 seconds] [120 seconds].**
- C. Pneumatic Valve Operators: Rolling-diaphragm, spring-loaded, piston type with spring range as required and start-point adjustment[**and positioning relay**]. Operator shall maintain full shutoff at maximum pump differential pressure.
- D. Pneumatic Damper Operators: Rolling-diaphragm, piston type with adjustable stops and spring return, sized to operate with sufficient reserve power to provide smooth modulating action or two-position action. Where actuators operate in sequence, provide pilot positioners.
1. Pilot Positioners: With the following characteristics:
 - a. Start Point: Adjustable from **2 to 12 psig** (14 to 83 kPa).
 - b. Operating Span: Adjustable from **5 to 13 psig** (35 to 90 kPa).
 - c. Linearity: Plus or minus 10 percent of output signal span.
 - d. Hysteresis: 3 percent of span.
 - e. Response: **0.25-psig** (1723-Pa) input change.
 - f. Maximum Pilot Signal Pressure: **20 psig** (140 kPa).
 - g. Maximum Control Air-Supply Pressure: **60 psig** (410 kPa).

2. Actuator Housing: Molded or die-cast zinc or aluminum. [**Terminal unit actuators may be high-impact plastic with ambient temperature rating of 50 to 140 deg F (10 to 60 deg C) unless located in return-air plenums.**]
3. Inlet-Vane Operators: High pressure, with pilot positioners.

2.16 CONTROL VALVES

A. [Available] Manufacturers:

1. Danfoss Inc.; Air Conditioning & Refrigeration Div.
2. Erie Controls.
3. Hayward Industrial Products, Inc.
4. Magnatrol Valve Corporation.
5. Neles-Jamesbury.
6. Parker Hannifin Corporation; Skinner Valve Division.
7. Pneuline Controls.
8. Sauter Controls Corporation.
9. **<Insert manufacturer's name.>**

B. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.

C. Hydronic system globe valves shall have the following characteristics:

1. **NPS 2 (DN 50)** and Smaller: Class [125] [250] bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
2. **NPS 2-1/2 (DN 65)** and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
3. Internal Construction: Replaceable plugs and stainless-steel or brass seats.
 - a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
 - b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.
4. Sizing: [3-psig (21-kPa)] [5-psig (35-kPa)] **<Insert value>** maximum pressure drop at design flow rate or the following:
 - a. Two Position: Line size.
 - b. Two-Way Modulating: Either the value specified above or twice the load pressure drop, whichever is more.
 - c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.
5. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.

6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.
- D. Steam system globe valves shall have the following characteristics:
1. **NPS 2 (DN 50)** and Smaller: Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
 2. **NPS 2-1/2 (DN 65)** and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
 3. Internal Construction: Replaceable plugs and stainless-steel seats.
 - a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom of guided plugs.
 - b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom of guided plugs.
 4. Sizing: For pressure drop based on the following services:
 - a. Two Position: 20 percent of inlet pressure.
 - b. Modulating [**15-psig (103-kPa) Steam**]: 80 percent of inlet steam pressure.
 - c. Modulating [**16- to 50-psig (110- to 350-kPa) Steam**]: 50 percent of inlet steam pressure.
 - d. Modulating [**More Than 50-psig (350-kPa) Steam**]: As indicated.
 5. Flow Characteristics: Modified linear characteristics.
 6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of operating (inlet) pressure.
- E. Butterfly Valves: **200-psig (1380-kPa)**, **150-psig (1034-kPa)** maximum pressure differential, ASTM A 126 cast-iron or ASTM A 536 ductile-iron body and bonnet, extended neck, stainless-steel stem, field-replaceable EPDM or Buna N sleeve and stem seals.
1. Body Style: [**Wafer**] [**Lug**] [**Grooved**].
 2. Disc Type: [**Nickel-plated ductile iron**] [**Aluminum bronze**] [**Elastomer-coated ductile iron**] [**Epoxy-coated ductile iron**].
 3. Sizing: **1-psig (7-kPa)** maximum pressure drop at design flow rate.
- F. Terminal Unit Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.
1. Rating: Class 125 for service at **125 psig (860 kPa)** and **250 deg F (121 deg C)** operating conditions.
 2. Sizing: **3-psig (21-kPa)** maximum pressure drop at design flow rate, to close against pump shutoff head.

3. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
- G. Self-Contained Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.
1. Rating: Class 125 for service at **125 psig** (860 kPa) and **250 deg F** (121 deg C) operating conditions.
 2. Thermostatic Operator: [**Wax**] [**Liquid**]-filled [**integral**] [**remote**] sensor with [**integral**] [**remote**] adjustable dial.

2.17 DAMPERS

A. [**Available**] Manufacturers:

1. [Air Balance Inc.](#)
2. [Don Park Inc.: Autodamp Div.](#)
3. [TAMCO \(T. A. Morrison & Co. Inc.\)](#).
4. [United Enertech Corp.](#)
5. [Vent Products Company, Inc.](#)
6. <Insert manufacturer's name.>

B. Dampers: AMCA-rated, [**parallel**] [**opposed**]-blade design; **0.108-inch-** (2.8-mm-) minimum thick, galvanized-steel or **0.125-inch-** (3.2-mm-) minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than **0.064-inch-** (1.6-mm-) thick galvanized steel with maximum blade width of **8 inches** (200 mm) and length of **48 inches** (1220 mm).

1. Secure blades to **1/2-inch-** (13-mm-) diameter, zinc-plated axles using zinc-plated hardware, with [**oil-impregnated sintered bronze**] [**nylon**] blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
2. Operating Temperature Range: From **minus 40 to plus 200 deg F** (minus 40 to plus 93 deg C).
3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.
4. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than **10 cfm per sq. ft.** (50 L/s per sq. m) of damper area, at differential pressure of **4-inch wg** (1000 Pa) when damper is held by torque of **50 in. x lbf** (5.6 N x m); when tested according to AMCA 500D.

2.18 AIR SUPPLY

A. [**Available**] Manufacturers:

1. [Drainview Products](#).
2. [Pneuline Controls](#).

3. **<Insert manufacturer's name.>**
- B. Control and Instrumentation Tubing: Copper tubing complying with **ASTM B 88, Type K** (ASTM B 88M, Type A) or ASTM B 280 Type ACR.
1. Fittings: Cast-bronze solder fittings complying with ASME B16.18; or wrought-copper solder fittings complying with ASME B16.22, except forged-brass compression-type fittings at connections to equipment.
 2. Joining Method: Soldered or brazed.
- C. Control and Instrumentation Tubing: ASTM D 2737 Type FR plenum-rated polyethylene, flame-retardant, nonmetallic tubing rated for **30 psig** (207 kPa) and ambient temperature range of **10 to 150 deg F** (minus 13 to plus 65 deg C) with flame-retardant harness for multiple tubing.
1. Fittings: Compression or push-on polyethylene fittings.
- D. Tank: ASME storage tank with drain test cock, automatic moisture removal trap, tank relief valve, and rubber-cork vibration isolation mounting pads.
- E. Duplex Air Compressor: Capacity to supply compressed air to temperature-control system.
1. Pressure control with adjustable electric contacts, set to start and stop both compressors at different pressures.
 2. Electrical alternation set with motor starters and disconnect to operate compressors alternately or on time schedule.
- F. Simplex Air Compressor: Tank-mounting compressor with capacity to supply compressed air to temperature-control system, with starter and disconnect.
1. Pressure control with adjustable electric contacts, set to start and stop compressor.
- G. Compressor Type: **[Reciprocating] [Scroll]**.
- H. Size compressor and tank to operate compressor not more than **[20] [30]** minutes during a 60-minute period.
- I. Compressor Accessories: Low-resistance intake-air filter, and belt guards.
- J. System Accessories: Air filter rated for 97 percent efficiency at rated airflow, and combination filter/pressure-reducing station or separate filter and pressure-reducing station.
- K. Refrigerated Air Dryer: Self-contained, refrigerated air dryer complete with heat exchangers, moisture separator, internal wiring and piping, and with manual bypass valve.
1. Heat Exchangers: Air-to-refrigerant coils with centrifugal-type moisture separator and automatic trap assembly.

2. Refrigeration Unit: Hermetically sealed, operating to maintain dew point of 13 deg F (minus 11 deg C) at 20 psig (140 kPa), housed in steel cabinet with access door and panel.
 3. Accessories: Air-inlet temperature gage, air-inlet pressure gage, on-off switch, high-temperature light, power-on light, refrigerant gage on back, air-outlet temperature gage, air-outlet pressure gage, and with contacts for remote indication of power status and high-temperature alarm.
- L. Desiccant Dryer: Obtains dew point in pneumatic air piping between compressor and tank at least 15 deg F (minus 9 deg C) below inlet-air dew point at design conditions.
- M. Pressure Gages: Black letters on white background, 2-1/2 inches (64 mm) in diameter, flush or surface mounting, with front calibration screw to match sensor, and having a graduated scale in psig (kPa).
- N. Instrument Pressure Gages: Black letters on white background, 1-1/2 inches (38 mm) in diameter, stem mounted, with suitable dial range.
- O. Diaphragm Control and Instrument Valves: 1/4-inch (6-mm) forged-brass body with reinforced polytetrafluoroethylene diaphragm, stainless-steel spring, and color-coded phenolic handle.
- P. Gage Cocks: Tee or level handle, bronze, rated for 125 psig (860 kPa).
- Q. Relays: For summing, reversing, and amplifying highest or lowest pressure selection; with adjustable I/O ratio.
- R. Switches: With indicating plates and accessible adjustment; calibrated and marked.
- S. Pressure Regulators: Zinc or aluminum castings with elastomeric diaphragm, balanced construction to automatically prevent pressure buildup, and producing flat reduced-pressure curve.
- T. Particle Filters: Zinc or aluminum castings with 97 percent filtration efficiency at rated airflow, quick-disconnect service devices, and aluminum or plastic bowl with metal guard and manual drain cock.
- U. Combination Filter/Regulators: Zinc or aluminum castings with elastomeric diaphragm, balanced construction to automatically prevent pressure buildup, and producing flat reduced-pressure curve; with threaded pipe connections, quick-disconnect service devices, and aluminum or plastic bowl with metal guard and manual drain cock.
- V. Airborne Oil Filter: Filtration efficiency of 99.9 percent for airborne lubricating oil particles of 0.025 micron or larger.
- W. Pressure Relief Valves: ASME rated and labeled.
1. High Pressure: Size for installed capacity.
 2. Low Pressure: Size for installed capacity of pressure regulators and set at 20 percent above low pressure.

- X. Pressure-Reducing Stations: Two parallel pressure regulators.

2.19 CONTROL CABLE

- A. Electronic and fiber-optic cables for control wiring are specified in Section 271500 "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that **[conditioned]** power supply is available to control units and operator workstation.
- B. Verify that pneumatic piping and duct-, pipe-, and equipment-mounted devices are installed before proceeding with installation.

3.2 INSTALLATION

- A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.
- B. Connect and configure equipment and software to achieve sequence of operation specified.
- C. Mount compressor and tank unit on **[elastomeric mounts]** **[spring isolators with 1-inch (25 mm) static deflection]** **[restrained spring isolators with 1-inch (25-mm) static deflection]**. Vibration isolators are specified in **[Section 230548 "Vibration and Seismic Controls for HVAC. "]** **[Section 230548.13 "Vibration Controls for HVAC. "]** Isolate air supply with wire-braid-reinforced rubber hose. Secure and anchor according to manufacturer's written instructions and seismic-control requirements.
 - 1. Pipe manual and automatic drains to nearest floor drain.
 - 2. Supply instrument air from compressor units through filter, pressure-reducing valve, and pressure relief valve, with pressure gages and shutoff and bypass valves.
- D. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices **[48 inches (1220 mm)]** **[60 inches (1530 mm)]** **<Insert dimension>** above the floor.
 - 1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.
- E. Install guards on thermostats in the following locations:
 - 1. Entrances.
 - 2. Public areas.

3. Where indicated.

- F. Install automatic dampers according to Section 233300 "Air Duct Accessories."
- G. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.
- H. Install labels and nameplates to identify control components according to Section 230553 "Identification for HVAC Piping and Equipment."
- I. Install hydronic instrument wells, valves, and other accessories according to Section 232116 "Hydronic Piping Specialties."
- J. Install steam and condensate instrument wells, valves, and other accessories according to Section 232216 "Steam and Condensate Piping Specialties."
- K. Install refrigerant instrument wells, valves, and other accessories according to Section 232300 "Refrigerant Piping."
- L. Install duct volume-control dampers according to Section 233113 "Metal Ducts" and Section 233116 "Nonmetal Ducts."
- M. Install electronic and fiber-optic cables according to Section 271500 "Communications Horizontal Cabling."

3.3 PNEUMATIC PIPING INSTALLATION

- A. Install piping in mechanical equipment rooms inside mechanical equipment enclosures, in pipe chases, or suspended ceilings with easy access.
 - 1. Install copper tubing with maximum unsupported length of **36 inches** (915 mm), for tubing exposed to view.
 - 2. Install polyethylene tubing in metallic raceways or electrical metallic tubing. Electrical metallic tubing materials and installation requirements are specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- B. Install terminal single-line connections, less than **18 inches** (460 mm) in length, with copper or polyethylene tubing run inside flexible steel protection.
- C. In concealed locations such as pipe chases and suspended ceilings with easy access, install **[copper] [polyethylene bundled and sheathed] [polyethylene tubing in electrical metallic]** tubing. Electrical metallic tubing materials and installation requirements are specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- D. In concrete slabs, furred walls, or ceilings with no access, install copper or polyethylene tubing in electrical metallic tubing or vinyl-jacketed polyethylene tubing.

1. Protect embedded-copper and vinyl-jacketed polyethylene tubing with electrical metallic tubing extending **6 inches (150 mm)** above finished slab and **6 inches (150 mm)** into slab. Pressure test tubing before and after pour for leak and pinch.
 2. Install polyethylene tubing in electrical metallic tubing extending **6 inches (150 mm)** above floor line; pull tubing into electrical metallic tubing after pour.
- E. Install tubing with sufficient slack and flexible connections to allow for vibration of piping and equipment.
- F. Purge tubing with dry, oil-free compressed air before connecting control instruments.
1. Bridge cabinets and doors with flexible connections fastened along hinge side; protect against abrasion. Tie and support tubing.
- G. Number-code or color-code control air piping for future identification and service of control system, except local individual room control tubing.
- H. Pressure Gages or Test Plugs: Install on branch lines at each receiver controller and on signal lines at each transmitter, except individual room controllers.

3.4 ELECTRICAL WIRING AND CONNECTION INSTALLATION

- A. Install raceways, boxes, and cabinets according to Section 260533 "Raceways and Boxes for Electrical Systems."
- B. Install building wire and cable according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Install signal and communication cable according to Section 271500 "Communications Horizontal Cabling."
1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
 2. Install exposed cable in raceway.
 3. Install concealed cable in raceway.
 4. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.
 5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
 6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
 7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.
- D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.
- E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect[, **test, and adjust**] field-assembled components and equipment installation, including connections[, **and to assist in field testing**]. Report results in writing.
- B. Perform the following field tests and inspections and prepare test reports:
1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
 2. Test and adjust controls and safeties.
 3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 4. Pressure test control air piping at **30 psig (207 kPa)** or 1.5 times the operating pressure for 24 hours, with maximum **5-psig (35-kPa)** loss.
 5. Pressure test high-pressure control air piping at **150 psig (1034 kPa)** and low-pressure control air piping at **30 psig (207 kPa)** for 2 hours, with maximum **1-psig (7-kPa)** loss.
 6. Test calibration of [**pneumatic**] [**electronic**] controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
 7. Test each point through its full operating range to verify that safety and operating control set points are as required.
 8. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
 9. Test each system for compliance with sequence of operation.
 10. Test software and hardware interlocks.
- C. DDC Verification:
1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
 2. Check instruments for proper location and accessibility.
 3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
 4. Check instrument tubing for proper fittings, slope, material, and support.
 5. Check installation of air supply for each instrument.
 6. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
 7. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
 8. Check temperature instruments and material and length of sensing elements.
 9. Check control valves. Verify that they are in correct direction.
 10. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
 11. Check DDC system as follows:
 - a. Verify that DDC controller power supply is from emergency power supply, if applicable.

- b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
 - c. Verify that spare I/O capacity has been provided.
 - d. Verify that DDC controllers are protected from power supply surges.
- D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.6 ADJUSTING

A. Calibrating and Adjusting:

1. Calibrate instruments.
2. Make three-point calibration test for both linearity and accuracy for each analog instrument.
3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
4. Control System Inputs and Outputs:
 - a. Check analog inputs at 0, 50, and 100 percent of span.
 - b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
 - c. Check digital inputs using jumper wire.
 - d. Check digital outputs using ohmmeter to test for contact making or breaking.
 - e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
5. Flow:
 - a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
 - b. Manually operate flow switches to verify that they make or break contact.
6. Pressure:
 - a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
 - b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.
7. Temperature:
 - a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
 - b. Calibrate temperature switches to make or break contacts.
8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.

9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
10. Provide diagnostic and test instruments for calibration and adjustment of system.
11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[three]** <Insert number> visits to Project during other than normal occupancy hours for this purpose.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Refer to Section 017900 "Demonstration and Training."

END OF SECTION 230900

SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. DDC system for monitoring and controlling of HVAC systems.
2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

- B. Related Requirements:

1. Section **230923.13** "Energy Meters" for thermal and electric power energy meters that connect to DDC systems.
2. Section **230923.17** "Level Instruments" for liquid-level switches, sensors, and transmitters that connect to DDC systems.
3. Section **230923.22** "Position Instruments" for limit switches that connect to DDC systems.
4. Section **230923.33** "Vibration Instruments" for vibration instruments that connect to DDC systems.
5. Section **230923.43** "Weather Stations" for weather stations that connect to DDC systems.
6. Section 230993 "Sequence of Operations for HVAC Controls" for control sequences in DDC systems.

1.3 DEFINITIONS

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.
- B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.
- C. BACnet Specific Definitions:

1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.
 2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
 3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
 4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.
 5. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.
- D. Binary: Two-state signal where a high signal level represents "ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.
- E. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.
- F. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.
- G. COV: Changes of value.
- H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.
- I. Distributed Control: Processing of system data is decentralized and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems shall be capable of operating in a standalone mode using the last best available data.
- J. DOCSIS: Data-OverCable Service Interface Specifications.
- K. E/P: Voltage to pneumatic.
- L. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.
- M. HLC: Heavy load conditions.

- N. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.
- O. I/P: Current to pneumatic.
- P. LAN: Local area network.
- Q. LNS: LonWorks Network Services.
- R. LON Specific Definitions:
1. FTT-10: Echelon Transmitter-Free Topology Transceiver.
 2. LonMark: Association comprising suppliers and installers of LonTalk products. Association provides guidelines for implementing LonTalk protocol to ensure interoperability through a standard or consistent implementation.
 3. LonTalk: An open standard protocol developed by the Echelon Corporation that uses a "Neuron Chip" for communication. LonTalk is a register trademark of Echelon.
 4. LonWorks: Network technology developed by Echelon.
 5. Node: Device that communicates using CEA-709.1-C protocol and that is connected to a CEA-709.1-C network.
 6. Node Address: The logical address of a node on the network, consisting of a Domain number, Subnet number, and Node number. "Node number" portion of an address is a number assigned to device during installation, is unique within a subnet, and is not a factory-set unique Node ID.
 7. Node ID: A unique 48-bit identifier assigned at factory to each CEA-709.1-C device. Sometimes called a "Neuron ID."
 8. Program ID: An identifier (number) stored in a device (usually EEPROM) that identifies node manufacturer, functionality of device (application and sequence), transceiver used, and intended device usage.
 9. Standard Configuration Property Type (SCPT): Pronounced "skip-it." A standard format type maintained by LonMark International for configuration properties.
 10. Standard Network Variable Type (SNVT): Pronounced "snivet." A standard format type maintained by LonMark used to define data information transmitted and received by individual nodes. "SNVT" is used in two ways. It is an acronym for "Standard Network Variable Type" and is often used to indicate a network variable itself (i.e., it can mean "a network variable of a standard network variable type").
 11. Subnet: Consists of a logical grouping of up to 127 nodes, where logical grouping is defined by node addressing. Each subnet is assigned a number, which is unique within a Domain. See "Node Address."
 12. TP/FT-10: Free Topology Twisted Pair network defined by CEA-709.3 and is most common media type for a CEA-709.1-C control network.

13. TP/XF-1250: High-speed, 1.25-Mbps, twisted-pair, doubly terminated bus network defined by "LonMark Interoperability Guidelines" typically used only to connect multiple TP/FT-10 networks.
 14. User-Defined Configuration Property Type (UCPT): Pronounced "U-Keep-It." A Configuration Property format type that is defined by device manufacturer.
 15. User-Defined Network Variable Type (UNVT): Network variable format defined by device manufacturer. UNVTs create non-standard communications that other vendors' devices may not correctly interpret and may negatively impact system operation. UNVTs are not allowed.
- S. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- T. Modbus TCP/IP: An open protocol for exchange of process data.
- U. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
- V. MTBF: Mean time between failures.
- W. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.
- X. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
- Y. PDA: Personal digital assistant.
- Z. Peer to Peer: Networking architecture that treats all network stations as equal partners.
- AA. POT: Portable operator's terminal.
- BB. PUE: Performance usage effectiveness.
- CC. RAM: Random access memory.
- DD. RF: Radio frequency.
- EE. Router: Device connecting two or more networks at network layer.
- FF. Server: Computer used to maintain system configuration, historical and programming database.
- GG. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.
- HH. UPS: Uninterruptible power supply.
- II. USB: Universal Serial Bus.

JJ. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.

KK. VAV: Variable air volume.

LL. WLED: White light emitting diode.

1.4 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at **[Project site]** <Insert location>.

1.5 ACTION SUBMITTALS

A. Multiple Submissions:

1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B. Product Data: For each type of product include the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation, and maintenance instructions including factors effecting performance.
5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
 - a. Operator workstations.
 - b. Servers.
 - c. Printers.
 - d. Gateways.
 - e. Routers.
 - f. Protocol analyzers.
 - g. DDC controllers.
 - h. Enclosures.

- i. Electrical power devices.
 - j. UPS units.
 - k. Accessories.
 - l. Instruments.
 - m. Control dampers and actuators.
 - n. Control valves and actuators.
 - o. **<Insert product>**.
 6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
 7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.
- C. Software Submittal:
 1. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, **<Insert product>** and DDC controller.
 2. Description and technical data of all software provided, and cross-referenced to products in which software will be installed.
 3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
 4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
 5. Listing and description of each engineering equation used with reference source.
 6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
 7. Description of operator interface to alphanumeric and graphic programming.
 8. Description of each network communication protocol.
 9. Description of system database, including all data included in database, database capacity and limitations to expand database.
 10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughout.
 11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.
- D. LEED Submittals:
 1. Include supporting data showing energy, flow, gas, moisture, motion, pressure, **<Insert other>** and temperature instruments, where and if used in Project; and associated application for monitoring and control to satisfy requirements of Project LEED credits.
 - a. Indicate applicable locations and area coverage, control set points, description of control operation and other required information to satisfy submission requirements for award of LEED credit.

2. Organize and identify standalone, supporting data for each LEED credit.
3. Project LEED credits include the following:

- a. **<Insert individual LEED credits applicable to Project>.**

E. Shop Drawings:

1. General Requirements:

- a. Include cover drawing with Project name, location, Owner, Architect, Contractor, and issue date with each Shop Drawings submission.
- b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
- c. Prepare Drawings using CAD.
- d. Drawings Size: **<Insert requirements>.**

2. Include plans, elevations, sections, and mounting details where applicable.
3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail means of vibration isolation and show attachments to rotating equipment.
5. Plan Drawings indicating the following:

- a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork, and piping.
- b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
- c. Each desktop operator workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
- d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
- e. Network communication cable and raceway routing.
- f. Information, drawn to scale, of **<Insert requirements>.**
- g. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.

6. Schematic drawings for each controlled HVAC system indicating the following:

- a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
- b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
- c. A graphic showing location of control I/O in proper relationship to HVAC system.
- d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
- e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.

- f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
 - g. Narrative sequence of operation.
 - h. Graphic sequence of operation, showing all inputs and output logical blocks.
7. Control panel drawings indicating the following:
 - a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
 - b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
 - c. Front, rear, and side elevations and nameplate legend.
 - d. Unique drawing for each panel.
8. DDC system network riser diagram indicating the following:
 - a. Each device connected to network with unique identification for each.
 - b. Interconnection of each different network in DDC system.
 - c. For each network, indicate communication protocol, speed, and physical means of interconnecting network devices, such as copper cable type, or fiber-optic cable type. Indicate raceway type and size for each.
 - d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.
9. DDC system electrical power riser diagram indicating the following:
 - a. Each point of connection to field power with requirements (volts/phase//hertz/amperes/connection type) listed for each.
 - b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
 - c. Each product requiring power with requirements (volts/phase//hertz/amperes/connection type) listed for each.
 - d. Power wiring type and size, race type, and size for each.
10. Monitoring and control signal diagrams indicating the following:
 - a. Control signal cable and wiring between controllers and I/O.
 - b. Point-to-point schematic wiring diagrams for each product.
 - c. Control signal tubing to sensors, switches, and transmitters.
 - d. Process signal tubing to sensors, switches, and transmitters.
 - e. Pneumatic main air and control signal tubing to pneumatic **[damper]** **[and]** **[valve]** actuators, pilot-positioners if applicable, and associated transducers.
11. Color graphics indicating the following:
 - a. Itemized list of color graphic displays to be provided.

- b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
- c. Intended operator access between related hierarchical display screens.

F. System Description:

1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
3. System and product operation under each potential failure condition including, but not limited to, the following:
 - a. Loss of power.
 - b. Loss of network communication signal.
 - c. Loss of controller signals to inputs and outputs.
 - d. Operator workstation failure.
 - e. Server failure.
 - f. Gateway failure.
 - g. Network failure
 - h. Controller failure.
 - i. Instrument failure.
 - j. Control damper and valve actuator failure.
 - k. **<Insert potential failure conditions>**.
4. Complete bibliography of documentation and media to be delivered to Owner.
5. Description of testing plans and procedures.
6. Description of Owner training.

G. Samples:

1. For each of the following exposed product, installed in finished space for approval of selection of aesthetic characteristics:
 - a. Gas instruments specified in Section 230923.16 "Gas Instruments."
 - b. Moisture instruments specified in Section 230923.19 "Moisture Instruments."
 - c. Motion instruments specified in Section 230923.21 "Motion Instruments."
 - d. Pressure instruments specified in Section 230923.23 "Pressure Instruments."
 - e. Temperature instruments specified in Section 230923.27 "Temperature Instruments."
2. **<Insert devices>**.

H. Delegated-Design Submittal: For DDC system products and installation indicated as being delegated.

1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.
2. Schedule and design calculations for control dampers and actuators.
 - a. Flow at Project design and minimum flow conditions.
 - b. Face velocity at Project design and minimum airflow conditions.
 - c. Pressure drop across damper at Project design and minimum airflow conditions.
 - d. AMCA 500-D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
 - e. Maximum close-off pressure.
 - f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.
 - i. Actuator signal to control damper (on, close or modulate).
 - j. Actuator position on loss of power.
 - k. Actuator position on loss of control signal.
3. Schedule and design calculations for control valves and actuators.
 - a. Flow at Project design and minimum flow conditions.
 - b. Pressure-differential drop across valve at Project design flow condition.
 - c. Maximum system pressure-differential drop (pump close-off pressure) across valve at Project minimum flow condition.
 - d. Design and minimum control valve coefficient with corresponding valve position.
 - e. Maximum close-off pressure.
 - f. Leakage flow at maximum system pressure differential.
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.
 - i. Actuator signal to control damper (on, close or modulate).
 - j. Actuator position on loss of power.
 - k. Actuator position on loss of control signal.
4. Schedule and design calculations for selecting flow instruments.
 - a. Instrument flow range.
 - b. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter and output signal for remote control.
 - c. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter and output signal for remote control.
 - d. Pressure-differential loss across instrument at Project design flow conditions.
 - e. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

1. Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - a. Product installation location shown in relationship to room, duct, pipe, and equipment.
 - b. Structural members to which products will be attached.
 - c. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices, and other installed devices.
 - d. Size and location of wall access panels for products installed behind walls and requiring access.
2. Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - a. Ceiling components.
 - b. Size and location of access panels for products installed above inaccessible ceiling assemblies and requiring access.
 - c. Items penetrating finished ceiling including the following:
 - 1) Lighting fixtures.
 - 2) Air outlets and inlets.
 - 3) Speakers.
 - 4) Sprinklers.
 - 5) Access panels.
 - 6) Motion sensors.
 - 7) Pressure sensors.
 - 8) Temperature sensors and other DDC control system instruments.
 - 9) **<Insert item>**.

B. Qualification Data:

1. Systems Provider Qualification Data:
 - a. Resume of project manager assigned to Project.
 - b. Resumes of application engineering staff assigned to Project.
 - c. Resumes of installation and programming technicians assigned to Project.
 - d. Resumes of service technicians assigned to Project.
 - e. Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity and building's primary function.
 - f. Description of past project DDC system, noting similarities to Project scope and complexity indicated.
 - g. Names of staff assigned to past project that will also be assigned to execute work of this Project.

- h. Owner contact information for past project including name, phone number, and e-mail address.
 - i. Contractor contact information for past project including name, phone number, and e-mail address.
 - j. Architect[**and Engineer**] contact information for past project including name, phone number, and e-mail address.
 - 2. Manufacturer's qualification data.
 - 3. Testing agency's qualifications data.
 - C. Welding certificates.
 - D. Product Certificates:
 - 1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
 - 2. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with LonWorks.
 - 3. **<Insert list of products>**.
 - E. Product Test Reports: For each product that requires testing to be performed by **[manufacturer] [manufacturer and witnessed by a qualified testing agency] [a qualified testing agency]**.
 - F. Preconstruction Test Reports: For each separate test performed.
 - G. Source quality-control reports.
 - H. Field quality-control reports.
 - I. Sample Warranty: For manufacturer's warranty.
- 1.7 CLOSEOUT SUBMITTALS
- A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.
 - 1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
 - b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
 - c. As-built versions of submittal Product Data.
 - d. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
 - e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.

- f. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
- g. Engineering, installation, and maintenance manuals that explain how to:
 - 1) Design and install new points, panels, and other hardware.
 - 2) Perform preventive maintenance and calibration.
 - 3) Debug hardware problems.
 - 4) Repair or replace hardware.
- h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
- i. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
- j. List of recommended spare parts with part numbers and suppliers.
- k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
- l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
- m. Licenses, guarantees, and warranty documents.
- n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
- o. Owner training materials.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Include product manufacturers' recommended parts lists for proper product operation over **[four] <Insert time period>**-year period following warranty period. Parts list shall be indicated for each year.
- C. Furnish parts, as indicated by manufacturer's recommended parts list, for product operation during **[one] [two] <Insert time period>**-year period following warranty period.
- D. Furnish quantity indicated of matching product(s) in Project inventory for each unique size and type of following:
 - 1. Network Controller: **[One] <Insert quantity>**.
 - 2. Programmable Application Controller: **[One] <Insert quantity>**.
 - 3. Application-Specific Controller: **[One] <Insert quantity>**.
 - 4. **[Room]** Carbon Dioxide Sensor and Transmitter: **[One] <Insert quantity>**.
 - 5. **[Room]** Moisture Sensor and Transmitter: **[One] <Insert quantity>**.

6. **[Room]**Pressure Sensor and Transmitter: **[One] <Insert quantity>**.
7. **[Room]**Temperature Sensor**[and Transmitter]: [One] <Insert quantity>**.
8. General-Purpose Relay: **[One] <Insert quantity>**.
9. Multifunction Time-Delay Relay: **[One] <Insert quantity>**.
10. Latching Relay: **[One] <Insert quantity>**.
11. Current-Sensing Relay: **[One] <Insert quantity>**.
12. Combination On-Off Status Sensor and On-Off Relay: **[One] <Insert quantity>**.
13. Transformer: **[One] <Insert quantity>**.
14. DC Power Supply: **[One] <Insert quantity>**.
15. Supply of **[20] <Insert number>** percent spare fiber-optic cable splice organizer cabinets for several re-terminations.
16. **<Insert product>**.

1.9 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:

1. Nationally recognized manufacturer of DDC systems and products.
2. DDC systems with similar requirements to those indicated for a continuous period of **[five] [10] <Insert number>** years within time of bid.
3. DDC systems and products that have been successfully tested and in use on at least **[three] [five] <Insert number>** past projects.
4. Having complete published catalog literature, installation, operation and maintenance manuals for all products intended for use.
5. Having full-time in-house employees for the following:
 - a. Product research and development.
 - b. Product and application engineering.
 - c. Product manufacturing, testing, and quality control.
 - d. Technical support for DDC system installation training, commissioning, and troubleshooting of installations.
 - e. Owner operator training.

B. DDC System Provider Qualifications:

1. Authorized representative of, and trained by, DDC system manufacturer.
2. In-place facility located within **<Insert distance>** of Project.
3. Demonstrated past experience with installation of DDC system products being installed for period within **[three] [five] <Insert number>** consecutive years before time of bid.
4. Demonstrated past experience on **[five] <Insert number>** projects of similar complexity, scope and value.
5. Each person assigned to Project shall have demonstrated past experience.
6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
7. Service and maintenance staff assigned to support Project during warranty period.
8. Product parts inventory to support on-going DDC system operation for a period of not less than **[5] <Insert number>** years after Substantial Completion.

9. DDC system manufacturer's backing to take over execution of Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.
- C. Testing Agency Qualifications: Member company of NETA or an NRTL.
1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.
- D. Welding Qualifications: Qualify procedures and personnel according to the following:
1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
 2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
 3. AWS D1.3/D1.3M, "Structural Welding Code - Sheet Steel."
 4. AWS D1.4/D1.4M, "Structural Welding Code - Reinforcing Steel."
- E. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
- F. Mockups: Build mockups to verify selections made under Sample submittals, to demonstrate aesthetic effects, and to set quality standards for materials and products and for fabrication and installation.
1. Build mockups of completed installation where products are exposed to view and are located in areas with aesthetic requirements that warrant special attention, including the following spaces:
 - a. **<Insert specific locations for mockups>.**
 2. Build mockups of completed installation for areas indicated on Drawings.
 3. Approval of mockups does not constitute approval of deviations from Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
- 1.10 PRECONSTRUCTION TESTING
- A. Preconstruction Testing Service: **[Owner will engage] [Engage]** a qualified testing agency to perform preconstruction testing on field mockups.
1. **<Insert configurations of assemblies>.**
 2. Include test assemblies representative of proposed materials and construction.
 3. Build mockup at testing agency facility using personnel, materials, and methods of construction that will be used at Project site.
 4. Notify Architect **[seven] <Insert number>** days in advance of dates and times of tests.
- B. Preconstruction Testing: Performed by a qualified testing agency on manufacturer's standard assemblies.
1. **<Insert preconstruction testing requirements>.**

1.11 WARRANTY

- A. **Manufacturer's Warranty:** Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.
1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
 2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
 - a. Install updates only after receiving Owner's written authorization.
 3. Warranty service shall occur during normal business hours and commence within **[16] [24] <Insert number>** hours of Owner's warranty service request.
 4. Warranty Period: **[Two] <Insert number>** year(s) from date of Substantial Completion.
 - a. For Gateway: **[Two] [Three] <Insert number>**-year parts and labor warranty for each.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
- B. **Basis-of-Design Product:** Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
1. [Alerton Inc.](#)
 2. [American Auto-Matrix.](#)
 3. [Automated Logic Corporation.](#)
 4. [Delta Controls Inc.](#)
 5. [Honeywell International Inc.](#)
 6. [Invensys Building Systems.](#)
 7. [Johnson Controls, Inc.](#)
 8. [KMC Controls \(formerly Kreuter Manufacturing Company\).](#)
 9. [Siemens Building Technologies, Inc.](#)
 10. [Schneider Electric USA, Inc.](#)
 11. [Teletrol Systems Incorporated.](#)
 12. [Trane.](#)
 13. **<Insert manufacturer's name>.**

2.2 DDC SYSTEM DESCRIPTION

- A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.
1. DDC system shall consist of a[**high-speed,**] peer-to-peer network of distributed DDC controllers[, **other network devices**], operator interfaces, and software.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 WEB ACCESS

- A. DDC system shall be [**Web based**] [**or**] [**Web compatible**].
1. Web-Based Access to DDC System:
 - a. DDC system software shall be based on server thin-client architecture, designed around open standards of Web technology. DDC system server shall be accessed using a Web browser over DDC system network, using Owner's LAN, and remotely over Internet[**through Owner's LAN**].
 - b. Intent of thin-client architecture is to provide operators complete access to DDC system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
 - c. Web access shall be password protected.
 2. Web-Compatible Access to DDC System:
 - a. [**Operator workstation**] [**and**] [**or**] [**server**] shall perform overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.
 - b. DDC system shall support Web browser access to building data. Operator using a standard Web browser shall be able to access control graphics and change adjustable set points.
 - c. Web access shall be password protected.

2.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design DDC system to satisfy requirements indicated.
- B. Delegated Design: Engage a qualified professional to design DDC system to satisfy requirements indicated.

1. System Performance Objectives:
 - a. DDC system shall manage HVAC systems.
 - b. DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
 - c. DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
 - d. DDC system shall operate while unattended by an operator and through operator interaction.
 - e. DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.

- C. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 1. Flame-Spread Index: **[25]** <Insert value> or less.
 2. Smoke-Developed Index: **[50]** <Insert value> or less.

- D. DDC System Speed:
 1. Response Time of Connected I/O:
 - a. AI point values connected to DDC system shall be updated at least every **[five]** **[two]** seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
 - b. BI point values connected to DDC system shall be updated at least every **[five]** **[two]** <Insert number> seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
 - c. AO points connected to DDC system shall begin to respond to controller output commands within **[two]** **[one]** second(s). Global commands shall also comply with this requirement.
 - d. BO point values connected to DDC system shall respond to controller output commands within **[two]** **[one]** <Insert number> second(s). Global commands shall also comply with this requirement.

 2. Display of Connected I/O:
 - a. Analog point COV connected to DDC system shall be updated and displayed at least every **[10]** **[five]** <Insert number> seconds for use by operator.
 - b. Binary point COV connected to DDC system shall be updated and displayed at least every **[10]** **[five]** <Insert number> seconds for use by operator.
 - c. Alarms of analog and digital points connected to DDC system shall be displayed within **[45]** **[30]** **[15]** <Insert number> seconds of activation or change of state.

- d. Graphic display refresh shall update within [**eight**] [**four**] <Insert number> seconds.
 - e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.
- E. Network Bandwidth: Design each network of DDC system to include at least [**30**] <Insert number> percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.
- F. DDC System Data Storage:
1. Include server(s) with disk drive data storage to archive not less than [**24**] [**48**] [**60**] <Insert number> consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.
 2. When logged onto a server, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.
 3. Server(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.
 4. Server(s) shall use IT industry-standard database platforms such as Microsoft SQL Server and Microsoft Data Engine (MSDE).
- G. Future Expandability:
1. DDC system size shall be expandable to an ultimate capacity of at least [**two**] [**three**] [**four**] <Insert number> times total I/O points indicated.
 2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.
 3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.
- H. Input Point Displayed Accuracy: Input point displayed values shall meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.
1. Energy:
 - a. Thermal: Within [**5**] [**3**] [**1**] <Insert number> percent of reading.
 - b. Electric Power: Within [**1**] <Insert number> percent of reading.
 - c. Requirements indicated on Drawings for meters not supplied by utility.
 2. Flow:

- a. Air: Within [5] [2] <Insert number> percent of design flow rate.
 - b. Air (Terminal Units): Within [10] [5] <Insert number> percent of design flow rate.
 - c. Water: Within [2] [5] <Insert number> percent of design flow rate.
 - d. Steam: Within [5] <Insert number> percent of design flow rate.
3. Gas:
- a. Carbon Dioxide: Within [50] <Insert value> ppm.
 - b. Carbon Monoxide: Within [5] <Insert number> percent of reading.
 - c. Oxygen: Within [5] <Insert number> percent of reading.
 - d. Refrigerant: Within [50] <Insert value> ppm.
4. Moisture (Relative Humidity):
- a. Air: Within [5] [2] <Insert number> percent RH.
 - b. Space: Within [5] [2] <Insert number> percent RH.
 - c. Outdoor: Within [5] [2] <Insert number> percent RH.
5. Level: Within [5] [2] <Insert number> percent of reading.
6. Pressure:
- a. Air, Ducts and Equipment: [1] [0.5] <Insert number> percent of instrument [range] [span].
 - b. Space: Within [1] [0.5] [0.25] <Insert number> percent of instrument [range] [span].
 - c. Water: Within [1] [0.5] [0.25] <Insert number> percent of instrument [range] [span].
 - d. Steam: Within [1] [0.5] [0.25] <Insert number> percent of instrument [range] [span].
7. Speed: Within [10] [5] <Insert number> percent of reading.
8. Temperature, Dew Point:
- a. Air: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - b. Space: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - c. Outdoor: Within [3 deg F (1.5 deg C)] [2 deg F (1 deg C)] <Insert value>.
9. Temperature, Dry Bulb:
- a. Air: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - b. Space: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - c. Outdoor: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] <Insert value>.
 - d. Chilled Water: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - e. Condenser Water: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - f. Heating Hot Water: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.

- g. Energy Recovery Runaround Liquid: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - h. Steam: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] <Insert value>.
 - i. Temperature Difference: Within [0.25 deg F (0.15 deg C)] <Insert value>.
 - j. <Insert system>.
 - k. Other Temperatures Not Indicated: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
10. Temperature, Wet Bulb:
- a. Air: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - b. Space: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - c. Outdoor: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] <Insert value>.
11. Vibration: Within [5] [10] <Insert number> percent of reading.
- I. Precision of I/O Reported Values: Values reported in database and displayed shall have following precision:
- 1. Current:
 - a. Milliamperes: Nearest 1/100th of a milliampere.
 - b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.
 - 2. Energy:
 - a. Electric Power:
 - 1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
 - 2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
 - 3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.
 - b. Thermal, Rate:
 - 1) Heating: For Btu/h, nearest Btu/h up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For Mbh, round to nearest Mbh up to 1000 Mbh; nearest 10 Mbh between 1000 and 10,000 Mbh; nearest 100 Mbh above 10,000 Mbh (For watts, nearest watt up to 1000 W; for kilowatts, round to nearest kilowatt up to 1000 kW; nearest 10 kW between 1000 and 10,000 kW; nearest 100 kW for above 10,000 kW).
 - 2) Cooling: For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons (For watts, nearest watt up to 1000 W; for kilowatts, round to nearest kilowatt up to 1000 kW; nearest 10 kW between 1000 and 10,000 kW; nearest 100 kW for above 10,000 kW).

- c. Thermal, Usage:
 - 1) Heating: For Btu, nearest Btu up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For Mbtu, round to nearest Mbtu up to 1000 Mbtu; nearest 10 Mbtu between 1000 and 10,000 Mbtu; nearest 100 Mbtu above 10,000 Mbtu (For watt-hours, nearest watt-hour up to 1000 Wh; for kilowatt-hours, round to nearest kilowatt-hour up to 1000 kWh; nearest 10 kWh between 1000 and 10,000 kWh; nearest 100 kWh for above 10,000 kWh).
 - 2) Cooling: For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above 10,000 tons (For watt-hours, nearest watt-hour up to 1000 Wh; for kilowatt-hours, round to nearest kilowatt-hour up to 1000 kWh; nearest 10 kWh between 1000 and 10,000 kWh; nearest 100 kWh for above 10,000 kWh).
3. Flow:
 - a. Air: Nearest 1/10th of a cfm through 100 cfm; nearest cfm between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).
 - b. Water: Nearest 1/10th gpm through 100 gpm; nearest gpm between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).
 - c. Steam: Nearest 1/10th lb/hr through 100 lbs/hr; nearest lbs/hr between 100 and 1000 lbs/hr; nearest 10 lbs/hr above 1000 lbs/hr (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).
4. Gas:
 - a. Carbon Dioxide (ppm): Nearest ppm.
 - b. Carbon Monoxide (ppm): Nearest ppm.
 - c. Oxygen (Percentage): Nearest 1/10th of 1 percent.
 - d. Refrigerant (ppm): Nearest ppm.
5. Moisture (Relative Humidity):
 - a. Relative Humidity (Percentage): Nearest 1 percent.
6. Level: Nearest 1/100th of an inch through 10 inches; nearest 1/10 of an inch between 10 and 100 inches; nearest inch above 100 inches (Nearest 1/100th of a mm through 10 mm; nearest 1/10th of a mm between 10 and 100 mm; nearest mm above 100 mm).
7. Speed:

- a. Rotation (rpm): Nearest 1 rpm.
 - b. Velocity: Nearest 1/10th fpm through 100 fpm; nearest fpm between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm (Nearest 1/100th of a M/s through 10 M/s; nearest 1/10th of a M/s above 10 M/s).
8. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.
9. Pressure:
- a. Air, Ducts and Equipment: Nearest 1/10th in. w.c. (Nearest Pa up to 1000 Pa; nearest 10 Pa above 1000 Pa).
 - b. Space: Nearest 1/100th in. w.c. (Nearest 1/10th Pa).
 - c. Steam: Nearest 1/10th psig through 100 psig; nearest psig above 100 psig (Nearest kPa through 1000 kPa; nearest 10 kPa above 1000 kPa).
 - d. Water: Nearest 1/10 psig through 100 psig; nearest psig above 100 psig (Nearest kPa through 1000 kPa; nearest 10 kPa above 1000 kPa).
10. Temperature:
- a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
 - b. Outdoor: Nearest degree.
 - c. Space: Nearest 1/10th of a degree.
 - d. Chilled Water: Nearest 1/10th of a degree.
 - e. Condenser Water: Nearest 1/10th of a degree.
 - f. Heating Hot Water: Nearest degree.
 - g. Heat Recovery Runaround: Nearest 1/10th of a degree.
 - h. Steam: Nearest degree.
11. Vibration: Nearest 1/10th in/s (Nearest 1/10th mm/s).
12. Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.
- J. Control Stability: Control variables indicated within the following limits:
1. Flow:
 - a. Air, Ducts and Equipment, except Terminal Units: Within [5] [2] <Insert number> percent of design flow rate.
 - b. Air, Terminal Units: Within [10] [5] <Insert number> percent of design flow rate.
 - c. Water: Within [2] [5] <Insert number> percent of design flow rate.
 - d. Steam: Within [5] <Insert number> percent of design flow rate.
 2. Gas:
 - a. Carbon Dioxide: Within [50] <Insert value> ppm.
 - b. Carbon Monoxide: Within [5] <Insert number> percent of reading.
 - c. Oxygen: Within [5] <Insert number> percent of reading.
 3. Moisture (Relative Humidity):
 - a. Air: Within [5] [2] <Insert number> percent RH.

- b. Space: Within [5] [2] <Insert number> percent RH.
 - c. Outdoor: Within [5] [2] <Insert number> percent RH.
 4. Level: Within [5] [2] <Insert number> percent of reading.
 5. Pressure:
 - a. Air, Ducts and Equipment: [1] [0.5] <Insert number> percent of instrument [range] [span].
 - b. Space: Within [1] [0.5] [0.25] <Insert number> percent of instrument [range] [span].
 - c. Water: Within [1] [0.5] [0.25] <Insert number> percent of instrument [range] [span].
 - d. Steam: Within [1] [0.5] [0.25] <Insert number> percent of instrument [range] [span].
 6. Temperature, Dew Point:
 - a. Air: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - b. Space: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 7. Temperature, Dry Bulb:
 - a. Air: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - b. Space: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - c. Chilled Water: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - d. Condenser Water: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - e. Heating Hot Water: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - f. Energy Recovery Runaround Liquid: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - g. <Insert system>.
 8. Temperature, Wet Bulb:
 - a. Air: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
 - b. Space: Within [1 deg F (0.5 deg C)] [0.5 deg F (0.2 deg C)] <Insert value>.
- K. Environmental Conditions for Controllers, Gateways, and Routers:
 1. Products shall operate without performance degradation under ambient environmental temperature, pressure, and humidity conditions encountered for installed location.
 - a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions

impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.

2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: **[Type 2] [Type 3] [Type 12] <Insert type>**.
 - b. Outdoors, Unprotected: **[Type 4] [Type 4X]**.
 - c. Indoors, Heated with Filtered Ventilation: **[Type 1] [Type 2] <Insert type>**.
 - d. Indoors, Heated with Non-Filtered Ventilation: **[Type 2] [Type 12] <Insert type>**.
 - e. Indoors, Heated and Air Conditioned: **[Type 1] <Insert type>**.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: **[Type 12] [Type 4] [Type 4X] <Insert type>**.
 - 2) Air-Moving Equipment Rooms: **[Type 1] [Type 2] [Type 12] <Insert type>**.
 - g. Localized Areas Exposed to Washdown: **[Type 4] [Type 4X] <Insert type>**.
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: **[Type 2] [Type 3] [Type 12] <Insert type>**.
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: **[Type 4] [Type 4X] <Insert type>**.
 - j. Hazardous Locations: Explosion-proof rating for condition.
 - k. **<Insert location and enclosure requirements>**.
- L. Environmental Conditions for Instruments and Actuators:
 1. Instruments and actuators shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[, **cooled**] and ventilated as required by instrument and application.
 2. Instruments, actuators, and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments and actuators not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: **[Type 2] [Type 3] [Type 12] <Insert type>**.

- b. Outdoors, Unprotected: **[Type 4] [Type 4X]**.
- c. Indoors, Heated with Filtered Ventilation: **[Type 1] [Type 2] <Insert type>**.
- d. Indoors, Heated with Non-Filtered Ventilation: **[Type 2] [Type 12] <Insert type>**.
- e. Indoors, Heated and Air-conditioned: **[Type 1] <Insert type>**.
- f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: **[Type 12] [Type 4] [Type 4X] <Insert type>**.
 - 2) Air-Moving Equipment Rooms: **[Type 1] [Type 2] [Type 12] <Insert type>**.
- g. Localized Areas Exposed to Washdown: **[Type 4] [Type 4X] <Insert type>**.
- h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: **[Type 2] [Type 3] [Type 12] <Insert type>**.
- i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: **[Type 4] [Type 4X] <Insert type>**.
- j. Hazardous Locations: Explosion-proof rating for condition.
- k. **<Insert location and enclosure requirements>**.

M. DDC System Reliability:

- 1. Design, install and configure DDC controllers, **[gateways,] [routers,] [and] <Insert product>** to yield a MTBF of at least **[40,000] [20,000] <Insert number>** hours, based on a confidence level of at least **[90] <Insert number>** percent. MTBF value shall include any failure for any reason to any part of products indicated.
- 2. If required to comply with MTBF indicated, include DDC system and product redundancy to maintain DCC system, and associated systems and equipment that are being controlled, operational and under automatic control.
- 3. Critical systems and equipment that require a higher degree of DDC system redundancy than MTBF indicated shall be indicated on Drawings.

N. Electric Power Quality:

- 1. Power-Line Surges:
 - a. Protect **[susceptible]** DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
 - b. Do not use fuses for surge protection.
 - c. Test protection in the normal mode and in the common mode, using the following two waveforms:
 - 1) 10-by-1000-mic.sec. waveform with a peak voltage of 1500 V and a peak current of 60 A.
 - 2) 8-by-20-mic.sec. waveform with a peak voltage of 1000 V and a peak current of 500 A.
- 2. Power Conditioning:

- a. Protect [**susceptible**] DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:
 - 1) At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
 - 2) During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
 - 3) Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
 - 4) Total harmonic distortion shall not exceed 3-1/2 percent at full load.
 3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.
- O. Backup Power Source:
1. HVAC systems and equipment served by a backup power source shall have associated DDC system products that control such systems and equipment also served from a backup power source.
- P. UPS:
1. DDC system products powered by UPS units shall include the following:
 - a. Desktop operator workstations.
 - b. Printers.
 - c. Servers.
 - d. Gateways.
 - e. DDC controllers[, **except application-specific controllers**].
 2. DDC system instruments and actuators powered by UPS units shall include the following:
 - a. Instruments associated with the following systems controlled by DDC system:
 - 1) **<Insert list of systems>**.
 - b. Dampers and actuators associated with the following systems controlled by DDC system:
 - 1) **<Insert list of systems>**.
 - c. Valves and actuators associated with the following systems controlled by DDC system:
 - 1) **<Insert list of systems>**.

Q. Continuity of Operation after Electric Power Interruption:

1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.5 PANEL-MOUNTED, MANUAL OVERRIDE SWITCHES

A. Manual Override of Control Dampers:

1. Include panel-mounted, two-position, selector switch for each automatic control damper being controlled by DDC controller.
2. Label each switch with damper designation served by switch.
3. Label switch positions to indicate either "Manual" or "Auto" control signal to damper.
4. With switch in "Auto" position signal to control damper actuator shall be control loop output signal from DDC controller.
5. With switch in "Manual" position, signal to damper actuator shall be controlled at panel with either an integral or separate switch to include local control.
 - a. For Binary Control Dampers: Manual two-position switch shall have "Close" and "Open" switch positions indicated. With switch in "Close" position, damper shall close. With switch in "Open" position, damper shall open.
 - b. For Analog Control Dampers: A gradual switch shall have "Close" and "Open" switch limits indicated. Operator shall be able to rotate switch knob to adjust damper to any position from close to open.
6. DDC controller shall monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller shall signal an override condition to alert operator that damper is under manual, not automatic, control.
7. Configure manual override switches to allow operator to manually operate damper while at panel without DDC controller **[installed] [and] [operational]**.
8. Terminal equipment including **[VAV units,] [fan-coil units,] [and] [unit heaters]** do not require manual override unless otherwise indicated by sequence of operation.

B. Manual Override of Control Valves:

1. Include panel-mounted, two-position, selector switch for each automatic control valve being controlled by a DDC controller.
2. Label each switch with valve designation served by switch.
3. Label switch positions to indicate either "Manual" or "Auto" control signal to valve.
4. With switch in "Auto" position, signal to control-valve actuator shall be a control loop output signal from DDC controller.

5. With switch in "Manual" position, signal to valve actuator shall be controlled at panel with either an integral or a separate switch to include local control.
 - a. For Binary Control Dampers: Manual two-position switch shall have "Close" and "Open" switch positions indicated. With switch in "Close" position, damper shall close. With switch in "Open" position, damper shall open.
 - b. For Analog Control Dampers: A gradual switch shall have "Open" and "Close" switch limits indicated. Operator shall be able to rotate switch knob to adjust damper to any position from close to open.
6. DDC controller shall monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller shall signal an override condition to alert operator that valve is under manual, not automatic, control.
7. Configure manual override switches to allow operator to manually operate valve while at panel without DDC controller **[installed] [and] [operational]**.
8. Terminal equipment including **[VAV units,] [fan-coil units,] [and] [unit heaters]** do not require manual override unless otherwise indicated by sequence of operation.

2.6 SYSTEM ARCHITECTURE

- A. System architecture shall consist of no more than **[two] [or] [three] <Insert number>** levels of LANs.
 1. Level one LAN shall connect network controllers and operator workstations.
 2. **[Level one] [or] [Level two]** LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.
 3. **[Level two] [or] [Level three]** LAN shall connect application-specific controllers to programmable application controllers and network controllers.
 4. **[Level two] [or] [Level three]** LAN shall connect application-specific controllers to application-specific controllers.
- B. Minimum Data Transfer and Communication Speed:
 1. LAN Connecting Operator Workstations and Network Controllers: **[100] [10] [2.5] [1.25] <Insert value>** Mbps.
 2. LAN Connecting Programmable Application Controllers: **[1000] [100] <Insert value>** kbps.
 3. LAN Connecting Application-Specific Controllers: **[115,000] [76,800] [38,400] [19,200] <Insert value>** bps.
- C. DDC system shall consist of dedicated **[and separated]** LANs that are not shared with other building systems and tenant data and communication networks.
- D. System architecture shall be modular and have inherent ability to expand to not less than **[two] [three] <Insert number>** times system size indicated with no impact to performance indicated.

- E. System architecture shall perform modifications without having to remove and replace existing network equipment.
- F. Number of LANs and associated communication shall be transparent to operator. All I/O points residing on any LAN shall be capable of global sharing between all system LANs.
- G. System design shall eliminate dependence on any single device for system alarm reporting and control execution. Each controller shall operate independently by performing its' own control, alarm management and historical data collection.
- H. Special Network Architecture Requirements:
 - 1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is controlling air-handling system air-handling unit(s). Basically, create a DDC system LAN that aligns with air-handling system being controlled.
 - 2. **<Insert additional requirements>**.

2.7 DDC SYSTEM OPERATOR INTERFACES

- A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:
 - 1. Desktop and portable operator workstation with hardwired connection through LAN port.
 - 2. Portable operator terminal with hardwired connection through LAN port.
 - 3. Portable operator workstation with wireless connection through LAN router.
 - 4. PDA with wireless connection through LAN router.
 - 5. Remote connection using outside of system personal computer or PDA through Web access.
 - 6. Remote connection using portable operator workstation and telephone dial-up modem.
- B. Access to system, regardless of operator means used, shall be transparent to operator.
- C. Network Ports: For hardwired connection of desktop or portable operator workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:
 - 1. Each mechanical equipment room.
 - 2. Each boiler room.
 - 3. Each chiller room or outdoor chiller yard.
 - 4. Each cooling tower location.
 - 5. Each different roof level with roof-mounted air-handling units or rooftop units.
 - 6. Security system command center.
 - 7. Fire-alarm system command center.

D. Desktop Workstations:

1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2. Able to communicate with any device located on any DDC system LAN.
3. Able to communicate, with modems, remotely with any device connected to any DDC system LAN.
4. Communication via a modem shall not interfere with LAN activity and LAN activity shall not prevent workstation from handling incoming calls.

E. Portable Workstations:

1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2. Able to communicate with any device located on any DDC system LAN.
3. Connect to DDC system [**Level two**] [**or**] [**Level three**] LAN through a communications port on an application-specific controller, or a room temperature sensor connected to an application-specific controller.
4. Connect to system through a wireless router connected to Level one LAN.
5. Portable workstation shall be able to communicate with any device connected to any system LAN regardless of point of physical connection to system.
6. Monitor, program, schedule, adjust set points, and report capabilities of I/O connected anywhere in system.
7. Have dynamic graphic displays that are identical to desktop workstations.

F. POT:

1. Connect DDC controller through a communications port local to controller.
2. Able to communicate with any DDC system controller that is directly connected [**or with LAN**] [**or connected to DDC system**].

G. Personal Digital Assistant:

1. Connect to system through a wireless router connected to LAN.
2. Able to communicate with any DDC controller connected to DDC system.

H. Telephone Communications:

1. Through use of a standard modem, operator shall be able to communicate with any device connected to any system LAN.
2. Have auto-dial and auto-answer communications to allow desktop and portable workstations and DDC controllers to communicate with remote workstations and remote DDC controllers via telephone lines.

a. Desktop and Portable Operator Workstation Computers with Modems:

- 1) Operators shall be able to perform all control functions, report functions, and database generation and modification functions as if directly connected to system LAN.

- 2) Have routines to automatically answer calls, and either file or display information sent remotely.
- 3) Communications taking place over telephone lines shall be completely transparent to operator.
- 4) Dial-up program shall maintain a user-definable cross-reference and associated telephone numbers so it is not required to remember or manually dial telephone numbers.

b. DDC Controllers:

- 1) Not have modems unless specifically indicated for a unique controller.
- 2) Controllers with modems shall automatically place calls to report critical alarms, or to upload trend and historical information for archiving.
- 3) Analyze and prioritize alarms to minimize initiation of calls.
- 4) Buffer noncritical alarms in memory and report them as a group of alarms, or until an operator manually requests an upload.
- 5) Make provisions for handling busy signals, no-answers, and incomplete data transfers.
- 6) Call default devices when communications cannot be established with primary devices.

I. Critical Alarm Reporting:

1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
3. DDC system shall notify recipients by any or all means, including e-mail, text message, and prerecorded phone message to mobile and landline phone numbers.

J. Simultaneous Operator Use: Capable of accommodating up to **[five] [10] [20] <Insert number>** simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.8 NETWORKS

A. Acceptable networks for connecting operator workstations and network controllers include the following:

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. IP.
4. IEEE 8802-3, Ethernet.
5. **<Insert type>**.

- B. Acceptable networks for connecting programmable application controllers include the following:
1. ATA 878.1, ARCNET.
 2. CEA-709.1-C.
 3. IP.
 4. IEEE 8802-3, Ethernet.
 5. **<Insert type>**.
- C. Acceptable networks for connecting application-specific controllers include the following:
1. ATA 878.1, ARCNET.
 2. CEA-709.1-C.
 3. EIA-485A.
 4. IP.
 5. IEEE 8802-3, Ethernet.
 6. **<Insert type>**.

2.9 NETWORK COMMUNICATION PROTOCOL

- A. Network communication protocol(s) used throughout entire DDC system shall be open to public and available to other companies for use in making future modifications to DDC system.
- B. ASHRAE 135 Protocol:
1. ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.
 2. DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.
 3. If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
 4. Operator workstations, controllers, and other network devices shall be tested and listed by BACnet Testing Laboratories.
- C. CEA-709.1-C Protocol:
1. DDC system shall be an open implementation of LonWorks technology using CEA 709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for communication throughout DDC system.
 2. LNS shall be used for all network management including addressing and binding of network variables.
 - a. Final LNS database shall be submitted with Project closeout submittals.
 - b. All devices shall be online and commissioned into LNS database.

3. All devices connected to DDC system network(s) shall use CEA-709.1-C protocol and be installed so SCPT output from any node on network can be bound to any other node in the domain.

D. Industry Standard Protocols:

1. DDC system shall use any one or a combination of the following industry standard protocols for network communication while complying with other DDC system requirements indicated:
 - a. ASHRAE 135.
 - b. CEA-709.1-C.
 - c. Modbus Application Protocol Specification V1.1b.
 - d. **<Insert standard protocol>**.
2. Operator workstations [**and network controllers**] shall communicate through [**ASHRAE 135**] [**or**] [**CEA-709.1-C**] protocol.
3. Portions of DDC system networks using ASHRAE 135 communication protocol shall be an open implementation of network devices complying with ASHRAE 135. Network devices shall be tested and listed by BACnet Testing Laboratories.
4. Portions of DDC system networks using CEA-709.1-C communication protocol shall be an open implementation of LonWorks technology using CEA-709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for DDC system.
5. Portions of DDC system networks using Modbus Application Protocol Specification V1.1b communication protocol shall be an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b.
6. Gateways shall be used to connect networks and network devices using different protocols.

2.10 DDC SYSTEM WIRELESS NETWORKS

- A. Use [**Zigbee**] [**or**] [**an open industry standard and technology used by multiple DDC system manufacturers**] **<Insert wireless technology>** technology to create a wireless mesh network to provide wireless connectivity for network devices at multiple system levels including communications from programmable application controllers and application-specific controllers to temperature sensors and from network controllers to programmable application controllers and application-specific controllers.
- B. Installer shall design wireless networks to comply with DDC system performance requirements indicated. Wireless network devices shall co-exist on same network with hardwired devices.
- C. Hardwired controllers shall be capable of retrofit to wireless devices with no special software.
- D. A wireless coordinator shall provide a wireless interface between programmable application controllers, application-specific controllers, and network controllers.

E. Wireless Coordinators:

1. Each wireless mesh network shall use wireless coordinator(s) for initiation and formation of network.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to 47 CFR 15, Subpart B, Class A.
6. Operate as a bidirectional transceiver with sensors and routers to confirm and synchronize data transmission.
7. Capable of communication with sensors and routers up to a maximum distance of **250 feet (76 m)** in line of sight.
8. Include visual indicators to provide diagnostic information required for operator verification of operation.

F. Wireless Routers:

1. Each wireless mesh network shall use wireless routers with any controller to provide a wireless interface to a network controller, through a wireless coordinator.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to 47 CFR 15, Subpart B, Class A.
6. Operate as a bidirectional transceiver with other mesh network devices to ensure network integrity.
7. Capable of communication with other mesh network devices at a maximum distance of **250 feet (76 m)** in line of sight.
8. Include indication for use in commissioning and troubleshooting.

G. Wireless Temperature Sensors:

1. Wireless temperature sensors shall sense and transmit room temperatures, temperature set point, room occupancy notification and low battery condition to an associated router.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to CFR 15, Subpart B, Class A.
6. Include set point adjustment between **55 to 85 deg F (13 to 30 deg C)**.
7. Multiple sensors shall be able to report to a router connected to a DDC controller for averaging or high and low selection.

H. One-to-One Wireless Network Receivers:

1. One-to-one wireless receivers shall receive wireless RF signals containing temperature data from multiple wireless room temperature sensors and

communicate information to programmable application controllers or application-specific controllers.

- a. Use direct sequence spread spectrum RF technology.
- b. Operate on the 2.4-GHz ISM Band.
- c. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
- d. FCC compliant to 47 CFR 15, Subpart B, Class A.
- e. Operate as a bidirectional transceiver with the sensors to confirm and synchronize data transmission.
- f. Capable of communication up to a distance of 200 feet (61 m).
- g. Include visual indication of the following:
 - 1) Power.
 - 2) Receiver activity.
 - 3) Wireless RF transmission from wireless sensors.
 - 4) No transmission, weak signal, adequate signal or excellent signal.

I. One-to-One Wireless Network Sensors:

1. One-to-one wireless sensors shall sense and report room temperatures to one-to-one receiver.
 - a. Use direct sequence spread spectrum RF technology.
 - b. Operate on the 2.4-GHz ISM Band.
 - c. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
 - d. FCC compliant to CFR 15, Subpart B, Class A.
 - e. Include set point adjustment between 55 to 85 deg F (13 to 30 deg C).

2.11 DESKTOP OPERATOR WORKSTATIONS

A. Basis-of-Design Product: Subject to compliance with requirements, provide [Dell's "Precision T-series"] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. <Insert manufacturer's name>.

B. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.

C. Personal Computer:

1. Minimum Processor Speed: <Insert gigahertz>.
2. RAM:
 - a. Capacity: [24] [48] <Insert value> [GB] [TB].

- b. Speed and Type: **[1333]** <Insert value> MHz, <Insert type>.
 - c. Expandable Capacity: **[24]** **[72]** <Insert value> **[GB]** **[TB]**.
3. Hard Drive:
 - a. Number of Hard Drives: **[One]** **[Two]** <Insert number>.
 - b. Capacity: <Insert number and measurement unit>.
 - c. Minimum Average Seek Time: <Insert number and measurement unit>.
 - d. Cache Buffer Size: <Insert number and measurement unit>.
 - e. <Insert requirements>.
4. Second Hard Drive:
 - a. Capacity: <Insert number and measurement unit>.
 - b. Minimum Average Seek Time: <Insert number and measurement unit>.
 - c. Cache Buffer Size: <Insert number and measurement unit>.
 - d. <Insert requirements>.
5. Optical Drive:
 - a. Type: <Insert type>.
 - b. Minimum Average Access Time: <Insert number> ms.
 - c. Data Transfer Speed: <Insert number> **[MB]** **[TB]**/s.
 - d. Reading Formats: Data, audio, recordable, <Insert other> and rewritable.
6. Optical Read and Write Drive:
 - a. Include with at least 2 MB of data buffer.
 - b. Type: <Insert type>.
 - c. Minimum Data Buffer Capacity: <Insert number and measurement unit>.
 - d. Minimum Average Access Time: <Insert number> ms.
 - e. Nominal Data Transfer Rates:
 - 1) Reading: <Insert number> **[MB]** **[TB]**/s.
 - 2) Writing: <Insert number> **[MB]** **[TB]**/s.
 - f. Average access time of 150 ms or less.
 - g. MTBF of at least 100,000 power-on hours.
7. At least four expansion slots of **[32]** **[64]** <Insert number> bit.
8. Video Card:
 - a. Resolution: **[1920 by 1200]** <Insert values> pixels.
 - b. RAM: <Insert number> **[MB]** **[GB]** **[TB]**.
 - c. Controller Speed: <Insert number> **[MHz]** **[GHz]**.
 - d. On-Board Memory Speed: <Insert number> **[MHz]** **[GHz]**.
 - e. On-Board Memory Data Width: <Insert number> bit.
9. Sound Card:
 - a. At least 128 voice wavetable synthesis.

- b. Capable of delivering three-dimensional sound effects.
 - c. High-resolution 16-bit stereo digital audio recording and playback with user-selectable sample rates up to 48,000 Hz.
 - 10. Network Interface Card: Include card with connection, as applicable.
 - a. 10-100-1000 base TX Ethernet with RJ45 connector port.
 - b. 100 base FX Ethernet with SC or ST port.
 - 11. Cable Modem:
 - a. **<Insert number>** Mbps.
 - b. Certified to comply with DOCSIS Cable Modem to Customer Premise Equipment Interface Specification, Version 3.0 and backward compatible with earlier versions.
 - c. **[Ethernet] [or] [USB]** connectivity.
 - 12. Optical Modem: Full duplex link for connection to fiber-optic cable provided.
 - 13. I/O Ports:
 - a. Two second-generation USB 2.0 ports on front panel, six on back panel, and three internal on motherboard.
 - b. One serial port.
 - c. One parallel port.
 - d. Two PS/2 ports.
 - e. One RJ-45.
 - f. One stereo line-in and headphone line-out on back panel.
 - g. One microphone and headphone connector on front panel.
 - h. One IEEE 1394 on front and back panel with PCI-e card.
 - i. One ESATA port on back panel.
 - 14. Battery: Life of at least three years to maintain system clock/calendar and ROM, as a minimum.
- D. Keyboard:
- 1. 101 enhanced keyboard.
 - 2. Full upper- and lowercase ASCII keyset, numeric keypad, dedicated cursor control keypad, and 12 programmable function keys.
 - 3. Wireless operation within up to **72 inches (1800 mm)** in front of workstation.
- E. Pointing Device:
- 1. Either a two- or three-button mouse.
 - 2. Wireless operation within up to **72 inches (1800 mm)** in front of workstation.
- F. Flat Panel Display Monitor:
- 1. Display:
 - a. Color display with **<Insert inches (mm)>** diagonal viewable area.

- b. **[Digital] [or] [analog]** input signal.
- c. Aspect Ratio: **[16 to 9] <Insert value>**.
- d. Antiglare display.
- e. Response Time: **<Insert number>** ms.
- f. Dynamic Contrast Ratio: **[50000 to 1] <Insert ratio>**.
- g. Brightness: **[250 cd/sq. m] <Insert value>**.
- h. Tilt adjustable base.
- i. Energy Star compliant.
- j. Resolution: **[1920 by 1080] <Insert value>** pixels at 60 Hz with pixel size of **[0.277] <Insert number>** mm or smaller.
- k. Number of Displays: **[One] [Two] <Insert number>**.

G. Speakers:

1. Two, with individual controls for volume, bass and treble.
2. Signal to Noise Ratio: At least 65 dB.
3. Power: At least 4 W per speaker/channel.
4. Magnetic shielding to prevent distortion on the video monitor.

H. I/O Cabling: Include applicable cabling to connect I/O devices.

2.12 PORTABLE OPERATOR WORKSTATIONS

A. Basis-of-Design Product: Subject to compliance with requirements, provide **[Dell's "Latitude"] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:

1. **<Insert manufacturer's name>**.

B. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.
3. Hardware and software shall support local downloading to DDC controllers.
4. Data transfer rate to DDC controller shall be at network speed.

C. Processor:

1. Minimum Processor Speed: **<Insert gigahertz>**.
2. RAM:
 - a. Capacity: **<Insert value> [GB] [TB]**.
 - b. Speed and Type: **<Insert value> MHz, <Insert type>**.
 - c. Expandable Capacity: **<Insert value> [GB] [TB]**.
3. Hard Drive:
 - a. Number of Hard Drives: **[One] [Two] <Insert number>**.
 - b. Capacity: **<Insert number and measurement unit>**.

- c. Minimum Average Seek Time: **<Insert number and measurement unit>**.
 - d. Cache Buffer Size: **<Insert number and measurement unit>**.
 - e. **<Insert requirements>**.
4. Video Card: **<Insert number and measurement unit>** of RAM.
- D. Input and Output Ports:
 1. Serial port.
 2. Shared port for external keyboard or mouse.
 3. Four USB 2.0 ports.
 4. Ethernet port.
 5. IEEE 1394 integrated port.
 6. Serial infrared communications port.
- E. Battery:
 1. 9-cell, 81 Wh lithium ion battery and ac adapter.
 2. Battery life of at least three years.
 3. Battery charge time of less than three hours.
 4. Spare Battery(ies). **[One] [Two]**.
- F. Keyboard:
 1. 85-key **[backlit]** keyboard.
 2. Full upper- and lowercase ASCII keyset.
- G. Integral Pointing Device: Touchpad with two buttons or equivalent pointing device.
- H. Display:
 1. **<Insert inches (mm)>** diagonal or larger high-definition WLED color display.
 2. Antiglare screen.
 3. **[1920 by 1080]** **<Insert value>** pixel resolution.
 4. Brightness: 300 nits.
- I. Network Interface Card: Include card with connection, as application.
 1. 10-100-1000 base TX Ethernet with RJ45 connector port.
 2. 100 base FX Ethernet with SC or ST port.
- J. Digital Video Disc Rewrite Recorder (DVD+/-RW):
 1. Compatible with DVD disks and data, audio, recordable, and rewritable compact disks.
 2. Nominal Data Transfer Rates:
 - a. Reading: **<Insert number> [MB] [TB]/s**.
 - b. Writing: **<Insert number> [MB] [TB]/s**.
 3. 160-ms access time.

K. Accessories:

1. Leather carrying case.
2. Docking station.
3. Wireless-N communication card.
4. Bluetooth module with 2.1 standard technologies.
5. Mobile broadband card.
6. Wireless optical mouse.
7. **<Insert value> [GB] [TB]** portable hard drive.
8. Light-sensitive Web cam and noise-cancelling digital array microphone.
9. Cable with network jackets on each end. Minimum cable length shall be **<Insert length>**.

2.13 POT

- A. Description: Handheld device with integral keypad or touch screen operator interface.
- B. Display: Multiple lines of text display for use in operator interaction with DDC system.
- C. Cable: Flexible **[coiling]** cable, at least **36 inches (900 mm)** long, with a plug-in jack for connection to DDC controllers, network ports or instruments with an integral LAN port. As an alternative to hardwired connection, POT shall be accessible to DDC controllers through a wireless network connection.
- D. POT shall be powered through network connection.
- E. Connection of POT to DDC system shall not interrupt or interfere with normal network operation in any way, prevent alarms from being transmitted, or preclude central initiated commands and system modification.
- F. POT shall give operator the ability to do the following:
 1. Display and monitor BI point status.
 2. Change BO point set point (on or off, open or closed).
 3. Display and monitor analog point values.
 4. Change analog control set points.
 5. Command a setting of AO point.
 6. Display and monitor I/O point in alarm.
 7. Add a new or delete an existing I/O point.
 8. Enable and disable I/O points, initiators, and programs.
 9. Display and change time and date.
 10. Display and change time schedules.
 11. Display and change run-time counters and run-time limits.
 12. Display and change time and event initiation.
 13. Display and change control application and DDC parameters.
 14. Display and change programmable offset values.
 15. Access DDC controller initialization routines and diagnostics.
 16. **<Insert requirements>**.

2.14 SERVERS

- A. Basis-of-Design Product: Subject to compliance with requirements, provide **[Dell's "PowerEdge T series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
1. <Insert manufacturer's name>.
- B. Performance Requirements:
1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
 2. Energy Star compliant.
 3. Minimum Processor Speed: <Insert gigahertz>.
 4. RAM:
 - a. Capacity: <Insert value> [GB] [TB].
 - b. Speed and Type: <Insert value> MGz, <Insert type>.
 - c. Expandable Capacity: <Insert value> [GB] [TB].
 5. Redundant Array of Independent Disks: [Zero] [One] [Two] [Three] [Four] [Five] <Insert number> configuration.
 6. Drive Bays: Eight at 2.5 inches (65 mm) or eight at 3.5 inches (90 mm).
 7. Hard-Drive Storage: [Two] [Three] [Four] drives each with <Insert value> [GB] [TB] storage and nominal rotational speed of 7200 rpm.
 8. Network Interface: Dual port Ethernet.
 9. DVD +RW Drive.
 10. Color, flat-screen display with <Insert inches (mm)> diagonal viewable area.
 11. Keyboard and mouse.
 12. Next-day on-site warranty for [two] [three] <Insert number>-year period following Substantial Completion.
- C. Servers shall include the following:
1. Full-feature backup server (server and backup minimum requirement).
 2. Software licenses.
 3. CAT-5e or CAT-6 cable installation between server(s) and network.
- D. Web Server:
1. If required to be separate, include Web server hardware and software to match, except backup server is not required.
 2. Firewalls between server Web and networks.
 3. Password protection for access to server from Web server.
 4. CAT-5e or CAT 6 cable installation between the server(s) and building Ethernet network.
- E. Power each server through a [dedicated] UPS unit.

2.15 PRINTERS

A. Black and White Laser Printer:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hewlett-Packard Company's "LazerJet 2420 Series"] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.
2. **[1200 by 1200] <Insert value>** dots per inch resolution.
3. First sheet printed within 10 seconds.
4. **<Insert number>** page per minute rated print speed at best quality mode.
5. Print buffer with at least **<Insert value>** MB of RAM, expandable to at least 288 MBs.
6. Complies with Energy Star requirements.
7. Capable of handling letter- and legal-size paper and overhead transparencies.
8. Two paper trays; one tray with **<Insert number>** sheet capacity, and one tray with **<Insert number>** sheet capacity.
9. At least **<Insert number>** page toner/cartridge capacity.

B. Color Laser Printer:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hewlett-Packard Company's "LazerJet CP4025dn Series"] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.
2. **[1200 by 1200] <Insert value>** dots per inch resolution black and white, **[1200 by 1200] <Insert value>** dots per inch resolution black and white and color.
3. First sheet printed within 10 seconds.
4. **<Insert number>** page per minute rated print speed at best quality mode.
5. Print buffer with at least **[512] <Insert value>** MB of RAM, expandable to at least **[one] <Insert value>** GB.
6. Complies with Energy Star requirements.
7. Capable of handling letter- and legal-size paper and overhead transparencies.
8. Two paper trays; one tray with **<Insert number>** sheet capacity, and one tray with **500 <Insert number>** sheet capacity.
9. Two-sided printing.
10. At least **<Insert number>** page toner/cartridge capacity.

C. Color Inkjet Printer:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hewlett-Packard Company's "InkJet 2800dt Series"] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:

- a. **<Insert manufacturer's name>**.
 2. Inkjet technology with true four-color printing (black, cyan, magenta, and yellow).
 3. Print quality of [**1200 by 600**] **<Insert value>** dots per inch with black on inkjet paper and [**4800 by 1200**] **<Insert value>** dots per inch color printing on premium photo paper.
 4. Rated speed of **<Insert number>** pages per minute printing black and white in normal mode and **<Insert number>** pages per minute printing color in normal mode.
 5. Two paper trays; one tray with **<Insert number>** sheet capacity, and one tray with **<Insert number>** sheet capacity.
 6. Capable of handling letter- and legal-size paper and overhead transparencies.
 7. **<Insert number>** MB of RAM.
 8. Duplex printing (printing on both sides of paper).
- D. Dot Matrix Printer:
1. Basis-of-Design Product: Subject to compliance with requirements, provide [**Epson America Inc.'s "LQ-2090"**] **<Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.
 2. Letter-quality, wide-carriage, 24-pin dot matrix printer.
 3. **<Insert number>** kb print buffer.
 4. Minimum Print Speed:
 - a. 330 characters per second (draft).
 - b. 110 characters per second (letter quality).
 5. Seven print fonts.
 6. Continuous - forms feed with manual single sheet feed.
 7. Capable of handling **16-inch-** (400-mm-) wide continuous-feed paper.

2.16 SYSTEM SOFTWARE

- A. System Software Minimum Requirements:
1. Real-time multitasking and multiuser [**32-**] [**or**] [**64-**]bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
 2. Operating system shall be capable of operating DOS and Microsoft Windows applications.
 3. Database management software shall manage all data on an integrated and non-redundant basis. Additions and deletions to database shall be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.

4. Network communications software shall manage and control multiple network communications to provide exchange of global information and execution of global programs.
5. Operator interface software shall include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
6. Scheduling software shall schedule centrally based time and event, temporary, and exception day programs.

B. Operator Interface Software:

1. Minimize operator training through use of English language pronouncing and English language point identification.
2. Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.
3. Operator sign-off shall be a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Automatic sign-off period shall be programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Operator sign-on and sign-off activity shall be recorded and sent to printer.
6. Security Access:
 - a. Operator access to DDC system shall be under password control.
 - b. An alphanumeric password shall be field assignable to each operator.
 - c. Operators shall be able to access DDC system by entry of proper password.
 - d. Operator password shall be same regardless of which computer or other interface means is used.
 - e. Additions or changes made to passwords shall be updated automatically.
 - f. Each operator shall be assigned an access level to restrict access to data and functions the operator is capable of performing.
 - g. Software shall have at least five access levels.
 - h. Each menu item shall be assigned an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
 - i. Display menu items to operator with those capable of access highlighted. Menu and operator access level assignments shall be online programmable and under password control.
7. Data Segregation:
 - a. Include data segregation for control of specific data routed to a workstation, to an operator or to a specific output device, such as a printer.
 - b. Include at least [32] **<Insert number>** segregation groups.
 - c. Segregation groups shall be selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
 - d. Points shall be assignable to multiple segregation groups. Display and output of data to printer or monitor shall occur where there is a match of

- operator or peripheral segregation group assignment and point segregations.
- e. Alarms shall be displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.
 - f. Operators and peripherals shall be assignable to multiple segregation groups and all assignments are to be online programmable and under password control.
8. Operators shall be able to perform commands including, but not limited to, the following:
- a. Start or stop selected equipment.
 - b. Adjust set points.
 - c. Add, modify, and delete time programming.
 - d. Enable and disable process execution.
 - e. Lock and unlock alarm reporting for each point.
 - f. Enable and disable totalization for each point.
 - g. Enable and disable trending for each point.
 - h. Override control loop set points.
 - i. Enter temporary override schedules.
 - j. Define holiday schedules.
 - k. Change time and date.
 - l. Enter and modify analog alarm limits.
 - m. Enter and modify analog warning limits.
 - n. View limits.
 - o. Enable and disable demand limiting.
 - p. Enable and disable duty cycle.
 - q. Display logic programming for each control sequence.
 - r. **<Insert requirements>**.
9. Reporting:
- a. Generated automatically and manually.
 - b. Sent to displays, printers, and disk files.
 - c. Types of Reporting:
 - 1) General listing of points.
 - 2) List points currently in alarm.
 - 3) List of off-line points.
 - 4) List points currently in override status.
 - 5) List of disabled points.
 - 6) List points currently locked out.
 - 7) List of items defined in a "Follow-Up" file.
 - 8) List weekly schedules.
 - 9) List holiday programming.
 - 10) List of limits and deadbands.
10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

1. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable (for example, site, building, floor, air-handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.
2. Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface shall use a pointing device with pull-down or penetrating menus, color, and animation to facilitate operator understanding of system.
3. Include at least 10 levels of graphic penetration with the hierarchy operator assignable.
4. Descriptors for graphics, points, alarms, and such shall be modified through operator's workstation under password control.
5. Graphic displays shall be online user definable and modifiable using the hardware and software provided.
6. Data to be displayed within a graphic shall be assignable regardless of physical hardware address, communication or point type.
7. Graphics are to be online programmable and under password control.
8. Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation.
9. Graphics shall also contain software points.
10. Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding.
11. Back-trace feature shall permit operator to move upward in the hierarchy using a pointing device. Back trace shall show all previous penetration levels. Include operator with option of showing each graphic full screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.
12. Display operator accessed data on the monitor.
13. Operator shall select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Defined and linked graphic below that selection shall then be displayed.
14. Include operator with means to directly access graphics without going through penetration path.
15. Dynamic data shall be assignable to graphics.
16. Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.
17. Use color, rotation, or other highly visible means, to denote status and alarm states. Color shall be variable for each class of points, as chosen by operator.
18. Points shall be dynamic with operator adjustable update rates on a per point basis from [one] <Insert value> second to over a [minute] <Insert value>.
19. For operators with appropriate privilege, points shall be commanded directly from display using pointing device.
 - a. For an analog command point such as set point, current conditions and limits shall be displayed and operator can position new set point using pointing device.

- b. For a digital command point such as valve position, valve shall show its current state such as open or closed and operator could select alternative position using pointing device.
 - c. Keyboard equivalent shall be available for those operators with that preference.
 - 20. Operator shall be able to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot and other information on other quadrants on screen. This feature shall allow real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.
 - 21. Help Features:
 - a. On-line context-sensitive help utility to facilitate operator training and understanding.
 - b. Bridge to further explanation of selected keywords. Document shall contain text and graphics to clarify system operation.
 - 1) If help feature does not have ability to bridge on keywords for more information, a complete set of user manuals shall be provided in an indexed word-processing program, which shall run concurrently with operating system software.
 - c. Available for Every Menu Item:
 - 1) Index items for each system menu item.
 - 22. Graphic generation software shall allow operator to add, modify, or delete system graphic displays.
 - a. Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols[**similar to those indicated**].
 - b. Graphic development package shall use a pointing device in conjunction with a drawing program to allow operator to perform the following:
 - 1) Define background screens.
 - 2) Define connecting lines and curves.
 - 3) Locate, orient, and size descriptive text.
 - 4) Define and display colors for all elements.
 - 5) Establish correlation between symbols or text and associated system points or other displays.
- D. Project-Specific Graphics: Graphics documentation including, but not limited to, the following:
- 1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.

2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:
 - a. Room layouts with room identification and name.
 - b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
 - c. Location and identification of each hardware point being controlled or monitored by DDC system.
 - d. **<Insert requirements>**.
3. Control schematic for each of following, including a graphic system schematic representation[, **similar to that indicated on Drawings,**] with point identification, set point and dynamic value indication[, **sequence of operation**] [**and**] [**control logic diagram**].
4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, [**gateways**] [**operator workstations**] [**and**] [**other network devices**].

E. Customizing Software:

1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned.
2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
3. As a minimum, include the following modification capability:
 - a. Operator assignment shall include designation of operator passwords, access levels, point segregation, and auto sign-off.
 - b. Peripheral assignment capability shall include assignment of segregation groups and operators to consoles and printers, designation of backup workstations and printers, designation of workstation header points and enabling and disabling of printout of operator changes.
 - c. System configuration and diagnostic capability shall include communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of command trace to points and application programs and initiation of diagnostics.
 - d. System text addition and change capability shall include English or native language descriptors for points, segregation groups and access levels and action messages for alarms, run time and trouble condition.
 - e. Time and schedule change capability shall include time and date set, time and occupancy schedules, exception and holiday schedules and daylight savings time schedules.
 - f. Point related change capability shall include the following:

- 1) System and point enable and disable.
 - 2) Run-time enable and disable.
 - 3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
 - 4) Assignment of alarm and warning limits.
- g. Application program change capability shall include the following:
- 1) Enable and disable of software programs.
 - 2) Programming changes.
 - 3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.
4. Software shall allow operator to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Additions and modifications shall be online programmable using operator workstation, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, database shall be uploaded and recorded on hard drive and disk for archived record.
5. Include high-level language programming software capability for implementation of custom DDC programs. Software shall include a compiler, linker, and up- and down-load capability.
6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences. Also include, as a minimum, the following:
- a. Proportional control (P).
 - b. Proportional plus integral (PI).
 - c. Proportional plus integral plus derivative (PID).
 - d. Adaptive and intelligent self-learning control.
- 1) Algorithm shall monitor loop response to output corrections and adjust loop response characteristics according to time constant changes imposed.
 - 2) Algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of system dynamics so that on system shut down and restart, learning process starts from where it left off.
7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select AO, analog controlled digital output, analog control AO, and digitally controlled AO.
8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.
9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.
10. Relational operators such as "Equal To," "Not Equal To," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.

F. Alarm Handling Software:

1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers[, **gateways**] [**and other network devices**].
2. Include first in, first out handling of alarms according to alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.
3. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
4. Alarms display shall include the following:
 - a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."
 - b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."
 - c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."
 - d. Include extended message capability to allow assignment and printing of extended action messages. Capability shall be operator programmable and assignable on a per point basis.
5. Alarms shall be directed to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.
6. Send e-mail alarm messages to designated operators.
7. Send e-mail, page, text and voice messages to designated operators for critical alarms.
8. Alarms shall be categorized and processed by class.
 - a. Class 1:
 - 1) Associated with fire, security and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.
 - 2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
 - 3) All conditions shall cause an audible sound and shall require individual acknowledgment to silence audible sound.
 - b. Class 2:
 - 1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
 - 2) Acknowledgement may be through a multiple alarm acknowledgment.
 - c. Class 3:
 - 1) General alarms; printed, displayed and placed in unacknowledged alarm buffer queues.

- 2) Each new alarm received shall cause an audible sound. Audible sound shall be silenced by "acknowledging" alarm or by pressing a "silence" key.
- 3) Acknowledgement of queued alarms shall be either on an individual basis or through a multiple alarm acknowledgement.
- 4) Alarms returning to normal condition shall be printed and not cause an audible sound or require acknowledgment.

d. Class 4:

- 1) Routine maintenance or other types of warning alarms.
 - 2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.
9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator shall be able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.
10. To ensure that no alarm records are lost, it shall be possible to assign a backup printer to accept alarms in case of failure of primary printer.

G. Reports and Logs:

1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available.
2. Each report shall be definable as to data content, format, interval, and date.
3. Report data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on **[workstation]** **[server]** for historical reporting.
4. Operator shall be able to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, or normal.
5. Reports and logs shall be stored on **[workstation]** **[and]** **[server]** hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.
6. Reports and logs shall be readily printed and set to be printed either on operator command or at a specific time each day.

H. Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.

1. All I/O: With current status and values.
2. Alarm: All current alarms, except those in alarm lockout.
3. Disabled I/O: All I/O points that are disabled.
4. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
5. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
6. Logs:
 - a. Alarm history.
 - b. System messages.
 - c. System events.

d. Trends.

- I. Custom Reports: Operator shall be able to easily define any system data into a daily, weekly, monthly, or annual report. Reports shall be time and date stamped and shall contain a report title.
- J. Tenant Override Reports: Prepare Project-specific reports.
 1. Weekly report showing daily total time in hours that each tenant has requested after-hours HVAC.
 2. Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC.
 3. Annual summary report that shows after-hours HVAC usage on a monthly basis.
- K. HVAC Equipment Reports: Prepare Project-specific reports.
 1. Chiller Report: Daily report showing operating conditions of each chiller according to ASHRAE 147, including, but not limited to, the following:
 - a. Chilled-water entering temperature.
 - b. Chilled-water leaving temperature.
 - c. Chilled-water flow rate.
 - d. Chilled-water inlet and outlet pressures.
 - e. Evaporator refrigerant pressure and temperature.
 - f. Condenser refrigerant pressure and liquid temperature.
 - g. Condenser-water entering temperature.
 - h. Condenser-water leaving temperature.
 - i. Condenser-water flow rate.
 - j. Refrigerant levels.
 - k. Oil pressure and temperature.
 - l. Oil level.
 - m. Compressor refrigerant discharge temperature.
 - n. Compressor refrigerant suction temperature.
 - o. Addition of refrigerant.
 - p. Addition of oil.
 - q. Vibration levels or observation that vibration is not excessive.
 - r. Motor amperes per phase.
 - s. Motor volts per phase.
 - t. Refrigerant monitor level (PPM).
 - u. Purge exhaust time or discharge count.
 - v. Ambient temperature (dry bulb and wet bulb).
 - w. Date and time logged.
 2. **<Insert requirements for each type of HVAC equipment requiring a report>.**
- L. Utility Reports: Prepare Project-specific reports.
 1. Electric Report:

- a. Include weekly report showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
 - b. Include monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each meter.
 - c. Include annual report showing the monthly electrical consumption and peak electrical demand with time and date stamp for each meter.
 - d. For each weekly, monthly, and annual report, include sum total of submeters combined by load type, such as lighting, receptacles, and HVAC equipment showing daily electrical consumption and peak electrical demand.
 - e. For each weekly, monthly, and annual report, include sum total of all submeters in building showing electrical consumption and peak electrical demand.
2. Natural Gas Report:
- a. Include weekly report showing daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
 - b. Include monthly report showing the daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
 - c. Include annual report showing the monthly natural gas consumption and peak natural gas demand with time and date stamp for each meter.
 - d. For each weekly, monthly, and annual report, include sum total of submeters combined by load type, such as boilers and service water heaters showing daily natural gas consumption and peak natural gas demand.
 - e. For each weekly, monthly, and annual report, include sum total of all submeters in building showing natural gas consumption and peak natural gas demand.
3. Service Water Report:
- a. Include weekly report showing daily service water consumption and peak service water demand with time and date stamp for each meter.
 - b. Include monthly report showing the daily service water consumption and peak service water demand with time and date stamp for each meter.
 - c. Include annual report showing the monthly service water consumption and peak service water demand with time and date stamp for each meter.
 - d. For each weekly, monthly, and annual report, include sum total of submeters combined by load type, such as cooling tower makeup and irrigation showing daily service water consumption and peak service water demand.
 - e. For each weekly, monthly, and annual report, include sum total of all submeters in building showing service water consumption and peak service water demand.
4. **<Insert requirements for each utility requiring a report>.**
- M. Energy Reports: Prepare Project-specific daily, weekly, monthly [**and annual**] [, **annual and since-installed**] energy reports.

1. Prepare report for each purchased energy utility, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Consumption in units of measure commonly used to report specific utility consumption over time.
 - c. Gross area served by utility.
 - d. Consumption per unit area served using utility-specific unit of measure.
 - e. Cost per utility unit.
 - f. Utility cost per unit area.
 - g. Convert all utilities to a common energy consumption unit of measure and report for each utility.
 - h. Consumption per unit area using common unit of measure.

2. Prepare report for each renewable energy source, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Harvested energy in units of measure commonly used to report specific harvested energy consumption over time.
 - c. Gross area served by renewable energy source.
 - d. Harvested energy per unit area served using specific unit of measure.
 - e. Cost per purchased utility unit displaced by renewable energy.
 - f. Cost savings attributed to harvested energy source.
 - g. Cost savings per unit area attributed to harvested energy.
 - h. Convert all renewable energy sources to a common energy consumption unit of measure and report for each.
 - i. Harvested energy per unit area using common unit of measure.

3. Prepare purchased energy utility report for each submetered area that indicates the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Gross area served.
 - c. Energy consumption by energy utility type.
 - d. Energy consumption per unit area by energy utility type.
 - e. Total energy consumption of all utilities in common units of measure.
 - f. Total energy consumption of all utilities in common units of measure per unit area.
 - g. Unit energy cost by energy utility type.
 - h. Energy cost by energy utility type.
 - i. Energy cost per unit area by energy utility type.
 - j. Total cost of all energy utilities.
 - k. Total cost of all energy utilities per unit area.

4. Prepare Project total purchased energy utility report that combines all purchased energy utilities and all areas served. Project total energy report shall indicate the following:

- a. Time period being reported with beginning and end date, and time indicated.
 - b. Gross area served.
 - c. Energy consumption by energy utility type.
 - d. Energy consumption per unit area by energy utility type.
 - e. Total energy consumption of all utilities in common units of measure.
 - f. Total energy consumption of all utilities in common units of measure per unit area.
 - g. Unit energy cost by energy utility type.
 - h. Energy cost by energy utility type.
 - i. Energy cost per unit area by energy utility type.
 - j. Total cost of all energy utilities.
 - k. Total cost of all energy utilities per unit area.
- N. HVAC System Efficiency Reports: Prepare Project-specific [**daily**] [**weekly**] [**monthly**] [**and annual**] [, **annual and since-installed**] HVAC system efficiency reports.
1. Prepare report for [**each**] chilled-water system, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Cooling energy supplied during time period.
 - c. Power energy consumed during time period by cooling equipment used to produce cooling energy supplied. [**List power consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
 - d. Energy efficiency coefficient of performance determined by dividing power energy consumed into cooling energy supplied.
 - e. Energy efficiency determined by dividing cooling energy supplied into power energy consumed.
 - f. Units of measure used in report shall be consistent with units indicated for system.
 2. Prepare report for [**each**] hot-water system, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Cooling energy supplied during time period.
 - c. Fuel consumed during time period by boilers used to produce heating energy supplied. [**List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
 - d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
 - e. Units of measure used in report shall be consistent with units indicated for system.
 3. Prepare report for [**each**] steam system, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.

- b. Cooling energy supplied during time period.
 - c. Fuel consumed during time period by boilers used to produce heating energy supplied. [**List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
 - d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
 - e. Units of measure used in report shall be consistent with units indicated for system.
4. <Insert requirements for each HVAC system requiring a report>.
- O. PUE Reports: Prepare Project-specific [daily] [weekly] [monthly] [and annual] [, **annual and since-installed**] PUE reports.
1. Prepare separate report for each [tenant] <Insert category>.
 2. Prepare Project PUE report that combines PUE and all tenants served.
 3. Calculate PUE following guidelines in [The Green Grid, White Paper No. 22] <Insert requirements>.
- P. Weather Reports:
1. Include daily report showing the following:
 - a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of [55 deg F (13 deg C)] <Insert temperature>.
 - e. Number of cooling degree-days for each day calculated from a base temperature of [65 deg F (18 deg C)] <Insert temperature>.
 - f. Daily minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
 2. Include weekly report showing the following:
 - a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of [55 deg F (13 deg C)] <Insert temperature>.
 - e. Number of cooling degree-days for each day calculated from a base temperature of [65 deg F (18 deg C)] <Insert temperature>.
 - f. Weekly minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
 3. Include monthly report showing the following:

- a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of [55 deg F (13 deg C)] <Insert temperature>.
 - e. Number of cooling degree-days for each day calculated from a base temperature of [65 deg F (18 deg C)] <Insert temperature>.
 - f. Monthly minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
4. Include annual (12-month) report showing the following:
- a. Monthly minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Monthly minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Monthly minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each month calculated from a base temperature of [55 deg F (13 deg C)] <Insert temperature>.
 - e. Number of cooling degree-days for each month calculated from a base temperature of [65 deg F (18 deg C)] <Insert temperature>.
 - f. Annual minimum, maximum, and average outdoor carbon dioxide level.
 - g. Monthly minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.

Q. Standard Trends:

1. Trend all I/O point present values, set points, and other parameters indicated for trending.
2. Trends shall be associated into groups, and a trend report shall be set up for each group.
3. Trends shall be stored within DDC controller and uploaded to hard drives automatically on reaching [75] <Insert value> of DDC controller buffer limit, or by operator request, or by archiving time schedule.
4. Preset trend intervals for each I/O point after review with Owner.
5. Trend intervals shall be operator selectable from 10 seconds up to 60 minutes. Minimum number of consecutive trend values stored at one time shall be 100 per variable.
6. When drive storage memory is full, most recent data shall overwrite oldest data.
7. Archived and real-time trend data shall be available for viewing numerically and graphically by operators.

R. Custom Trends: Operator shall be able to define a custom trend log for any I/O point in DDC system.

1. Each trend shall include interval, start time, and stop time.
2. Data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on [workstation] [server] hard drives.

3. Data shall be retrievable for use in spreadsheets and standard database programs.

S. Programming Software:

1. Include programming software to execute sequences of operation indicated.
2. Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.
3. Programming software shall be **[as follows] [any of the following] [one of the following]**:
 - a. Graphic Based: Programming shall use a library of function blocks made from preprogrammed code designed for DDC control systems.
 - 1) Function blocks shall be assembled with interconnection lines that represent to control sequence in a flowchart.
 - 2) Programming tools shall be viewable in real time to show present values and logical results of each function block.
 - b. Menu Based: Programming shall be done by entering parameters, definitions, conditions, requirements and constraints.
 - c. Line by Line and Text Based: Programming shall declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.
4. Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.

T. Database Management Software:

1. Where a separate SQL database is used for information storage, DDC system shall include database management software that separates database monitoring and managing functions by supporting multiple separate windows.
2. Database secure access shall be accomplished using standard SQL authentication including ability to access data for use outside of DDC system applications.
3. Database management function shall include summarized information on trend, alarm, event, and audit for the following database management actions:
 - a. Backup.
 - b. Purge.
 - c. Restore.
4. Database management software shall support the following:
 - a. Statistics: Display database server information and trend, alarm, event, and audit information on database.

- b. Maintenance: Include method of purging records from trend, alarm, event, and audit databases by supporting separate screens for creating a backup before purging, selecting database, and allowing for retention of a selected number of day's data.
 - c. Backup: Include means to create a database backup file and select a storage location.
 - d. Restore: Include a restricted means of restoring a database by requiring operator to have proper security level.
5. Database management software shall include information of current database activity, including the following:
 - a. Ready.
 - b. Purging record from a database.
 - c. Action failed.
 - d. Refreshing statistics.
 - e. Restoring database.
 - f. Shrinking a database.
 - g. Backing up a database.
 - h. Resetting Internet information services.
 - i. Starting network device manager.
 - j. Shutting down the network device manager.
 - k. Action successful.
6. Database management software monitoring functions shall continuously read database information once operator has logged on.
7. Include operator notification through on-screen pop-up display and e-mail message when database value has exceeded a warning or alarm limit.
8. Monitoring settings window shall have the following sections:
 - a. Allow operator to set and review scan intervals and start times.
 - b. E-mail: Allow operator to create and review e-mail and phone text messages to be delivered when a warning or an alarm is generated.
 - c. Warning: Allow operator to define warning limit parameters, set reminder frequency and link e-mail message.
 - d. Alarm: Allow operator to define alarm limit parameters, set reminder frequency and link e-mail message.
 - e. Database Login: Protect system from unauthorized database manipulation by creating a read access and a write access for each of trend, alarm, event, and audit databases as well as operator proper security access to restore a database.
9. Monitoring settings taskbar shall include the following informational icons:
 - a. Normal: Indicates by color and size, or other easily identifiable means that all databases are within their limits.
 - b. Warning: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their warning limit.
 - c. Alarm: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their alarm limit.

2.17 OFFICE APPLICATION SOFTWARE

- A. **Basis-of-Design Product:** Subject to compliance with requirements, include Microsoft's "Office Professional" <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
1. <Insert manufacturer's name>.
- B. Include current version of office application software at time of Substantial Completion.
- C. Office application software package shall include multiple separate applications and use a common platform for all applications, similar to Microsoft's "Office Professional."
1. Database.
 2. E-mail.
 3. Presentation.
 4. Publisher.
 5. Spreadsheet.
 6. Word processing.

2.18 MAINTENANCE MANAGEMENT SOFTWARE

- A. Scope:
1. Include complete and functional software-driven maintenance management system. Software shall perform scheduling of preventive maintenance and generation of work orders, for mechanical and electrical equipment and systems.
 2. Work orders shall be automatically generated from alarm conditions, run time, and calendar time. Each work order generated shall list parts, tools, craftspeople, and define task to be performed.
 3. Work order generated shall be used to schedule a repair or preventive maintenance routine.
 4. Work order shall be used to track completion of work, parts used and total cost of repair.
 5. A database shall include an inventory tracking system. Work orders generated shall automatically update inventory database to show quantity of tools, repair parts, and expendables used for a work order.
 6. Work orders and preventive maintenance schedules shall be printed on a dedicated printer assigned solely to maintenance management function.
- B. Additional Hardware Requirements:
1. Maintenance management software shall not require additional hardware, except for an additional printer that is dedicated to maintenance management.
 2. Maintenance management software shall be integrated into DDC system.
- C. Software Requirements:
1. From main menu of maintenance management system, it shall be possible through selection of icons to penetrate to individual functions described below.

2. Work Orders:
 - a. Automatically generate work orders initiated from alarm conditions, accumulated run time or calendar time. Work orders generated shall specify a particular task to be accomplished including the labor, material and tools needed to accomplish work.
 - b. Include at least two of the following types of work orders:
 - 1) Corrective and emergency maintenance work orders shall be generated for a specific job or repair for emergency, breakdown, or scheduled work.
 - 2) Preventive maintenance that are used on a periodic basis to generate preventive maintenance work orders.
 - c. Include the following functions:
 - 1) Work Order Tracking: Perform every function related to processing work orders including creating, approving and initiating work orders, checking their status history and closing or reworking them when appropriate.
 - 2) Work Requests: Report any problems that require corrective maintenance activity generated by dispatchers and those people designated to request work orders.
 - 3) Quick Reporting: Report work done on an open work order or a small job.
 - 4) Work Manager: Specify the type of labor to be applied to a specific work order at specific times. It shall include the capability to dispatch one or more laborers to top-priority jobs on as-needed basis and to interrupt work in progress to reassign labor to higher priority tasks.
 - d. Reports:
 - 1) Daily Maintenance Schedule by Supervisor: List a schedule of open work orders for a specified date by supervisor.
 - 2) Equipment Cost Roll-up Report: Include a roll-up of equipment costs incurred since the date the report was last run.
 - 3) Delinquent Work Order Report: List open work orders whose target completion date is earlier than the date the report is run.
 - 4) Employee Job Assignments: List labor codes that have job assignments for the specified date.
 - 5) Daily Work Order Assignment: List work orders that have labor assignments for the specified date.
 - 6) Estimated versus Actual Work Order Costs: List a cost summary of outstanding work orders.
 - 7) Open Work Orders Report: List open work orders for locations and equipment.
3. Inventory:

- a. Include an inventory tracking system to keep track of stocked, non-stocked and special-order items.
- b. Link inventory tracking to database and when items are consumed, as noted on a work order issued by system, inventory of stocked items shall be automatically updated.
- c. Include the following functions:
 - 1) Inventory Control: Enter, display, and update information on each inventory item. It shall allow viewing of master inventory records that are independent of storeroom locations or item/location records. Include a screen that lists inventory transactions that move items in or out of inventory or from one storeroom location to another. Minimum information tracked shall include the following:
 - a) Vendors supply items.
 - b) Item balances, including the bin and lot level for each storeroom location.
 - c) Alternative items.
 - 2) Issues and Transfers: Issue stock directly from inventory, with or without a work order. When transfer of stock from one location to another location occurs, provide appropriate adjustments in stock balance record. Include a trace record of stock transfers from one storeroom to another.
 - 3) Item Assembly Structures: Include modeling of equipment with inventory items and building of equipment and location hierarchies.
 - 4) Metered Material Usage:
 - a) Track usage by a piece of equipment.
 - b) Record against a standing work order for a selected piece of equipment.
 - c) Material usage transaction shall be written for each item of material used and be provided as an input to calculation for per unit material consumption report for a piece of equipment.
- d. Reports:
 - 1) Inventory Analysis Report: List for a given storeroom location, inventory items analysis information that allows quick identification of which inventory items represent greatest monetary investment for dollar value and rate of turnover.
 - 2) Inventory Cycle Count Report: List for a specified storeroom, inventory items that are due to be cycle-counted, based on cycle-count frequency and last count date.
 - 3) Economic Order Quantity Report: For a given storeroom location, display optimum economic ordering quantity for items in selected results set.
 - 4) Inventory Pick Report: A pick list, by work order for items needed to be pulled from a designated storeroom's inventory for work orders having a target start date of specified date.

- 5) Suggested Order Report: List inventory items in selected results set that are due to be recorded, for a specified storeroom location, based on the following calculation: Suggest a reorder if current balance minus reserve quantity plus on-order quantity is less than reorder point.
- 6) Reorder Point Report: List selected set of items and optimum minimum level to have in stock based on demand, lead delivery time and a reserve safety stock.
- 7) Inventory Valuation Report: Gives an accounting of cost of current inventory, for inventory records in a designated storeroom location.
- 8) Item Order Status: Lists items on order.
- 9) List of Expired Items: Lists expired lot items in a storeroom. Report shall include item number, description, expiration date, bin number, lot number, manufacturer lot number, and quantity of expired items in that lot and bin.
- 10) Item Availability at All Locations: Lists alternative storeroom locations for selected items.
- 11) Where Used Report: List equipment on which item is recorded as being used.

4. Equipment:

- a. Include equipment and location records; establish relationships between equipment, between locations, and between equipment and locations; track maintenance costs; and enter and review meter readings.
- b. Include the following functions:
 - 1) Equipment: Store equipment numbers and corresponding information including equipment class, location, vendor, up/down status and maintenance costs for each piece of equipment. Include building of equipment assemblies. Equipment assemblies hierarchical ordering shall be provided for arrangement of buildings, departments, equipment, and sub-assemblies.
 - 2) Operating Locations: Facilitate creation of records for operating locations of equipment, and track equipment that is used in multiple locations. In addition, allow hierarchical organization of equipment operating in facility by means of grouping equipment locations into areas of responsibility.
 - 3) Failure Codes: Develop and display failure hierarchies to acquire an accurate history of types of failures that affect equipment and operating locations.
 - 4) Condition Monitoring: Display time related or limit measurements recorded for a piece of equipment. It shall be possible to generate work orders from this screen and to take immediate action on problem conditions.
- c. Reports:
 - 1) Availability Statistic by Location: List equipment availability by location over a user-specified time period.

- 2) Equipment Failure Summary: List total number of failures by problem code for a piece of equipment for a specified time period.
 - 3) Detailed Equipment Failure Report by Equipment: List of failure reports for the current piece of equipment for a specified time period.
 - 4) Equipment Hierarchy Report: List of equipment.
 - 5) Equipment History Graphs: Include a graphical report in histogram format that displays equipment breakdown history over a specified period.
 - 6) Equipment Measurement Report: Tabular listing and description of each measurement point for a piece of equipment and the history of measurements taken for that point.
 - 7) Maintenance Cost by Equipment: List of transactions costs for elected equipment in the specified date range.
 - 8) Failure Count by Equipment: Graphically report the number of failures for each piece of equipment showing number of failures for each piece of equipment over a specified time period, occurrence of each problem code within set of failures and failures by problem code.
 - 9) Failure Analysis Graphs: Graphically report number of failures for each piece of equipment over a specified time period, number of occurrences of each problem code within set of failures and failures by problem code.
 - 10) Failure Code Hierarchy Report: List of failure codes in each level of the failure hierarchy.
 - 11) Location Failure Summary: A summary for each selected location of failures reported and any hierarchy level locations for specified time period.
 - 12) Failure Summary by Location: A summary of failures for the selected location and their subordinate locations that are part of the hierarchical system.
 - 13) Detailed Failure Report by Location: List all failures for selected location and its subordinate locations that are part of a hierarchical system.
 - 14) Maintenance Cost by System: List of total costs reported in a given date range for locations in selected hierarchical system.
 - 15) Location Hierarchy Report: Lists member locations of a hierarchical system displayed in hierarchical fashion.
5. Purchasing:
- a. Include preparation and generation of purchase requisitions and purchase orders; to report receipt of both items and services, match invoices with purchase orders and receipts and define and convert foreign currencies.
 - b. Include the following functions:
 - 1) Purchase Requisition: Create and process purchase requisitions for items and services.
 - 2) Purchase Orders: Create and process purchase orders for items and services from scratch or from purchase requisitions. Record receipts of items and services.

- 3) Invoices: Include functionality to match purchase orders with invoices and receipts. It shall also be possible to match a service receipt to an invoice. Project for entering of an invoice for bills that do not require purchase orders or receipts.
 - 4) Currency Management: Define currencies and specify exchange rates. Include preparation of purchase requisitions and purchase orders in currency of vendor, while tracking costs in systems base currency.
- c. Reports:
- 1) Invoice Approval Report: Include an approval form for entered invoices.
 - 2) Inventory Receipts Register: List purchase orders and inventory received for the user-specified time frame.
 - 3) Direct Purchase Back-Order Report: List of items ordered as a direct purchase not received by the required delivery date.
 - 4) Standard Purchase Order: A printing of primary purchase order with vendors shipping information, and items purchased.
 - 5) Purchase Order Status Report: List of purchase orders whose status has changed during a certain time period.
 - 6) Standard Purchase Requisition: A printing of primary purchase requisition, including vendor name and shipping information.
6. Job Plans:
- a. Include creation of a detailed description of work to be performed by a work order. The job plan shall contain operations, procedures, and list of estimated material, labor, and tools required for work.
7. Labor:
- a. Store information on employees, contractors, and crafts and include the following functions:
 - 1) Labor: Create, modify, and view employee records. Employee records shall contain pay rate, overtime worked, overtime refused, specials skills and certifications.
 - 2) Crafts: Create, modify, and view craftspeople records.
 - 3) Labor Reporting: Report labor usage by employee or craft externally from the work orders module.
 - b. Reports:
 - 1) Employee Attendance Analysis: List of planned attendance, actual attendance, vacation and sick time in hours as a percentage of planned attendance for selected employees for specified time period.
 - 2) Labor Productivity Analysis: List of actual labor hours by labor report category showing each by percentage.

- 3) Labor Availability versus Commitments by Crafts: A graphical report that details available labor hours versus committed work order hours by craft and day.
8. Calendars:
 - a. Establish calendar records indicating working time for equipment, location, craft, and labor records.
9. Resources:
 - a. Include entry and retrieval of data associated with resources required to maintain facility and to include the following functions:
 - 1) Companies: Establish and update data on vendors and other companies.
 - 2) Tools: Create and maintain information on the tools used on jobs. The information contained within this module shall be available to job plans and work orders.
 - 3) Service Contracts: Specify information on service contracts with vendors or manufacturers.
10. Custom Applications:
 - a. Include creation of customized database tables and application screens that supplement functions specified.
11. Setup:
 - a. Include configuration of database, security, and setup applications.
 - b. Perform the following functions:
 - 1) Reports and Other Applications: Register reports and other applications for use within system.
 - 2) Documents: Enter, track, and link information from Drawings to equipment and inventory items.
 - 3) Chart of Accounts: Add or modify accounts; set up financial periods; enter inventory accounts, company accounts, and resource recovery accounts; and define tax codes and rates.
 - 4) Signature Security: Establish each user's access rights to modules, applications, screens, and options.
 - 5) Database Configuration: Customize database, including adjusting field lengths and modifying data types.
 - 6) Application Setup: Change position of icons and menu items on the main menu screen.
 - 7) Application Launching: Allow for connecting of third-party applications to data fields and push buttons.
12. Utilities:

- a. Include utilities module that allows system administrator to customize system and to maintain database.
- b. Include the following functions:
 - 1) Interactive SQL: Include access to database for database management functions of import/export and backup.
 - 2) Edit Windows: Display a dialog box to customize an application.
 - 3) Archive Data: Remove records from database and store them for future reference.

D. Documentation:

1. Include complete documentation for the system consisting of a User Manual and Systems Administrator Guide.
2. User Manual shall describe how to use each application module and screen with step-by-step instructions detailing entry and retrieval of data for functions specified.
3. Include a step-by-step description of how each report is defined and retrieved.
4. Bind documentation and clearly title it indicating volume number and use.

2.19 ASHRAE 135 GATEWAYS

- A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes, but is not limited to, boilers, chillers, **<Insert equipment,>** and variable-speed drives.
- B. Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by Owner.
- C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.
- D. Gateway Minimum Requirements:
 1. Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.
 2. Write to all writeable object properties on non-BACnet network from BACnet network and vice versa where applicable.
 3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.
 4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.
 5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.

6. Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

2.20 ASHRAE 135 PROTOCOL ANALYZER

- A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.
- B. Analyzer shall include the following minimum capabilities:
 1. Capture and store to a file data traffic on all network levels.
 2. Measure bandwidth usage.
 3. Filtering options with ability to ignore select traffic.

2.21 CEA-709.1-C NETWORK HARDWARE

- A. Routers:
 1. Network routers, including routers configured as repeaters, shall comply with requirements of CEA-709.1-C and include connection between two or more CEA-709.3 TP/FT-10 channels or between two or more CEA-709.3 TP/FT-10 channels and a TP/XF-1250 channel.
 2. IP Routers:
 - a. Perform layer three routing of CEA-709.1-C packets over an IP network according to CEA-852-B.
 - b. Include appropriate connection to the IP network and connections to CEA-709.3 TP/FT-10 or TP/XF-1250 network.
 - c. Support the Dynamic Host Configuration Protocol for IP configuration and use of a CEA-852-B Configuration Server (for CEA-852-B configuration), but shall not rely on these services for configuration.
 - d. Capable of manual configuration via a console RS-232 port.
- B. Gateways:
 1. Perform bidirectional protocol translation from one non-CEA-709.1-C protocol to CEA-709.1-C.
 2. Incorporate a network connection to a TP/FT-10 network according to CEA-709.3 and a connection for a non-CEA-709.1-C network.

2.22 WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Single-Band Wireless Routers:
 1. **Manufacturers:** Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. [Cisco Linksys](#).
 - b. [D-Link Corporation/D-Link Systems, Inc.](#)
 - c. [Netgear Inc.](#)
 - d. <Insert manufacturer's name>.
2. Description: High-speed router with integral Ethernet ports.
 3. Technology: IEEE 802.11n; [2.4] <Insert number>-GHz speed band.
 4. Speed: Up to [300] <Insert number> Mbps.
 5. Compatibility: IEEE 802.11n/g/b/a wireless devices.
 6. Ethernet Ports: Four, gigabit (1000 Mbps).
 7. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 according to IEEE 802.11i.
- B. Dual-Band Wireless Routers:
1. **Manufacturers:** Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. [Cisco Linksys](#).
 - b. [D-Link Corporation/D-Link Systems, Inc.](#)
 - c. [Netgear Inc.](#)
 - d. <Insert manufacturer's name>.
 2. Description: High-speed, dual-band router with integral Ethernet ports and USB port.
 3. Technology: IEEE 802.11n; 2.4- and 5-GHz speed bands.
 4. Speed: Up to [300] <Insert number> Mbps on 2.4-GHz band and up to [450] <Insert number> Mbps on 5-GHz band.
 5. Compatibility: IEEE 802.11n/g/b/a wireless devices.
 6. Ethernet Ports: Four, gigabit (1000 Mbps).
 7. USB Port: One, USB 2.0 or 3.0.
 8. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 according to IEEE 802.11i.

2.23 DDC CONTROLLERS

- A. DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.
- B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.
- C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.

- D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.
- E. Environment Requirements:
1. Controller hardware shall be suitable for the anticipated ambient conditions.
 2. Controllers located in conditioned space shall be rated for operation at [32 to 120 deg F (Zero to 50 deg C)] <Insert temperature range>.
 3. Controllers located outdoors shall be rated for operation at [40 to 150 deg F (40 to 65 deg C)] <Insert temperature range>.
- F. Power and Noise Immunity:
1. Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
 2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches (900 mm) of enclosure.
- G. DDC Controller Spare Processing Capacity:
1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
 - a. Network Controllers: [50] [60] [70] <Insert value> percent.
 - b. Programmable Application Controllers: Not less than [60] [70] [80] <Insert number> percent.
 - c. Application-Specific Controllers: Not less than [70] [80] [90] <Insert number> percent.
 2. Memory shall support DDC controller's operating system and database and shall include the following:
 - a. Monitoring and control.
 - b. Energy management, operation, and optimization applications.
 - c. Alarm management.
 - d. Historical trend data of all connected I/O points.
 - e. Maintenance applications.
 - f. Operator interfaces.
 - g. Monitoring of manual overrides.
- H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:
1. Network Controllers:
 - a. [10] [20] <Insert number> percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: [Two] [Three] <Insert number>.

- 2) AOs: **[Two]** **[Three]** <Insert number>.
 - 3) BIs: **[Three]** **[Five]** <Insert number>.
 - 4) BOs: **[Three]** **[Five]** <Insert number>.
2. Programmable Application Controllers:
- a. **[10]** **[20]** <Insert number> percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: **[Two]** **[Three]** <Insert number>.
 - 2) AOs: **[Two]** **[Three]** <Insert number>.
 - 3) BIs: **[Three]** **[Five]** <Insert number>.
 - 4) BOs: **[Three]** **[Five]** <Insert number>.
3. Application-Specific Controllers:
- a. **[10]** <Insert number> percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: **[One]** **[Two]** <Insert number>.
 - 2) AOs: **[One]** **[Two]** <Insert number>.
 - 3) BIs: **[One]** **[Two]** <Insert number>.
 - 4) BOs: **[One]** **[Two]** <Insert number>.
- I. Maintenance and Support: Include the following features to facilitate maintenance and support:
1. Mount microprocessor components on circuit cards for ease of removal and replacement.
 2. Means to quickly and easily disconnect controller from network.
 3. Means to quickly and easily access connect to field test equipment.
 4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.
- J. General Requirements for CEA-709.1-C DDC Controllers:
1. Controllers shall be LonMark certified.
 2. Distinguishable and accessible switch, button, or pin, when pressed shall broadcast its 48-bit Node ID and Program ID over network.
 3. TP/FT-10 transceiver according to CEA-709.3 and connections for TP/FT-10 control network wiring.
 4. TP/XF-1250 transceiver according to CEA-709.3 and connections for TP/XF-1250 control network wiring.
 5. Communicate using CEA-709.1-C protocol.
 6. Controllers configured into subnets, as required, to comply with performance requirements indicated.
 7. Network communication through LNS network management and database standard for CEA-709.1-C network devices.

8. Locally powered, not powered through network connection.
9. Functionality required to support applications indicated, including, but not limited to, the following:
 - a. Input and outputs indicated and as required to support sequence of operation and application in which it is used. SNVTs shall have meaningful names identifying the value represented by an SNVT. Unless an SNVT of an appropriate engineering type is unavailable, all network variables shall be of an SNVT with engineering units appropriate to value the variable represents.
 - b. Configurable through SCPTs defined in LonMark SCPT List, operator-defined UCPTs, network configuration inputs (NCIs) of an SNVT type defined in LonMark SNVT List, NCIs of an operator-defined network variable type, or hardware settings on controller itself for all settings and parameters used by application in which it is used.
10. Programmable controllers shall conform to LonMark Interoperability Guidelines and have LonMark certification.

K. Input and Output Point Interface:

1. Hardwired input and output points shall connect to network, programmable application, and application-specific controllers.
2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.
3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.
4. AIs:
 - a. AIs shall include monitoring of low-voltage (zero- to 10-V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.
 - b. AIs shall be compatible with, and field configurable to, sensor and transmitters installed.
 - c. Controller AIs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of [8] [12] <Insert value> bits or better to comply with accuracy requirements indicated.
 - d. Signal conditioning including transient rejection shall be provided for each AI.
 - e. Capable of being individually calibrated for zero and span.
 - f. Incorporate common-mode noise rejection of at least 50 dB from zero to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.
5. AOs:
 - a. Controller AOs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of [8] [12] <Insert value> bits or better to comply with accuracy requirements indicated.
 - b. Output signals shall have a range of [4 to 20 mA dc] [or] [zero- to 10-V dc] as required to include proper control of output device.

- c. Capable of being individually calibrated for zero and span.
 - d. AOs shall not exhibit a drift of greater than 0.4 percent of range per year.
6. BIs:
- a. Controller BIs shall accept contact closures and shall ignore transients of less than 5-ms duration.
 - b. Isolation and protection against an applied steady-state voltage of up to 180-V ac peak.
 - c. BIs shall include a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against effects of contact bounce and noise.
 - d. BIs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.
 - e. Pulse accumulation input points shall comply with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Buffer shall be provided to totalize pulses. Pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero on operator's command.
7. BOs:
- a. Controller BOs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.
 - 1) Relay contact closures shall have a minimum duration of 0.1 second. Relays shall include at least 180 V of isolation. Electromagnetic interference suppression shall be provided on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be 1 A at 24-V ac.
 - 2) Triac outputs shall include at least 180 V of isolation. Minimum contact rating shall be 1 A at 24-V ac.
 - b. BOs shall include for two-state operation or a pulsed low-voltage signal for pulse-width modulation control.
 - c. BOs shall be selectable for either normally open or normally closed operation.
 - d. Include tristate outputs (two coordinated BOs) for control of three-point floating-type electronic actuators without feedback.
 - e. Limit use of three-point floating devices to VAV terminal unit control applications, **[and other applications indicated on Drawings,] <Insert applications>**. Control algorithms shall operate actuator to one end of its stroke once every **[12] [24] <Insert time>** hours for verification of operator tracking.

2.24 NETWORK CONTROLLERS

A. General Network Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
3. Controller shall have enough memory to support its operating system, database, and programming requirements.
4. Data shall be shared between networked controllers and other network devices.
5. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
6. Controllers [**that perform scheduling**] shall have a real-time clock.
7. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
8. Controllers shall be fully programmable.

B. Communication:

1. Network controllers shall communicate with other devices on DDC system [**Level one**] <Insert level> network.
2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation[**or PDA**].
2. Local Keypad and Display:
 - a. Equip controller with local keypad and digital display for interrogating and editing data.
 - b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least [**72**] [**96**] <Insert number> hours.

2.25 PROGRAMMABLE APPLICATION CONTROLLERS

A. General Programmable Application Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. Controller shall have enough memory to support its operating system, database, and programming requirements.
3. Data shall be shared between networked controllers and other network devices.

4. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
5. Controllers [**that perform scheduling**] shall have a real-time clock.
6. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
7. Controllers shall be fully programmable.

B. Communication:

1. Programmable application controllers shall communicate with other devices on network.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation[**or PDA**].
2. Local Keypad and Display:
 - a. Equip controller with local keypad and digital display for interrogating and editing data.
 - b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.26 APPLICATION-SPECIFIC CONTROLLERS

A. Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.

1. Capable of standalone operation and shall continue to include control functions without being connected to network.
2. Data shall be shared between networked controllers and other network devices.

B. Communication: Application-specific controllers shall communicate with other application-specific controller and devices on network, and to programmable application and network controllers.

- C. Operator Interface: Controller shall be equipped with a service communications port for connection to a portable operator's workstation. [**Connection shall extend to port on space temperature sensor that is connected to controller.**]
- D. Serviceability:
 - 1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
 - 2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
 - 3. Controller shall use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

2.27 CONTROLLER SOFTWARE

- A. General Controller Software Requirements:
 - 1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
 - 2. I/O points shall be identified by up to [30] <Insert number>-character point name and up to [16] <Insert number>-character point descriptor. Same names shall be used at operator workstations.
 - 3. Control functions shall be executed within controllers using DDC algorithms.
 - 4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.
- B. Security:
 - 1. Operator access shall be secured using individual security passwords and user names.
 - 2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
 - 3. Operator log-on and log-off attempts shall be recorded.
 - 4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.
- C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:
 - 1. Weekly Schedule:
 - a. Include separate schedules for each day of week.
 - b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
 - c. Each schedule may consist of up to 10 events.
 - d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.

2. Exception Schedules:
 - a. Include ability for operator to designate any day of the year as an exception schedule.
 - b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.
3. Holiday Schedules:
 - a. Include capability for operator to define up to 99 special or holiday schedules.
 - b. Schedules may be placed on scheduling calendar and will be repeated each year.
 - c. Operator shall be able to define length of each holiday period.
- D. System Coordination:
 1. Include standard application for proper coordination of equipment.
 2. Application shall include operator with a method of grouping together equipment based on function and location.
 3. Group may then be used for scheduling and other applications.
- E. Binary Alarms:
 1. Each binary point shall be set to alarm based on operator-specified state.
 2. Include capability to automatically and manually disable alarming.
- F. Analog Alarms:
 1. Each analog object shall have both high and low alarm limits.
 2. Alarming shall be able to be automatically and manually disabled.
- G. Alarm Reporting:
 1. Operator shall be able to determine action to be taken in event of an alarm.
 2. Alarms shall be routed to appropriate operator workstations based on time and other conditions.
 3. Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.
- H. Remote Communication:
 1. System shall have ability to dial out in the event of an alarm.
- I. Electric Power Demand Limiting:
 1. Demand-limiting program shall monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.

2. Demand-limiting program shall predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.
3. Demand reduction shall be accomplished by the following means:
 - a. Reset air-handling unit supply temperature set points.
 - b. Reset space temperature set points.
 - c. De-energize equipment based on priority.
4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which electric power service provider computes demand charges.
5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.
6. Include means operator to make the following changes online:
 - a. Addition and deletion of loads controlled.
 - b. Changes in demand intervals.
 - c. Changes in demand limit for meter(s).
 - d. Maximum shutoff time for equipment.
 - e. Minimum shutoff time for equipment.
 - f. Select rotational or sequential shedding and restoring.
 - g. Shed and restore priority.
7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly and annual basis:
 - a. Total electric consumption.
 - b. Peak demand.
 - c. Date and time of peak demand.
 - d. Daily peak demand.
- J. Maintenance Management: System shall monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.
- K. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.
- L. Control Loops:
 1. Support any of the following control loops, as applicable to control required:
 - a. Two-position (on/off, open/close, slow/fast) control.
 - b. Proportional control.
 - c. Proportional plus integral (PI) control.
 - d. Proportional plus integral plus derivative (PID) control.

- 1) Include PID algorithms with direct or reverse action and anti-windup.
- 2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
- 3) Controlled variable, set point, and PID gains shall be operator-selectable.

e. Adaptive (automatic tuning).

M. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.

N. Energy Calculations:

1. Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.
2. Include an algorithm that calculates a sliding-window average (rolling average). Algorithm shall be flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).
3. Include an algorithm that calculates a fixed-window average. A digital input signal shall define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.

O. Anti-Short Cycling:

1. BO points shall be protected from short cycling.
2. Feature shall allow minimum on-time and off-time to be selected.

P. On and Off Control with Differential:

1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

Q. Run-Time Totalization:

1. Include software to totalize run-times for all BI [**and BO**] points.
2. A high run-time alarm shall be assigned, if required, by operator.

2.28 ENCLOSURES

A. General Enclosure Requirements:

1. House each controller and associated control accessories in a [**single**] enclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.
2. Do not house more than one controller in a single enclosure.
3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.

4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
5. Individual wall-mounted single-door enclosures shall not exceed [36 inches (900 mm)] <Insert dimension> wide and [48 inches (1200 mm)] [60 inches (1500 mm)] <Insert dimension> high.
6. Individual wall-mounted double-door enclosures shall not exceed [60 inches (1500 mm)] <Insert dimension> wide and [36 inches (900 mm)] <Insert dimension> high.
7. Freestanding enclosures shall not exceed [48 inches (1200 mm)] <Insert dimension> wide and [72 inches (1800 mm)] <Insert dimension> high.
8. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.
9. Supply each enclosure with a complete set of as-built schematics, tubing, and wiring diagrams and product literature located in a pocket on inside of door. [**For enclosures with windows, include pocket on bottom of enclosure.**]

B. Internal Arrangement:

1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
4. Factory or shop install products, tubing, cabling, and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than [10] [20] <Insert number> percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install a maximum of two wires on each side of a terminal.
9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.
10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch- (6-mm-) high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
14. Label each end of cable, wire, and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least [25] <Insert number> percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.
3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

D. Wall-Mounted, NEMA 250, Type 1:

1. **Basis-of-Design Product:** Subject to compliance with requirements, provide **[Hoffman's (a brand of Pentair Technical Products) "Contractor Series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
2. Enclosure shall be NRTL listed according to UL 50 or UL 50E.
3. Construct enclosure of steel, not less than:
 - a. Enclosure size less than 24 in. (600 mm): [0.053 in. (1.35 mm)] [or] [0.067 in. (1.7 mm)] thick.
 - b. Enclosure size 24 in. (600 mm) and larger: [0.067 in. (1.7 mm)] [or] [0.093 in. (2.36 mm)] thick.
4. Finish enclosure inside and out with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Exterior color shall be [white] [NSF/ANSI 61 gray] [selected by Architect] [manufacturer's standard] <Insert color>.
 - b. Interior color shall be [white] [NSF/ANSI 61 gray] [manufacturer's standard].
5. Hinged door full size of front face of enclosure and supported using:
 - a. Enclosures sizes less than 36 in. (900 mm) tall: Multiple butt hinges.
 - b. Enclosures sizes 36 in. (900 mm) tall and larger: Continuous piano hinges.

6. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Size less than 24 in. (600 mm): **[Solid] [or] [Perforated]** steel, 0.053 in. (1.35 mm) thick.
 - b. Size 24 in. (600 mm) and larger: Solid **[aluminum, 0.10 in. (3 mm)] [or] [steel, 0.093 in. (2.36 mm)]** thick.
 7. Internal panel mounting hardware, grounding hardware and sealing washers.
 8. Grounding stud on enclosure body.
 9. Thermoplastic pocket on inside of door for record Drawings and Product Data.
- E. Wall Mounted NEMA 250, Types 4 and 12:
1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hoffman's (a brand of Pentair Technical Products) "Concept Series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
 2. Enclosure shall be NRTL listed according to UL 508A.
 3. Seam and joints are continuously welded and ground smooth.
 4. Where recessed enclosures are indicated, include enclosures with face flange for flush mounting.
 5. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
 6. Single-door enclosure sizes up to 60 inches tall by 36 inches wide (1500 mm tall by 900 mm wide).
 7. Double-door enclosure sizes up to 36 inches tall by 60 inches wide (900 mm tall by 1500 mm wide).
 8. Construct enclosure of steel, not less than the following:
 - a. Size Less Than 24 Inches (600 mm): **[0.053 inch (1.35 mm)] [or] [0.067 inch (1.7 mm)]** thick.
 - b. Size 24 Inches (600 mm) and Larger: **0.067 inch (1.7 mm)** thick.
 9. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Exterior color shall be **[white] [NSF/ANSI 61 gray] [as selected by Architect] [manufacturer's standard]** <Insert color>.
 - b. Interior color shall be **[white] [NSF/ANSI 61 gray] [manufacturer's standard]**.
 10. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.
 - a. Sizes through 24 Inches (600 mm) Tall: Two hinges.

- b. Sizes between **24 Inches** (600 mm) through **48 Inches** (1200 mm) Tall: Three hinges.
 - c. Sizes Larger **48 Inches** (1200 mm) Tall: Four hinges.
 11. Double-door enclosures with overlapping door design to include unobstructed full-width access.
 - a. Single-door enclosures **48 inches** (1200 mm) and taller, and all double-door enclosures, with three-point (top, middle and bottom) latch system.
 12. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Size Less Than **24 Inches** (600 mm): **[Solid] [or] [perforated]** steel, **0.053 inch** (1.35 mm) thick.
 - b. Size **24 Inches** (600 mm) and Larger: Solid **[aluminum, 0.10 inch** (3 mm)] **[or] [steel, 0.093 inch** (2.36 mm)] thick.
 13. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
 14. Grounding stud on enclosure body.
 15. Thermoplastic pocket on inside of door for record Drawings and Product Data.
- F. Wall-Mounted, NEMA 250, Type 4X SS:
 1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hoffman's (a brand of Pentair Technical Products) "Concept Type 4X or Continuous Hinge with 3-Point Latch Type 4X Enclosures"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
 2. Enclosure shall be NRTL listed according to UL 508A.
 3. Seam and joints are continuously welded and ground smooth.
 4. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
 5. Construct enclosure of **[Type 304] [Type 316L]** stainless steel, not less than the following:
 - a. Size Less Than **24 Inches** (600 mm): **0.053 inch** (1.35 mm) thick.
 - b. Size **24 Inches** (600 mm) and Larger: **0.067 inch** (1.7 mm) thick.
 6. Outside body and door of enclosure with brushed No. 4 finish.
 7. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.
 - a. Sizes through **24 Inches** (600 mm) Tall: Two hinges.
 - b. Sizes between **24 Inches** (600 mm) through **48 Inches** (1200 mm) Tall: Three hinges.

- c. Sizes Larger **48 Inches** (1200 mm) Tall: Four hinges.
 8. Corner-formed door, full size of enclosure face, supported using continuous piano hinge full length of door.
 9. Doors fitted with three-point (top, middle, and bottom) latch system with single, heavy-duty, liquid-tight Type 316 stainless-steel handle with integral locking mechanism.
 10. Removable internal panel shall be **0.093-inch** (2.36-mm) solid steel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 11. Internal panel mounting studs and hardware, grounding hardware, and sealing washers.
 12. Install corrosion-resistant polyester vent drain in a stainless-steel sleeve at the bottom of enclosure.
 13. Include enclosure with stainless-steel mounting brackets.
- G. Freestanding, NEMA 250, Type 1:
 1. **Basis-of-Design Product:** Subject to compliance with requirements, provide **[Hoffman's (a brand of Pentair Technical Products) "Free-Stand Series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
 2. Enclosure shall be NRTL listed according to UL 508A.
 3. Seam and joints are continuously welded and ground smooth.
 4. Externally formed body flange around perimeter of enclosure face.
 5. Single-door enclosure sizes up to **84 inches tall by 36 inches wide** (2100 mm tall by 900 mm wide).
 6. Double-door enclosure sizes up to **84 inches tall by 72 inches wide** (2100 mm tall by 900 mm wide).
 7. Construct enclosure of steel, not less than **0.067 inch** (1.7 mm) thick.
 8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Exterior color shall be **[white] [NSF/ANSI 61 gray] [as selected by Architect] [manufacturer's standard] <Insert color>**.
 - b. Interior color shall be **[white] [NSF/ANSI 61 gray] [manufacturer's standard]**.
 9. Corner-formed flush door, full size of enclosure face, supported using four concealed hinges with easily removable hinge pins.
 10. Double-door enclosures with overlapping door design to include unobstructed full-width access.
 11. Doors with three-point (top, middle, and bottom) latch system with single heavy-duty handle and integral locking mechanism.
 12. Removable back covers.

13. Removable solid steel internal panel, **0.093 inch (2.36 mm)** thick, with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
14. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
15. Grounding stud on enclosure body.
16. Thermoplastic pocket on inside of door for record Drawings and Product Data.
17. Nominal **4-inch- (100-mm-)** tall integral lifting base, not less than **0.123 inch (3.12 mm)** thick, with predrilled holes for attachment to mounting surface.
18. Each top end of enclosure fitted with lifting tabs, not less than **0.172 inch (4.37 mm)** thick.
19. Internal rack-mount shelves and angles as required by application.

H. Freestanding, NEMA 250, Types 4 and 12:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hoffman's (a brand of Pentair Technical Products) "Free-Stand Series"]** **<Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.
2. Enclosure shall be NRTL listed according to UL 508A.
3. Seam and joints are continuously welded and ground smooth.
4. Externally formed body flange around perimeter of enclosure face.
5. Type 12 Enclosure Sizes:
 - a. Single-door enclosure sizes up to **90 inches tall by 36 inches wide (2250 mm tall by 900 mm wide)**.
 - b. Double-door enclosure sizes up to **90 inches tall by 72 inches wide (2250 mm tall by 900 mm wide)**.
6. Type 4 Enclosure Sizes:
 - a. Single-door enclosure sizes up to **72 inches tall by 36 inches wide (1800 mm tall by 900 mm wide)**.
7. Construct enclosure of steel, not less than **0.093 inch (2.36 mm)** thick.
8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Exterior color shall be **[white] [NSF/ANSI 61 gray] [as selected by Architect] [manufacturer's standard] <Insert color>**.
 - b. Interior color shall be **[white] [NSF/ANSI 61 gray] [manufacturer's standard]**.
9. Corner-formed door with continuous perimeter oil-resistant gasket supported using continuous piano hinge full length of door.

10. Doors fitted with three-point (top, middle, and bottom) latch system with latching rod rollers and single, heavy-duty oil-tight handle with integral locking mechanism.
 11. Removable solid steel internal panel, **0.093 inch (2.36 mm)** thick, with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 12. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
 13. Grounding stud on enclosure body.
 14. Thermoplastic pocket on inside of door for record Drawings and Product Data.
 15. Top of enclosure fitted with no fewer than two lifting eyes.
 16. Internal rack-mount shelves and angles as required by application.
- I. Accessories:
1. Electric Heater:
 - a. Aluminum housing with brushed finish.
 - b. Thermostatic control with adjustable set point from **zero to 100 deg F** (Minus 18 to 38 deg C).
 - c. Capacity: 100, 200, 400, and 800 W as required by application.
 - d. Fan draws cool air from bottom of enclosure and passes air across thermostat and heating elements before being released into enclosure cavity. Heated air is discharged through the top of heater.
 2. Ventilation Fans, Filtered Intake and Exhaust Grilles:
 - a. Number and size of fans, filters, and grilles as required by application.
 - b. Compact cooling fans engineered for 50,000 hours of continuous operation without lubrication or service.
 - c. Fans capable of being installed on any surface and in any position within enclosure for spot cooling or air circulation.
 - d. Thermostatic control with adjustable set point from **32 to 140 deg F** (Zero to 60 deg C).
 - e. Airflow Capacity at Zero Pressure:
 - 1) **4-Inch (100-mm) Fan: 100 cfm (47 L/s).**
 - 2) **6-Inch (150-mm) Fan: 240 cfm (113 L/s).**
 - 3) **10-Inch (250-mm) Fan: 560 cfm (264 L/s).**
 - f. Maximum operating temperature of **158 deg F (70 deg C).**
 - g. **4-inch (100-mm)** fan thermally protected and provided with permanently lubricated ball-bearings.
 - h. **6- and 10-inch (150- and 250-mm)** fans with ball-bearing construction and split capacitor motors thermally protected to avoid premature failure.
 - i. Dynamically balanced impellers molded from polycarbonate material.
 - j. Fan furnished with power cord and polarized plug for power connection.
 - k. Fan brackets, finger guards, and mounting hardware provided with fans to complete installation.

- I. Removable Intake and Exhaust Grilles: **[ABS plastic] [or] [stainless steel]** of size to match fan size and suitable for NEMA 250, Types 1 and 12 enclosures.
 - m. Filters for NEMA 250, Type 1 Enclosures: Washable **[foam] [or] [aluminum]**, of a size to match intake grille.
 - n. Filters for NEMA 250, Type 12 Enclosures: Disposable, of a size to match intake grille.
3. Air Conditioner:
 - a. Electric-powered, self-contained air-conditioning unit specially designed for electrical enclosures to maintain temperature inside enclosure below ambient temperature outside enclosure.
 - b. Thermostatic control with adjustable set point from **60 to 120 deg F** (16 to 49 deg C).
 - c. Enclosure side or top mounting with unit capacity as required by application.
 - d. Designed for closed-loop cooling with continuous operation in ambient environments up to **125 deg F** (52 deg C).
 - e. HFC refrigerant.
 - f. Reusable and washable air filter.
 - g. High-performance, industrial-grade, and high-efficiency fans.
 - h. Furnished with power cord and polarized plug for power connection.
 - i. Condensate management system with base pan side drain.
 - j. Mounting hardware, gaskets, mounting template, and instruction manual furnished with unit.
 - k. Outdoor units equipped with head pressure control for low ambient operation, compressor heater, coated condenser coil, and thermostat.
4. Thermoelectric Humidifier:
 - a. ABS plastic enclosure.
 - b. Capacity of **8 oz. (0.24 L)** of water per 24 hours.
 - c. Built-in drain captures moisture and plastic hose directs moisture to outside enclosure through a drain.
 - d. Controlled to maintain enclosure relative humidity at an adjustable set point.
 - e. Unit power supply shall be internally wired to enclosure electrical power source.
5. Framed Fixed Window Kit for NEMA 250, Types 4, 4X, and 12 Enclosures:
 - a. **0.25-inch- (6-mm-)** thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
 - b. Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
 - c. Window kit shall be factory or shop installed before shipment to Project.
6. Frameless Fixed Window Kit for NEMA 250, Type 1 Enclosures:

- a. **0.125-inch-** (3-mm-) thick, polycarbonate window mounted in enclosure door material.
 - b. Window attached to door with screw fasteners and continuous strip of high-strength double-sided tape around window perimeter.
 - c. Window kit shall be factory or shop installed before shipment to Project.
7. Frame Fixed or Hinged Window Kit for NEMA 250, Types 1 and 12 Enclosures:
- a. **0.25-inch-** (6-mm-) thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
 - b. Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
 - c. Window kit shall be factory or shop installed before shipment to Project.
8. Bar handle with keyed cylinder lock set.

2.29 RELAYS

A. General-Purpose Relays:

1. Basis-of-Design Product: Subject to compliance with requirements, provide [**Siemens Building Technologies' "Furnas, 46 PA series"**] <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:
 - a. <Insert **manufacturer's name**>.
2. Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
3. Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
4. Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
7. Relays shall have LED indication and a manual reset and push-to-test button.
8. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Pickup Time: 15 ms or less.
 - d. Dropout Time: 10 ms or less.
 - e. Pull-in Voltage: 85 percent of rated voltage.
 - f. Dropout Voltage: 50 percent of nominal rated voltage.
 - g. Power Consumption: 2 VA.
 - h. Ambient Operating Temperatures: **Minus 40 to 115 deg F** (Minus 40 to 46 deg C).
9. Equip relays with coil transient suppression to limit transients to non-damaging levels.

10. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
11. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

B. Multifunction Time-Delay Relays:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Siemens Building Technologies' "Furnas, 46 PT series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
2. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.
3. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval, and recycle timing functions.
4. Use a plug-in-style relay with either an 8- or 11-pin octal plug.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a dust-tight cover.
7. Include knob and dial scale for setting delay time.
8. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
 - d. Repeatability: Within 2 percent.
 - e. Recycle Time: 45 ms.
 - f. Minimum Pulse Width Control: 50 ms.
 - g. Power Consumption: 5 VA or less at 120-V ac.
 - h. Ambient Operating Temperatures: **Minus 40 to 115 deg F** (Minus 40 to 46 deg C).
9. Equip relays with coil transient suppression to limit transients to non-damaging levels.
10. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
11. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

C. Latching Relays:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Siemens Building Technologies' "Furnas, 46 PF series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.

2. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.
3. Relays shall be either DPDT or three-pole double throw, depending on the control application.
4. Use a plug-in-style relay with a multibladed plug.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
7. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Pickup Time: 15 ms or less.
 - d. Dropout Time: 10 ms or less.
 - e. Pull-in Voltage: 85 percent of rated voltage.
 - f. Dropout Voltage: 50 percent of nominal rated voltage.
 - g. Power Consumption: 2 VA.
 - h. Ambient Operating Temperatures: **Minus 40 to 115 deg F** (Minus 40 to 46 deg C).
8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

D. Current Sensing Relay:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Square D's (a brand of Schneider Electric) "DEN series"]** <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.
2. Monitors ac current.
3. Independent adjustable controls for pickup and dropout current.
4. Energized when supply voltage is present and current is above pickup setting.
5. De-energizes when monitored current is below dropout current.
6. Dropout current is adjustable from 50 to 95 percent of pickup current.
7. Include a current transformer, if required for application.
8. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.

E. Combination On-Off Status Sensor and On-Off Relay:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Functional Devices, Inc.'s "RIBX series"]** <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:

- a. **<Insert manufacturer's name>**.
2. Description:
 - a. On-off control and status indication in a single device.
 - b. LED status indication of activated relay and current trigger.
 - c. Closed-Open-Auto override switch located on the load side of the relay.
3. Performance:
 - a. Ambient Temperature: **Minus 30 to 140 deg F** (Minus 34 to 60 deg C).
 - b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.
4. Status Indication:
 - a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
 - b. Current Sensor Range: As required by application.
 - c. Current Set Point: **[Fixed] [Adjustable] [Fixed or adjustable as required by application]**.
 - d. Current Sensor Output:
 - 1) Solid-state, single-pole double-throw contact rated for 30-V ac and dc and for 0.4 A.
 - 2) Solid-state, single-pole double-throw contact rated for 120-V ac and 1.0 A.
 - 3) Analog, zero- to 5- or 10-V dc.
 - 4) Analog, 4 to 20 mA, loop powered.
5. Relay: Single-pole double-throw, continuous-duty coil; rated for 10-million mechanical cycles.
6. Enclosure: NEMA 250, Type 1 enclosure.

2.30 ELECTRICAL POWER DEVICES

A. Transformers:

1. Transformer shall be sized for the total connected load, plus an additional 25 percent of connected load.
2. Transformer shall be at least **[40] [100] <Insert value> VA**.
3. Transformer shall have both primary and secondary fuses.

B. Power-Line Conditioner:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Controlled Power Company's "Series 800A"] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.

2. General Power-Line Conditioner Requirements:
 - a. Design to ensure maximum reliability, serviceability, and performance.
 - b. Overall function of the power-line conditioner is to receive raw, polluted electrical power and purify it for use by electronic equipment. The power-line conditioner shall provide isolated, regulated, transient, and noise-free sinusoidal power to loads served.
3. Standards: NRTL listed per UL 1012.
4. Performance:
 - a. Single phase, continuous, 100 percent duty rated KVA/KW capacity. Design to supply power for linear or nonlinear, high crest factor, resistive and reactive loads.
 - b. Automatically regulate output voltage to within 2 percent or better with input voltage fluctuations of plus 10 to minus 20 percent of nominal when system is loaded 100 percent. Use Variable Range Regulation to obtain improved line voltage regulation when operating under less than full load conditions.
 - 1) At 75 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 35 percent of nominal.
 - 2) At 50 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 40 percent of nominal.
 - 3) At 25 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 45 percent of nominal.
 - c. With input voltage distortion of up to 40 percent, limit the output voltage sine wave to a maximum harmonic content of 5 percent.
 - d. Automatically regulate output voltage to within 2.5 percent when load (resistive) changes from zero percent to 100 percent to zero percent.
 - e. Output voltage returns to 95 percent of nominal level within two cycles and to 100 percent within three cycles when the output is taken from no load to full resistive load or vice-versa. Recovery from partial resistive load changes is corrected in a shorter period of time.
 - f. K Factor: 30, designed to operate with nonlinear, non-sinusoidal, high crest factor loads without overheating.
 - g. Input power factor within 0.95 approaching unity with load power factor as poor as 0.6.
 - h. Attenuate load-generated odd current harmonics 23 dB at the input.
 - i. Electrically isolate the primary from the secondary. Meet isolation criteria as defined in NFPA 70, Article 250-5D.
 - j. Lighting and Surge Protection: Compares to UL 1449 rating of 330 V when subjected to Category B3 (6000 V/3000 A) combination waveform as established by IEEE C62.41.
 - k. Common-mode noise attenuation of 140 dB.
 - l. Transverse-mode noise attenuation of 120 dB.

- m. With loss of input power for up to 16.6 ms, the output sine wave remains at usable ac voltage levels.
 - n. Reliability of 200,000 hours' MTBF.
 - o. At full load, when measured at 1-m distance, audible noise is not to exceed 54 dB.
 - p. Approximately 92 percent efficient at full load.
5. Transformer Construction:
- a. Ferroresonant, dry type, convection cooled, 600V class. Transformer windings of Class H (220 deg C) insulated copper.
 - b. Use a Class H installation system throughout with operating temperatures not to exceed 150 deg C over a 40-deg C ambient temperature.
 - c. Configure transformer primary for multi-input voltage. Include input terminals for source conductors and ground.
 - d. Manufacture transformer core using M-6 grade, grain-oriented, stress-relieved transformer steel.
 - e. Configure transformer secondary in a 240/120-V split with a 208-V tap or straight 120 V, depending on power output size.
 - f. Electrically isolate the transformer secondary windings from the primary windings. Bond neutral conductor to cabinet enclosure and output neutral terminal.
 - g. Include interface terminals for output power hot, neutral and ground conductors.
 - h. Label leads, wires and terminals to correspond with circuit wiring diagram.
 - i. Vacuum impregnate transformer with epoxy resin.
6. Cabinet Construction:
- a. Design for panel or floor mounting.
 - b. NEMA 250, Type 1, general-purpose, indoor enclosure.
 - c. Manufacture the cabinet from heavy gauge steel complying with UL 50.
 - d. Include a textured baked-on paint finish.
- C. Transient Voltage Suppression and High-Frequency Noise Filter Unit:
- 1. **Basis-of-Design Product:** Subject to compliance with requirements, provide [**Current Technology's (a brand of Thomas & Betts Power Solutions) "Load Guard Model MSU45 series"**] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
 - 2. The maximum continuous operating voltage shall be at least 125 percent.
 - 3. The operating frequency range shall be 47 to 63 Hz.
 - 4. Protection modes according to NEMA LS-1.
 - 5. The rated single-pulse surge current capacity, for each mode of protection, shall be no less than the following:
 - a. Line to Neutral: 45,000 A.

- b. Neutral to Ground: 45,000 A.
 - c. Line to Ground: 45,000 A.
 - d. Per Phase: 90,000 A.
6. Clamping voltages shall be in compliance with test and evaluation procedures defined in NEMA LS-1. Maximum clamping voltage shall be as follows:
 - a. Line to Neutral: 360 V.
 - b. Line to Ground: 360 V.
 - c. Neutral to Ground: 360 V.
7. Electromagnetic interference and RF interference noise rejection or attenuation values shall comply with test and evaluation procedures defined in NEMA LS-1.
 - a. Line to Neutral:
 - 1) 100 kHz: 42 dB.
 - 2) 1 MHz: 25 dB.
 - 3) 10 MHz: 21 dB.
 - 4) 100 MHz: 36 dB.
 - b. Line to Ground:
 - 1) 100 kHz: 16 dB.
 - 2) 1 MHz: 55 dB.
 - 3) 10 MHz: 81 dB.
 - 4) 100 MHz: 80 dB.
8. Unit shall have LED status indicator that extinguishes to indicate a failure.
9. Unit shall be listed by an NRTL as a transient voltage surge suppressor per UL 1449, and as an electromagnetic interference filter per UL 1283.
10. Unit shall not generate any appreciable magnetic field.
11. Unit shall not generate an audible noise.

D. DC Power Supply:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Acopian Technical Company, Inc.'s "25J series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
2. Plug-in style suitable for mating with a standard eight-pin octal socket. Include the power supply with a mating mounting socket.
3. Enclose circuitry in a housing.
4. Include both line and load regulation to ensure a stable output. To protect both the power supply and the load, power supply shall have an automatic current limiting circuit.
5. Performance:

- a. Output voltage nominally 25-V dc within 5 percent.
- b. Output current up to 100 mA.
- c. Input voltage nominally 120-V ac, 60 Hz.
- d. Load regulation within 0.5 percent from zero- to 100-mA load.
- e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
- f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

2.31 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS

A. 250 through 1000 VA:

1. Basis-of-Design Product: Subject to compliance with requirements, include **[Oneac-Powervar Solutions' "ONePlus series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
2. UPS units shall provide continuous, regulated output power without using their batteries during brownout, surge, and spike conditions.
3. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.
 - a. Larger-capacity units shall be provided for systems with larger connected loads.
 - b. UPS shall provide **[five]** <Insert number> minutes of battery power.
4. Performance:
 - a. Input Voltage: Single phase, 120- or 230-V ac, compatible with field power source.
 - b. Load Power Factor Range (Crest Factor): 0.65 to 1.0.
 - c. Output Voltage: 101- to 132-V ac, while input voltage varies between 89 and 152-V ac.
 - d. On Battery Output Voltage: Sine wave.
 - e. Inverter overload capacity shall be minimum 150 percent for 30 seconds.
 - f. Recharge time shall be a maximum of six hours to 90 percent capacity after full discharge to cutoff.
 - g. Transfer Time: 6 ms.
 - h. Surge Voltage Withstand Capacity: IEEE C62.41, Categories A and B; 6 kV/200 and 500 A; 100-kHz ringwave.
5. UPS shall be automatic during fault or overload conditions.
6. Unit with integral line-interactive, power condition topology to eliminate all power contaminants.
7. Include front panel with power switch and visual indication of power, battery, fault and temperature.

8. Unit shall include an audible alarm of faults and front panel silence feature.
9. Unit with four NEMA WD 1, NEMA WD 6 Configuration 5-15R receptacles.
10. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure)[**and connect the points to the DDC system**].
11. Batteries shall be sealed lead-acid type and be maintenance free. Battery replacement shall be front accessible by user without dropping load.
12. Include tower models installed in ventilated cabinets to the particular installation location.

B. 1000 through 3000 VA:

1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Toshiba International Corporation, Industrial Division's "1000 series"]** **<Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>**.
2. UPS units shall provide continuous, regulated output power without using their batteries during brownout, surge, and spike conditions.
3. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.
 - a. Larger-capacity units, or multiple units, shall be provided for systems with larger connected loads.
 - b. UPS shall provide **[five] [10] <Insert number>** minutes of battery power.
4. Performance:
 - a. Input Voltage: Single phase, 120-V ac, plus 20 to minus 30 percent.
 - b. Power Factor: Minimum 0.97 at full load.
 - c. Output Voltage: Single phase, 120-V ac, within 3 percent, steady state with rated output current of 10.0 A, 30.0-A peak.
 - d. Inverter overload capacity shall be minimum 150 percent for 30 seconds.
 - e. Recharge time shall be a maximum of eight hours to 90 percent capacity.
5. UPS bypass shall be automatic during fault or overload conditions.
6. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure)[**and connect the points to the DDC system**].
7. Batteries shall be sealed lead-acid type and be maintenance free.
8. Include tower models installed in ventilated cabinets or rack models installed on matching racks, as applicable to the particular installation location and space availability/configuration.

2.32 PIPING AND TUBING

A. Pneumatic, and Pressure Instrument Signal Air, Tubing and Piping:

1. Products in this paragraph are intended for use with the following:
 - a. Main air and signal air to pneumatically controlled instruments, actuators and other control devices and accessories.
 - b. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers and accessories.
2. Copper Tubing:
 - a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered, with chemical and physical properties according to ASTM B 75.
 - b. Performance, dimensions, weight, and tolerance according to ASTM B 280.
 - c. Diameter, as required by application, not less than nominal 0.25 inch (6 mm).
 - d. Wall thickness, as required by the application, but not less than 0.030 inch (0.8 mm).
3. Copper Tubing Connectors and Fittings:
 - a. Brass, compression type.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [**Parker Hannifin Corp.'s "CPI"**] **<Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a) **<Insert manufacturer's name>**.
 - b. Brass, solder-joint type.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [**Mueller Industries, Inc.'s "Streamline"**] **<Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a) **<Insert manufacturer's name>**.
4. Galvanized-Steel Piping:
 - a. Galvanized pipe shall be ASTM A 53/A 53M, Schedule 40.
 - b. Fittings, galvanized malleable iron, ASME B16.3, Class 150.
5. Polyethylene Tubing:
 - a. Fire-resistant black virgin polyethylene according to ASTM D 1248, Type 1, Class C and Grade 5.
 - b. Tubing shall comply with stress crack test according to ASTM D 1693.
 - c. Diameter, as required by application, of not less than nominal 0.25 inch (6 mm).
6. Polyethylene Tubing Connectors and Fittings:

- a. Brass, barbed fittings.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [**Parker Hannifin Corp.'s "Poly-Tite"**] <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:
 - a) <Insert **manufacturer's name**>.
 - b. Brass, compression type.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [**Parker Hannifin Corp.'s "Poly-Tite"**] <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:
 - a) <Insert **manufacturer's name**>.
- B. Process Tubing:
1. Products in this paragraph are intended for signals to instruments connected to liquid and steam systems.
 2. Copper Tubing:
 - a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered with chemical and physical properties according to ASTM B 75.
 - b. Performance, dimensions, weight, and tolerance according to ASTM B 280.
 - c. Diameter, as required by application, of not less than nominal **0.25 inch** (6 mm).
 - d. Wall thickness, as required by application, but not less than **0.030 inch** (0.8 mm).
 3. Copper Tubing Connectors and Fittings:
 - a. Brass, compression type.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [**Parker Hannifin Corp.'s "CPI"**] <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:
 - a) <Insert **manufacturer's name**>.
 - b. Brass, solder-joint type.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [**Mueller Industries, Inc.'s "Streamline"**] <Insert **manufacturer's name; product name or designation**> or comparable product by one of the following:
 - a) <Insert **manufacturer's name**>.

4. Stainless-Steel Tubing:
 - a. Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, free from scale.
 - b. Chemical and physical properties according to ASTM A 269.
 - c. Diameter, as required by application, of not less than nominal 0.25 inch (6 mm).
 - d. Wall thickness, as required by application, but not less than 0.035 inch (0.9 mm).
 - e. Furnish stainless-steel tubing in [20-foot (6-mm)] straight random lengths.
5. Stainless-Steel Tubing Connectors and Fittings:
 - a. Connectors and fittings shall be stainless steel, with stainless-steel collets, flareless type.
 - 1) Basis-of-Design Product: Subject to compliance with requirements, provide [Parker Hannifin Corp.'s "CPI"] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a) <Insert manufacturer's name>.
 - b. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.

2.33 CONTROL WIRE AND CABLE

- A. Wire: Single conductor control wiring above 24 V.
 1. Wire size shall be at least [No. 18] [No. 16] [No. 14] <Insert value> AWG.
 2. Conductor shall be 7/24 soft annealed copper strand with 2- to 2.5-inch (50- to 65-mm) lay.
 3. Conductor insulation shall be 600 V, Type THWN or Type THHN, and 90 deg C according to UL 83.
 4. Conductor colors shall be black (hot), white (neutral), and green (ground).
 5. Furnish wire on spools.
- B. Single Twisted Shielded Instrumentation Cable above 24 V:
 1. Wire size shall be a minimum [No. 18] [No. 20] [No. 22] <Insert value> AWG.
 2. Conductors shall be a twisted, 7/24 soft annealed copper strand with a 2- to 2.5-inch (50- to 65-mm) lay.
 3. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
 4. Shielding shall be 100 percent type, 0.35/0.5-mil aluminum/Mylar tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
 5. Outer jacket insulation shall have a 600-V, 90-deg C rating and shall be Type TC cable.

6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red, and white.
7. Furnish wire on spools.

C. Single Twisted Shielded Instrumentation Cable 24 V and Less:

1. Wire size shall be a minimum [No. 18] [No. 20] [No. 22] <Insert value> AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch (50- to 65-mm) lay.
3. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
4. Shielding shall be 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 300-V, 105-deg C rating and shall be Type PLTC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red, and white.
7. Furnish wire on spools.

D. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.

1. Cable shall be plenum rated.
2. Cable shall comply with NFPA 70.
3. Cable shall have a unique color that is different from other cables used on Project.
4. Copper Cable for Ethernet Network:
 - a. [100BASE-TX] [1000BASE-T] [or] [1000BASE-TX].
 - b. TIA/EIA 586, [Category 5e] [or] [Category 6].
 - c. Minimum [No. 24] [No. 22] AWG solid.
 - d. [Shielded Twisted Pair (STP)] [or] [Unshielded Twisted Pair (UTP)].
 - e. Thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, Class CMP as plenum rated.

2.34 RACEWAYS FOR CONTROL WIRING, CABLING, AND TUBING

A. Metal Conduits, Tubing, and Fittings:

1. **Manufacturers:** Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. [AFC Cable Systems Inc.](#)
 - b. [Allied Tube & Conduit.](#)
 - c. [Anamet Electrical, Inc.](#)
 - d. [Current Technology Inc.](#)

- e. [Electri-Flex Company](#).
 - f. [O-Z/Gedney; an EGS Electrical Group brand; an Emerson Industrial Automation business](#).
 - g. [Picoma Industries](#).
 - h. [Republic Conduit](#).
 - i. [Robroy Industries](#).
 - j. [Southwire Company](#).
 - k. [Western Tube and Conduit Corporation](#).
 - l. [Wheatland Tube Company](#).
 - m. **<Insert manufacturer's name>**.
2. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 3. GRC: Comply with NEMA ANSI C80.1 and UL 6.
 4. ARC: Comply with NEMA ANSI C80.5 and UL 6A.
 5. IMC: Comply with NEMA ANSI C80.6 and UL 1242.
 6. PVC-Coated Steel Conduit: PVC-coated **[rigid steel conduit] [IMC]**.
 - a. Comply with NEMA RN 1.
 - b. Coating Thickness: **0.040 inch** (1 mm), minimum.
 7. EMT: Comply with NEMA ANSI C80.3 and UL 797.
 8. FMC: Comply with UL 1; **[zinc-coated steel] [or] [aluminum]**.
 9. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.
 10. Fittings for Metal Conduit: Comply with NEMA ANSI FB 1 and UL 514B.
 - a. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 1203 and NFPA 70.
 - b. Fittings for EMT:
 - 1) Material: **[Steel] [or] [die cast]**.
 - 2) Type: **[Setscrew] [or] [compression]**.
 - c. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external bonding jumper.
 - d. Coating for Fittings for PVC-Coated Conduit: Minimum thickness of **0.040 inch** (1 mm), with overlapping sleeves protecting threaded joints.
 11. Joint Compound for IMC, GRC, or ARC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.
- B. Nonmetallic Conduits, Tubing, and Fittings:
1. **Manufacturers**: Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available**

manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

- a. [AFC Cable Systems.](#)
 - b. [Anamet Electrical, Inc.](#)
 - c. [CANTEX Inc.](#)
 - d. [Carlson Electrical Products.](#)
 - e. [CertainTeed Corporation.](#)
 - f. [Condux International, Inc.](#)
 - g. [Current Technology Inc.](#)
 - h. [Dura-Line.](#)
 - i. [Electri-Flex Company.](#)
 - j. [Kraloy.](#)
 - k. [Niedax-Kleinhuis USA, Inc.](#)
 - l. [RACO; Hubbell.](#)
 - m. **<Insert manufacturer's name>.**
2. Listing and Labeling: Nonmetallic conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 3. ENT: Comply with NEMA TC 13 and UL 1653.
 4. RNC: [**Type EPC-40-PVC**] **<Insert type>**, complying with NEMA TC 2 and UL 651 unless otherwise indicated.
 5. LFNC: Comply with UL 1660.
 6. Rigid HDPE: Comply with UL 651A.
 7. Continuous HDPE: Comply with UL 651A.
 8. Coilable HDPE: Preassembled with conductors or cables, and complying with ASTM D 3485.
 9. RTRC: Comply with UL 2515A and NEMA TC 14.
 10. Fittings for ENT and RNC: Comply with NEMA TC 3; match to conduit or tubing type and material.
 11. Fittings for LFNC: Comply with UL 514B.
 12. Solvent cements and adhesive primers shall have a VOC content of 510 and 550 g/L or less.
 13. Solvent cements and adhesive primers shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Metal Wireways and Auxiliary Gutters:

1. **Manufacturers:** Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:
 - a. [Cooper B-Line, Inc.; a division of Cooper Industries.](#)
 - b. [Hoffman; a brand of Pentair Equipment Protection.](#)
 - c. [MonoSystems, Inc.](#)

- d. [Square D; by Schneider Electric.](#)
 - e. <Insert manufacturer's name>.
 2. Description: Sheet metal, complying with UL 870 and NEMA 250, [Type 1] [Type 3R] [Type 4] [Type 12] <Insert type> unless otherwise indicated, and sized according to NFPA 70.
 - a. Metal wireways installed outdoors shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 3. Fittings and Accessories: Include covers, couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for complete system.
 4. Wireway Covers: [Hinged] [Screw-cover] [Flanged-and-gasketed] type unless otherwise indicated.
 5. Finish: Manufacturer's standard enamel finish.
 - D. Surface Metal Raceways: Galvanized steel with snap-on covers complying with UL 5. [Manufacturer's standard enamel finish in color as selected by Architect] [Prime coated, ready for field painting].
 1. [Manufacturers:](#) Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. [MonoSystems, Inc.](#)
 - b. [Panduit Corp.](#)
 - c. [Wiremold / Legrand.](#)
 - d. <Insert manufacturer's name>.
- 2.35 CONTROL POWER WIRING AND RACEWAYS
- A. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" electrical power conductors and cables.
 - B. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.
- 2.36 FIBER-OPTIC CABLE, CONNECTORS, AND RACEWAY
- A. Cables:
 1. [Manufacturers:](#) Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

- a. [AMP NETCONNECT; a Tyco Electronics brand, a TE Connectivity Ltd. company.](#)
- b. [AT&T.](#)
- c. [Belden Inc.](#)
- d. [Berk-Tek.](#)
- e. [Communications Specialties, Inc.](#)
- f. [Corning Cable Systems.](#)
- g. [Optical Cable Corporation.](#)
- h. [Times Fiber Communications, Inc.](#)
- i. **<Insert manufacturer's name>.**

2. Performance Requirements:

- a. Fiber: Multimode graded index. Core/cladding size shall be either 62.5/125 or 100/140 micrometers.
- b. Numerical Aperture:
 - 1) 62.5/125 Micrometer Fiber: 0.275 plus or minus 0.015.
 - 2) 100/140 Micrometer Fiber: 0.29 plus or minus 0.015.
- c. Maximum Attenuation:
 - 1) 850 nm: 6.0 dB/km.
 - 2) 1300 nm: 5.0 dB/km.
- d. Minimum Bandwidth Dispersion: 300 Mhz-km at 850 nm.
- e. Core/Cladding Index Difference: 0.3 percent plus or minus 0.05 percent, measured using refractive rear field measurement procedure.
- f. Color-code finished fibers for easy identification.
- g. Splice Loss: Fibers shall be spliced together to form a longer fiber using a commercially available fiber splicing machine recommended by cable manufacturer. Maximum loss per fiber splice shall be 0.20 dB.
- h. Connection: Fibers shall be connected using fiber-optic connectors. Nominal connector loss shall not be greater than 1 dB.
- i. Fiber-optic cable shall be suitable for use with 100Base-FX or 100Base-SX standard (as applicable) as defined in IEEE 802.3.

3. Mechanical and Environmental Requirements:

- a. Tensile Strength: Fiber cable shall withstand a minimum tensile strength of 2700 N with maximum elongation of less than 0.5 percent.
- b. Bending Radius: Minimum static bending radius for cable shall be 10 times outside diameter for non-armored cables and 20 times outside diameter for armored cables. Non-armored cables shall withstand being flexed at minimum static bending radius plus or minus 90 degrees for at least 20 cycles at 20 to 40 cycles per minute at 20 deg C. Armored cables shall withstand being flexed at minimum static bending radius plus or minus 90 degrees for at least 10 cycles at 20 to 40 cycles per minute at 20 deg C.
- c. Vibration: Cable shall withstand a vibration test with vibration amplitude of 5 mm and frequency of 10 cycles per second for at least five hours.

- d. Twist: Cable shall withstand twisting of 360 degrees over a length of 2 m for at least 10 cycles at 10 cycles per minute.
 - e. Temperature: Cable shall withstand the following temperatures:
 - 1) Installation: Minus 30 to 70 deg C.
 - 2) Operation: Minus 40 to 70 deg C.
 - 3) Storage/Shipping: Minus 40 to 70 deg C.
 - f. Lifetime: Average lifetime of a 2-km, 12-fiber cable shall be at least 20 years when installed in a natural ambient environment. End of useful life shall be reached if failing to comply with requirements indicated or a spontaneous catastrophic fiber failure.
 - g. Crush Resistance: Cable shall withstand a compressive force of 705 N/cm for armored cables and 600 N/cm for non-armored cables. There shall be no attenuation increase after force is removed.
4. Cable Structure:
- a. Number of Fibers: Supply the required number of fibers in each cable for DDC system indicated, plus not less than 50 percent spare. Cable structure shall have fibers grouped for easy handling.
 - b. Strength Members: Include cable with strength members to satisfy mechanical and environmental conditions indicated.
 - c. Cable Core: Core shall consist of stranded buffer tubes around a central member of appropriate geometric size and shall be filled and bound to maintain core integrity. A fibrous strength member may be stranded around core to provide necessary strength for cable.
 - d. Cable Jacket: Protect cable by an extruded-polyethylene jacket.
 - e. Cable Armor: For cables requiring extra mechanical protection, one or two layers of galvanized corrugated steel tape coated by an anticorrosive compound shall be either helically or longitudinally applied over standard outer jacket. Apply a second outer jacket of polyethylene over coated steel tape. Thickness of sheaths and jackets are not specified as long as mechanical and environmental conditions are satisfied.
 - f. Cable Installation: Cables shall be suitable for a semiprotected outdoor installation.
5. Packaging and Shipping:
- a. Seal both ends of each length of cable.
 - b. Test individual fibers in each cable before shipping to verify compliance with Specifications.

B. Connectors:

- 1. **Manufacturers:** Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

- a. [AMP NETCONNECT; a Tyco Electronics brand, a TE Connectivity Ltd. company.](#)
 - b. [AT&T.](#)
 - c. [Communications Specialties, Inc.](#)
 - d. [Corning Cable Systems.](#)
 - e. [Current Technology Inc.](#)
 - f. [Data Base Access Systems, Inc.](#)
 - g. [EOTec; a brand of Ultra Electronics, Nuclear Sensors & Process Instrumentation.](#)
 - h. [Liteway, Inc.](#)
 - i. [Times Fiber Communications, Inc.](#)
 - j. **<Insert manufacturer's name>.**
2. Performance Requirements:
- a. Type: Fiber-optic connectors shall be either Type ST or Type SMA. Use either connector type exclusively. No substitutions are allowed.
 - b. Insertion Loss: Connector shall have an insertion loss of not greater than 1 dB.
 - c. Coupling Tolerance: Connector shall withstand at least 500 couplings with insertion loss within 0.25-dB tolerance limit.
 - d. Mechanical Requirements:
 - 1) Connector shall enclose outermost coating of single fiber cable and be able to be mated or unmated without using a tool.
 - 2) Mount connector rigidly in a metal frame.
 - 3) Connector shall allow a semiskilled person to properly install connector to a single fiber easily in a field environment with simple tools.
- C. Splice Organizer Cabinet:
1. **Manufacturers:** Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [3M.](#)
 - b. [ADC.](#)
 - c. [AMP NETCONNECT; a Tyco Electronics brand, a TE Connectivity Ltd. company.](#)
 - d. [Communications Specialties, Inc.](#)
 - e. [Corning Cable Systems.](#)
 - f. [Liteway, Inc.](#)
 - g. **<Insert manufacturer's name>.**
 2. Minimum Capacity: Each splice organizer shall accommodate number of connectors required for DDC system indicated, plus 100 percent spare.
 3. Mounting: Wall mount the splice organizer cabinet.

D. Raceways:

1. **Manufacturers:** Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. Anixterl Inc.
 - b. Condux International, Inc.
 - c. Dura-Line.
 - d. Pacific Plastics, Inc.
 - e. **<Insert manufacturer's name>.**
2. Mechanical and Performance Requirements:
 - a. Construction: Nonmetallic, flexible raceway system manufactured specifically for routing fiber-optic cables.
 - b. Suitable for use in return-air plenums, air-handling rooms, above ceilings and under access floors.
 - c. Exhibit low smoke generation and flame-spread characteristics, and have high-temperature service tolerance.
 - d. Size raceway according to NFPA 70 requirements for communications cables.
 - e. Tensile Strength at Yield: 10,800 psi.
 - f. Elongation at Break: 25 percent.

E. Cable Identification:

1. **Basis-of-Design Product:** Subject to compliance with requirements, provide **[Mueller Industries, Inc.'s "Streamline"] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. **<Insert manufacturer's name>.**
2. Labeling product shall be self-laminating cable marker.
3. Cable labeling shall include numeric designation, source, destination, and cable type.

2.37 ACCESSORIES

A. Pneumatic Pressure Gages:

1. Pressure gages shall a **1.5-inch-** (38-mm-) diameter face for pressures up through **30 psig** (207 kPa) and **2.5-inch-** (65-mm-) diameter face for greater pressures.
2. Include separate gages for branch pressure and main pressure lines.
3. White dial face with black printing.
4. Include **1-psig** (6.9-kPa) increment for scale ranges through **30 psig** (207 kPa) and **2-psig** (13.8-kPa) increment for larger ranges.
5. Accuracy: Within 1 percent of full-scale range.

B. Pressure Electric Switches:

1. Diaphragm-operated snap acting switch.
2. Set point adjustable from 3 to 20 psig (21 to 138 kPa).
3. Differential adjustable from 2 to 6 psig (14 to 41 kPa).
4. Rated for resistance loads at 120-V ac.
5. Body and switch housing shall be metal.

C. Damper Blade Limit Switches:

1. Sense positive open and/or closed position of the damper blades.
2. NEMA 250, Type 13, oil-tight construction.
3. Arrange for the mounting application.
4. Additional waterproof enclosure when required by its environment.
5. Arrange to prevent "over-center" operation.

D. I/P and E/P Transducers:

1. Commercial Grade:

- a. Basis-of-Design Product: Subject to compliance with requirements, provide **[MAMAC Systems, Inc.'s "Model EP-313"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1) <Insert manufacturer's name>.

- b. The transducer shall convert an AO signal to a stepped pneumatic signal. Unless otherwise required by the operating sequence, use a 3- to 15-psig (21- to 103-kPa) pneumatic signal for pneumatic actuation.
- c. Construct the entire assembly so that shock and vibration will neither harm the transducer nor affect its accuracy.
- d. Transducer shall have auto/manual output switch, manual output control and an output pressure gage.
- e. Accuracy: Within 1.0 percent of the output span.
- f. Linearity: Within 0.5 percent of the output span.
- g. Output Capacity: Not less than 550 scim at 15 psig (103 kPa).
- h. Transducer shall have separate zero and span calibration adjustments.
- i. The transducer shall withstand up to 40 psig (276 kPa) of supply pressure without damage.
- j. For use on only modulating pneumatic outputs that are associated with terminal units, including fan-coil units, VAV units, unit heaters, and <Insert equipment>.

2. Industrial Grade:

- a. Basis-of-Design Product: Subject to compliance with requirements, provide **[Fisher's (a brand of Emerson Electric Co.) "Type 646"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1) <Insert manufacturer's name>.

- b. The transducer shall convert an AO signal to a proportional pneumatic signal. Unless otherwise required by the operating sequence, use a 3- to 15-psig (21- to 103-kPa) pneumatic signal for pneumatic actuation. A stepped pneumatic signal is unacceptable.
- c. Construct the entire assembly so that shock and vibration will neither harm the transducer nor affect its accuracy.
- d. Suitable for operation in an ambient temperature range of minus 40 to 150 deg F (minus 40 to 66 deg C).
- e. Accuracy: Within 0.5 percent of the output span.
- f. Linearity: Within 0.5 percent of the output span.
- g. Output Capacity: Not less than 5 scfm.
- h. Transducer shall have zero and span calibration adjustments.
- i. The transducer shall withstand up to 50 psig (345 kPa) of supply pressure without damage.
- j. For use on all modulating pneumatic outputs, not requiring a commercial-grade transducer.

E. E/P Switch:

- 1. Construct the body of cast aluminum or brass; three pipe body (common, normally open, and normally closed).
- 2. Internal construction of steel, copper or brass.
- 3. Air Connections: Barb.
- 4. Rating of 30 psig (207 kPa) when installed in systems below 25 psig (172 kPa) and of 150 psig (1034 kPa) when installed in systems above 25 psig (172 kPa).
- 5. Include coil transient suppression.

F. Instrument Enclosures:

- 1. Basis-of-Design Product: Subject to compliance with requirements, provide **[Hoffman's (a brand of Pentair Technical Products) "Concept Series" or "Freestanding Series"]** <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
- 2. Include instrument enclosure for secondary protection to comply with requirements indicated in "Performance Requirements" Article.
- 3. NRTL listed and labeled to UL 50.
- 4. Sized to include at least 25 percent spare area on subpanel.
- 5. Instrument(s) mounted within enclosure on internal subpanel(s).
- 6. Enclosure face with engraved, laminated phenolic nameplate for each instrument within enclosure.
- 7. Enclosures housing pneumatic instruments shall include main pressure gage and a branch pressure gage for each pneumatic device, installed inside.
- 8. Enclosures housing multiple instruments shall route tubing and wiring within enclosure in a raceway having a continuous removable cover.

9. Enclosures larger than [12 inches (300 mm)] <Insert dimension> shall have a hinged full-size face cover.
10. Equip enclosure with lock and common key.

G. Manual Valves:

1. Needle Type:

- a. Basis-of-Design Product: Subject to compliance with requirements, provide [Parker Hannifin Corp.'s "V series"] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - 1) <Insert manufacturer's name>.
- b. PTFE packing.
- c. Construct of brass for use with copper and polyethylene tubing and of stainless steel for use with stainless-steel tubing.
- d. Aluminum T-bar handle.
- e. Include tubing connections.

2. Ball Type:

- a. Basis-of-Design Product: Subject to compliance with requirements, provide [NIBCO INC.'s "T-580-70-66"] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - 1) <Insert manufacturer's name>.
- b. Body: Bronze ASTM B 62 or ASTM B 61.
- c. Ball: Type 316 stainless steel.
- d. Stem: Type 316 stainless steel.
- e. Seats: Reinforced PTFE.
- f. Packing Ring: Reinforced PTFE.
- g. Lever: Stainless steel with a vinyl grip.
- h. 600 WOG.
- i. Threaded end connections.

H. Wall-Mounted Portable Operator's Workstation Cabinet:

1. **Basis-of-Design Product:** Subject to compliance with requirements, provide [Lowell Manufacturing Company's "Model L83-5S"] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. <Insert manufacturer's name>.
2. Surface-mounted wall cabinet for tilt-out operation of laptop computers and PDAs.
3. Cabinet shall have a load limit of 50 lb (23 kg).
4. Cabinet shall include the following:

- a. Oil-filled dampers for controlled lowering of equipment to operational position.
 - b. 3RU EIA mounting rails.
 - c. Removable laptop shelf.
 - d. Separate top compartment with mounting area, hinged rail, and security lock.
 - e. Front ventilation slots.
 - f. Knockouts for conduit connections on top and bottom of cabinet.
5. Cabinet shall be constructed of steel and painted with a powder-coat epoxy.
 6. Inside center of backbox shall have provision to mount a field-furnished and -installed, single gang electrical outlet box.

2.38 IDENTIFICATION

A. Instrument Air Pipe and Tubing:

1. Engraved tag shall bear the following information:
 - a. Service (Example): "Instrument Air."
 - b. Pressure Range (Example): 0 to 30 psig (0 to 200 kPa).
2. Letter size shall be a minimum of [0.25 inch (6 mm)] <Insert dimension> high.
3. Tag shall consist of white lettering on blue background.
4. Tag shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded blue with contrasting white center exposed by engraving through outer layer.
5. Include tag with a brass grommet, chain, and S-hook.

B. Control Equipment, Instruments, and Control Devices:

1. Engraved tag bearing unique identification.
 - a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.
2. Letter size shall be as follows:
 - a. Operator Workstations: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - b. Servers: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - c. Printers: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - d. DDC Controllers: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - e. Gateways: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - f. Repeaters: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - g. Enclosures: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.
 - h. Electrical Power Devices: Minimum of [0.25 inch (6 mm)] <Insert dimension> high.
 - i. UPS units: Minimum of [0.5 inch (13 mm)] <Insert dimension> high.

- j. Accessories: Minimum of [0.25 inch (6 mm)] <Insert dimension> high.
 - k. Instruments: Minimum of [0.25 inch (6 mm)] <Insert dimension> high.
 - l. Control Damper and Valve Actuators: Minimum of [0.25 inch (6 mm)] <Insert dimension> high.
3. Tag shall consist of white lettering on black background.
 4. Tag shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded black with contrasting white center exposed by engraving through outer layer.
 5. Tag shall be fastened with drive pins.
 6. Instruments, control devices and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.
- C. Valve Tags:
1. Brass tags and brass chains attached to valve.
 2. Tags shall be at least [1.5 inches (38 mm)] <Insert dimension> in diameter.
 3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve, and followed by three-digit sequential number. For example: TV-1.001.
 4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.
- D. Raceway and Boxes:
1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
 2. Paint cover plates on junction boxes and conduit same color as the tape banding for conduits. After painting, label cover plate "HVAC Controls," using an engraved phenolic tag.
 3. For raceways housing pneumatic tubing, add a phenolic tag labeled "HVAC Instrument Air Tubing."
 4. For raceways housing air signal tubing, add a phenolic tag labeled "HVAC Air Signal Tubing."
- E. Equipment Warning Labels:
1. Acrylic label with pressure-sensitive adhesive back and peel-off protective jacket.
 2. Lettering size shall be at least 14-point type with white lettering on red background.
 3. Warning label shall read "CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing."
 4. Lettering shall be enclosed in a white line border. Edge of label shall extend at least [0.25 inch (6 mm)] <Insert dimension> beyond white border.

2.39 SOURCE QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to evaluate the following according to industry standards for each product, and to verify DDC system reliability specified in performance requirements:
1. DDC controllers.
 2. Gateways.
 3. Routers.
 4. Operator workstations.
 5. **<Insert product>**.
- B. Product(s) **[and] [material(s)]** will be considered defective if **[it does] [they do]** not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
1. Verify compatibility with and suitability of substrates.
- B. Examine roughing-in for products to verify actual locations of connections before installation.
1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
 2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

- A. Communication Interface to Equipment with Integral Controls:
1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.

2. Equipment to Be Connected:

- a. Domestic water booster pumps specified in Section 221123.13 "Domestic-Water Packaged Booster Pumps."
- b. Air-terminal units specified in Section 233600 "Air Terminal Units."
- c. Kitchen hoods specified in Section 233813 "Commercial-Kitchen Hoods."
- d. Boilers specified in Section 235213 "Electric Boilers."
- e. Boilers specified in Section 235216 "Condensing Boilers."
- f. Boilers specified in Section 235223 "Cast-Iron Boilers."
- g. Boilers specified in Section 235233 "Water-Tube Boilers."
- h. Boilers specified in Section 235239 "Fire-Tube Boilers."
- i. Feedwater equipment specified in Section 235313 "Boiler Feedwater Pumps."
- j. Deaerators specified in Section 235316 "Deaerators."
- k. Chillers specified in Section 236413.13 "Direct-Fired Absorption Water Chillers."
- l. Chillers specified in Section 236413.16 "Indirect-Fired Absorption Water Chillers."
- m. Chillers specified in Section 236416 "Centrifugal Water Chillers."
- n. Chillers specified in Section 236419 "Reciprocating Water Chillers."
- o. Chillers specified in Section 236423 "Scroll Water Chillers."
- p. Chillers specified in Section 236426 "Rotary-Screw Water Chillers."
- q. Cooling towers specified in Section 236500 "Cooling Towers."
- r. Heat wheels and heat exchangers specified in Section 237200 "Air-to-Air Energy Recovery Equipment."
- s. Air-handling units specified in Section 237313 "Modular Indoor Central-Station Air-Handling Units."
- t. Rooftop units specified in Section 237413 "Packaged, Outdoor, Central-Station Air-Handling Units."
- u. Dedicated outdoor-air units specified in Section 237433 "Dedicated Outdoor-Air Units."
- v. Packaged terminal air-conditioners specified in Section 238113.11 "Packaged Terminal Air-Conditioners, Through-Wall Units," Section 238113.12 "Packaged Terminal Air-Conditioners, Freestanding Units," and Section 238113.13 "Packaged Terminal Air-Conditioners, outdoor, wall-mounted units."
- w. Computer-room air-conditioning units specified in Section 238123 "Computer-Room Air-Conditioners."
- x. Fan-coil units specified in Section 238219 "Fan Coil Units."
- y. Unit ventilators specified in Section 238223 "Unit Ventilators."
- z. Humidifiers specified in Section 238413 "Humidifiers."
- aa. Dehumidification units specified in Section 238416 "Mechanical Dehumidification Units."
- bb. Switchboards specified in Section 262300 "Low-Voltage Switchgear."
- cc. Motor-control centers specified in Section 262419 "Motor-Control Centers."
- dd. Variable-frequency controllers specified in Section 262923 "Variable-Frequency Motor Controllers."
- ee. Generator sets specified in Section 263213 "Engine Generators."
- ff. UPS specified in Section 263353 "Static Uninterruptible Power Supply."
- gg. Refrigerant monitoring.

hh. **<Insert equipment and Section number and title>.**

B. Communication Interface to Other Building Systems:

1. DDC system shall have a communication interface with systems having a communication interface.
2. Systems to Be Connected:
 - a. Elevators specified in Section 142100 "Electric Traction Elevators."
 - b. Elevators specified in Section 142113 "Electric Traction Freight Elevators."
 - c. Elevators specified in Section 142400 "Hydraulic Elevators."
 - d. Elevators specified in Section 142413 "Hydraulic Freight Elevators."
 - e. Escalators specified in Section 143100 "Escalators."
 - f. Automated water treatment systems specified in Section 232500 "HVAC Water Treatment."
 - g. Automated water treatment systems specified in Section 232516 "Water Treatment for Open-Loop Hydronic Systems."
 - h. Automated water treatment systems specified in Section 232519 "Water Treatment for Steam System Feedwater."
 - i. Power monitoring specified in Section 260913 "Electrical Power Monitoring and Control."
 - j. Lighting controls specified in Section 260926 "Lighting Control Panelboards."
 - k. Lighting controls specified in Section 260943.16 "Addressable-Fixture Lighting Controls."
 - l. Lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
 - m. Fire-alarm system specified in Section 283111 "Digital, Addressable Fire Alarm System."
 - n. Fire-alarm system specified in Section 283112 "Zoned (DC Loop) Fire-Alarm System."
 - o. Access controls specified in Section 281300 "Access Control."
 - p. Intrusion detection specified in Section 281600 "Intrusion Detection."
 - q. Perimeter security specified in Section 281643 "Perimeter Security Systems."
 - r. **<Insert system and Section number and title>.**

3.3 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

A. Interface with Existing Systems:

1. DDC systems shall interface existing systems to achieve integration.
2. Monitoring and Control of DDC System by Existing Control System:
 - a. DDC system performance requirements shall be satisfied when monitoring and controlling DDC system by existing control system.
 - b. Operator of existing system shall be able to upload, download, monitor, trend, control and program every input and output point in DDC system

- from existing control system using existing control system software and operator workstations.
- c. Remote monitoring and control from existing control system shall not require operators of existing control system to learn new software.
 - d. Interface of DDC system into existing control system shall be transparent to operators of existing control system and allow operators to **[program, monitor, and control]** **[monitor and control]** DDC system from any operator workstation connected to existing control system.
 - e. **<Insert requirements>**.
3. Integration of Existing Control System into DDC System:
- a. Existing control system performance requirements shall be satisfied when monitoring and controlling existing control system through DDC system.
 - b. Operator shall be able to upload, download, monitor, alarm, report, trend, control and program every input and output point in existing system from DDC system using operator workstations and software provided. The combined systems shall share one database.
 - c. Interface of existing control system I/O points into DDC system shall be transparent to operators. All operational capabilities shall be identical regardless of whether I/O already exists or I/O is being installed.
 - d. **<Insert requirements>**.
- B. Integration with Existing Enterprise System:
1. DDC system shall interface with an existing enterprise system to adhere to Owner standards already in-place and to achieve integration.
 2. Owner's control system integrator will provide the following services:
 - a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
 - b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
 - c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.
 3. Engage Owner's control system integrator to provide the following services:
 - a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
 - b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
 - c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.
 4. Control System Integrator Contact Information:
 - a. Company: **<Insert name>**.

- b. Company Street Address: **<Insert address>**.
 - c. Company Contact: **<Insert name>**.
 - d. Phone Number: **<Insert phone number>**.
 - e. E-mail Address: **<Insert e-mail address>**.
5. Attend meetings with control system integrator to integrate DDC system.

3.4 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

- A. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.
- B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
1. DDC control dampers, which are specified in Section **230923.12** "DDC Control Dampers."
 2. Airflow sensors and switches, which are specified in Section **230923.14** "Flow Instruments."
 3. Pressure sensors, which are specified in Section **230923.23** "Pressure Instruments."
 4. **<Insert additional control devices>**.
- C. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
1. DDC control valves, which are specified in Section **230923.11** "Control Valves."
 2. Pipe-mounted flow meters, which are specified in Section **230923.14** "Flow Instruments."
 3. Pipe-mounted sensors, switches, and transmitters. Flow meters are specified in Section **230923.14** "Flow Instruments." Liquid[**and steam**] temperature sensors, switches, and transmitters are specified in Section **230923.27** "Temperature Instruments."
 4. Tank-mounted sensors, switches, and transmitters. Pressure sensors, switches, and transmitters are specified in Section **230923.23** "Pressure Instruments." Liquid[**and steam**] temperature sensors, switches, and transmitters are specified in Section **230923.27** "Temperature Instruments."
 5. Pipe- and tank-mounted thermowells. Liquid[**and steam**] thermowells are specified in Section **230923.27** "Temperature Instruments."
 6. **<Insert additional control devices>**.

3.5 CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

- A. Deliver the following to air-handling unit manufacturer for factory installation. Include installation instructions to air-handling unit manufacturer[**and supervise installation for compliance with requirements**].
1. **[Programmable application] [or] [application-specific]** controller.
 2. Unit-mounted DDC control dampers and actuators, which are specified in Section **230923.12** "Control Dampers."
 3. Unit-mounted airflow sensors, switches and transmitters, which are specified in Section **230923.14** "Flow Instruments."
 4. Unit-mounted gas sensors and transmitters, which are specified in Section **230923.16** "Gas Instruments."
 5. Unit-mounted leak-detection switches, which are specified in Section **230923.18** "Leak-Detection Instruments."
 6. Unit-mounted speed sensors, switches and transmitters, which are specified in Section **230923.24** "DDC Speed Instruments."
 7. Unit-mounted pressure sensors, switches and transmitters, which are specified in Section **230923.23** "Pressure Instruments."
 8. Unit-mounted temperature sensors, switches, and transmitters. Air-temperature sensors, switches, and transmitters are specified in Section **230923.27** "Temperature Instruments."
 9. Relays.
 10. **<Insert additional control devices>**.
- B. Deliver the following to terminal unit manufacturer for factory installation. Include installation instructions to terminal unit manufacturer.
1. **[Programmable application] [or] [application-specific]** controller.
 2. Electric damper actuator. Dampers actuators are specified in Section **230923.12** "Control Dampers."
 3. Unit-mounted flow and pressure sensors, transmitters, and transducers. Flow sensors, transmitters, and transducers are specified in Section **230923.14** "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section **230923.23** "Pressure Instruments."
 4. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section **230923.27** "Temperature Instruments."
 5. Relays.
 6. **<Insert additional control devices>**.
- C. Deliver the following to fan-coil unit manufacturer for factory installation. Include installation instructions to fan-coil unit manufacturer.
1. **[Programmable application] [or] [application-specific]** controller.
 2. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section **230923.27** "Temperature Instruments."
 3. Flow and pressure switches. Air and liquid flow sensors, transmitters, and transducers are specified in Section **230923.14** "Flow Instruments." Pressure

sensors, switches, and transmitters are specified in Section **230923.23** "Pressure Instruments."

4. Leak-detection switches, which are specified in Section **230923.18** "Leak-Detection Instruments."
5. Relays.
6. **<Insert additional control devices>**.

3.6 GENERAL INSTALLATION REQUIREMENTS

- A. Install products to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Support products, tubing, piping wiring, and raceways. Brace products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.
- E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- F. Firestop penetrations made in fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."
- G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."
- H. Welding Requirements:
 1. Restrict welding and burning to supports and bracing.
 2. No equipment shall be cut or welded without approval. Welding or cutting will not be approved if there is risk of damage to adjacent Work.
 3. Welding, where approved, shall be by inert-gas electric arc process and shall be performed by qualified welders according to applicable welding codes.
 4. If requested on-site, show satisfactory evidence of welder certificates indicating ability to perform welding work intended.
- I. Fastening Hardware:
 1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.

- J. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.
- K. Corrosive Environments:
1. Avoid or limit use of materials in corrosive airstreams and environments, including, but not limited to, the following:
 - a. Laboratory exhaust-air streams.
 - b. Process exhaust-air streams.
 2. When conduit is in contact with a corrosive airstream and environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment. Comply with requirements for installation of raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
 3. Where instruments are located in a corrosive airstream and are not corrosive resistant from manufacturer, field install products in NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.7 OPERATOR WORKSTATION INSTALLATION

- A. Desktop Operator Workstations Installation:
1. Install operator workstation(s) at location(s) directed by Owner.
 2. Install multiple-receptacle power strip with cord for use in connecting multiple workstation components to a single duplex electrical power receptacle.
 3. Install software on workstation(s) and verify software functions properly.
 4. Develop Project-specific graphics, trends, reports, logs, and historical database.
 5. Power [**each**] workstation through a [**dedicated**] UPS unit. Locate UPS adjacent to workstation.
- B. Portable Operator Workstations Installation:
1. Turn over portable operator workstations to Owner at Substantial Completion.
 2. Install software on workstation(s) and verify software functions properly.
- C. Color Graphics Application:
1. Use system schematics indicated as starting point to create graphics.
 2. Develop Project-specific library of symbols for representing system equipment and products.
 3. Incorporate digital images of Project-completed installation into graphics where beneficial to enhance effect.
 4. Submit sketch of graphic layout with description of all text for each graphic for Owner's[**and Architect's**] review before creating graphic using graphics software.
 5. Seek Owner input in graphics development once using graphics software.

6. Final editing shall be done on-site with Owner's[**and Architect's**] review and feedback.
7. Refine graphics as necessary for Owner acceptance.
8. On receiving Owner acceptance, print a hard copy for inclusion in operation and maintenance manual. Prepare a scanned copy PDF file of each graphic and include with softcopy of DDC system operation and maintenance manual.

D. Wall-Mounted Portable Operator's Workstation Cabinet Installation:

1. Install wall-mounted portable operator's workstation cabinet(s) at location(s) indicated on Drawings.
2. Install wall-mounted portable operator's workstation cabinet(s) at following location(s) and at locations directed by Owner:
 - a. Each mechanical room.
 - b. Chiller room.
 - c. Boiler room.
 - d. **<Insert location>**.
3. Connect each cabinet to **[120-V, single-phase, 60Hz]** **<Insert power requirements>** field power source, and install single gang electrical box with **[NEMA WD 6, Type 20R duplex]** **<Insert receptacle type>** receptacle and metal cover plate in cabinet. Comply with requirements in Section 262726 "Wiring Devices."
4. Connect each cabinet to Ethernet network and install an Ethernet network port for connection to portable operator workstation Ethernet cable. Comply with requirements in Section 271500 "Communications Horizontal Cabling."

3.8 POT INSTALLATION

- A. Install **[one]** **[two]** **<Insert quantity>** portable operator terminal(s).
- B. Turn over POTs to Owner at Substantial Completion.
- C. Install software on each POT and verify that software functions properly.

3.9 SERVER INSTALLATION

- A. Install **[one]** **[two]** **<Insert quantity>** server(s) at location(s) directed by Owner.
- B. Install number of servers required to suit requirements indicated. Review Project requirements and indicate layout of proposed location in Shop Drawings.
- C. Install software indicated on server(s) and verify that software functions properly.
- D. Develop Project-specific graphics, trends, reports, logs, and historical database.
- E. Power servers through **[dedicated]** UPS unit. Locate UPS adjacent to server.

3.10 PRINTER INSTALLATION

- A. Provide the following printer(s) at location(s) directed by Owner:
1. Black and White Laser: Quantity, [**one**] [**one per desktop workstation**] <Insert quantity>.
 2. Color Laser: Quantity, [**one**] [**one per desktop workstation**] <Insert quantity>.
 3. Color Inkjet: Quantity, [**one**] [**one per desktop workstation**] <Insert quantity>.
 4. Dot Matrix: Quantity, [**one**] [**one per desktop workstation**] <Insert quantity>.
- B. Install printer software on workstations and verify that software functions properly.

3.11 GATEWAY INSTALLATION

- A. Install gateways if required for DDC system communication interface requirements indicated.
1. Install gateway(s) required to suit indicated requirements.
 - a. <Insert requirements>.
- B. Test gateway to verify that communication interface functions properly.

3.12 ROUTER INSTALLATION

- A. Install routers if required for DDC system communication interface requirements indicated.
1. Install router(s) required to suit indicated requirements.
 - a. <Insert requirements>.
- B. Test router to verify that communication interface functions properly.

3.13 CONTROLLER INSTALLATION

- A. Install controllers in enclosures to comply with indicated requirements.
- B. Connect controllers to field power supply[**and to UPS units where indicated**].
- C. Install controller with latest version of applicable software and configure to execute requirements indicated.
- D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.
- E. Installation of Network Controllers:

1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. Install controllers in a protected location that is easily accessible by operators.
3. Top of controller shall be within [72 inches (1800 mm)] [84 inches (2100 mm)] <Insert dimension> of finished floor.

F. Installation of Programmable Application Controllers:

1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. Install controllers in a protected location that is easily accessible by operators.
3. Top of controller shall be within [72 inches (1800 mm)] [84 inches (2100 mm)] <Insert dimension> of finished floor.

G. Application-Specific Controllers:

1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.14 INSTALLATION OF WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Install wireless routers to achieve optimum performance and best possible coverage.
- B. Mount wireless routers in a protected location that is within 60 inches (1500 mm) of floor and easily accessible by operators.
- C. Connect wireless routers to field power supply and to UPS units if network controllers are powered through UPS units.
- D. Install wireless router with latest version of applicable software and configure wireless router with WPA2 security and password protection. Create access password with not less than 12 characters consisting of letters and numbers and at least one special character. Document password in operations and maintenance manuals for reference by operators.
- E. Test and adjust wireless routers for proper operation with portable workstation and other wireless devices intended for use by operators.

3.15 ENCLOSURES INSTALLATION

- A. Install the following items in enclosures, to comply with indicated requirements:
 1. Gateways.
 2. Routers.
 3. Controllers.
 4. Electrical power devices.
 5. UPS units.

6. Relays.
7. Accessories.
8. Instruments.
9. Actuators
10. **<Insert devices>**.

B. Attach wall-mounted enclosures to wall using the following types of steel struts:

1. For NEMA 250, [**Type 1**] **<Insert type>** Enclosures: Use [**painted steel**] [**galvanized-steel**] [**corrosion-resistant-coated steel**] strut and hardware.
2. For NEMA 250, [**Type 4**] [**Type 4X**] **<Insert type>** Enclosures and Enclosures Located Outdoors: Use stainless-steel strut and hardware.
3. Install plastic caps on exposed cut edges of strut.

C. Align [**top**] [**or**] [**bottom**] of adjacent enclosures[**of like size**].

D. Install floor-mounted enclosures located [**in mechanical equipment rooms**] on concrete housekeeping pads. Attach enclosure legs using [**galvanized-**] [**or**] [**stainless-**]steel anchors.

E. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireway used for application shall have protection equal to NEMA 250 rating of connected enclosures.

3.16 ELECTRIC POWER CONNECTIONS

A. Connect electrical power to DDC system products requiring electrical power connections.

B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.

C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.

D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.

E. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

3.17 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification products and installation.

- B. Install engraved phenolic nameplate with unique identification on face for each of the following:
1. Operator workstation.
 2. Server.
 3. Printer.
 4. Gateway.
 5. Router.
 6. Protocol analyzer.
 7. DDC controller.
 8. Enclosure.
 9. Electrical power device.
 10. UPS unit.
 11. Accessory.
- C. Install engraved phenolic nameplate with unique instrument identification on face of each instrument connected to a DDC controller.
- D. Install engraved phenolic nameplate with identification on face of each control [**damper**] [**and**] [**valve**] actuator connected to a DDC controller.
- E. Where product is installed above accessible tile ceiling, also install matching engraved phenolic nameplate with identification on face of ceiling grid located directly below.
- F. Where product is installed above an inaccessible ceiling, also install engraved phenolic nameplate with identification on face of access door directly below.
- G. Warning Labels:
1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
 2. Shall be located in highly visible location near power service entry points.

3.18 NETWORK INSTALLATION

- A. Install fiber-optic cable when connecting between the following network devices and when located in different buildings on campus, or when distance between devices exceeds **<Insert distance>**:
1. Operator workstations.
 2. Operator workstations and network controllers.
 3. Network controllers.
 4. **<Insert network device>**.
- B. Install copper [**or fiber-optic**] cable when connecting between the following network devices [**located in same building**]:
1. Operator workstations.
 2. Operator workstations and network controllers.
 3. Network controllers.

4. **<Insert network device>.**

C. Install copper cable when connecting between the following:

1. Gateways.
2. Gateways and network controllers or programmable application controllers.
3. Routers.
4. Routers and network controllers or programmable application controllers.
5. Network controllers and programmable application controllers.
6. Programmable application controllers.
7. Programmable application controllers and application-specific controllers.
8. Application-specific controllers.
9. **<Insert network device>.**

D. Install network cable in continuous raceway.

1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

3.19 NETWORK NAMING AND NUMBERING

A. Coordinate with Owner and provide unique naming and addressing for networks and devices.

B. ASHRAE 135 Networks:

1. MAC Address:

- a. Every network device shall have an assigned and documented MAC address unique to its network.
- b. Ethernet Networks: Document MAC address assigned at its creation.
- c. ARCNET or MS/TP networks: Assign from 00 to 64.

2. Network Numbering:

- a. Assign unique numbers to each new network.
- b. Provide ability for changing network number through device switches or operator interface.
- c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.

3. Device Object Identifier Property Number:

- a. Assign unique device object identifier property numbers or device instances for each device network.
- b. Provide for future modification of device instance number by device switches or operator interface.
- c. LAN shall support up to 4,194,302 unique devices.

4. Device Object Name Property Text:

- a. Device object name property field shall support 32 minimum printable characters.
 - b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.
 - 1) Example 1: Device object name for device controlling boiler plant at Building 1000 would be "HW System B1000."
 - 2) Example 2: Device object name for a VAV terminal unit controller could be "VAV unit 102".
5. Object Name Property Text for Other Than Device Objects:
- a. Object name property field shall support 32 minimum printable characters.
 - b. Assign object name properties with plain-English names descriptive of application.
 - 1) Example 1: "Zone 1 Temperature."
 - 2) Example 2 "Fan Start and Stop."
6. Object Identifier Property Number for Other Than Device Objects:
- a. Assign object identifier property numbers according to **[Drawings] [or] [tables]** indicated.
 - b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented and be unique for like object types within device.

3.20 PIPING AND TUBING INSTALLATION

A. Above-Grade Pneumatic and Air Signal Piping and Tubing Installation:

1. Material Application:
 - a. Install copper tubing, except as follows:
 - 1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing.
 - 2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when **[concealed behind accessible ceilings] [and] [concealed in walls and connecting wall-mounted instruments with recessed connections]**.
 - b. Install copper tubing for sizes up through **[NPS 1 (DN 25)]** <Insert size> and install galvanized-steel pipe for larger sizes, except as follows:
 - 1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing where exposed to view.
 - 2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when **[concealed behind accessible ceilings] [and]**

[concealed in walls and connecting wall-mounted instruments with recessed connections].

- c. Install copper tubing[, **unless other accessible materials are indicated,**] for pneumatic main and control signals to instruments including, but not limited to, the following:
 - 1) Pneumatic actuators.
 - 2) I/P transducers.
 - 3) Sensors.
 - 4) Switches.
 - 5) Transmitters.
 - 6) **<Insert instrument>**.
 - d. Install copper tubing[, **unless other accessible materials are indicated,**] for air signals to instruments including, but not limited to, the following:
 - 1) Sensors.
 - 2) Switches.
 - 3) Transmitters.
 - 4) **<Insert instrument>**.
 - e. Install drawn-temper copper tubing, except within **36 inches (900 mm)** of device terminations tubing shall be annealed-tempered copper tubing.
 - f. Install compression fittings to connect copper tubing to instruments, control devices, and accessories.
 - g. Install **[barbed] [or] [compression]** fittings to connect polyethylene tubing to instruments, control devices, and accessories.
2. Routing:
- a. Do not expose tubing in finished spaces, such as spaces with ceilings; occupied spaces, offices, and conference rooms, unless expressly approved in writing by Architect. Tubing may be exposed in areas without ceilings.
 - b. Where tubing is installed in finished occupied spaces, install the tubing in surface metal raceway with appropriate fittings only where not feasible to conceal in wall, above ceiling or behind architectural enclosures or covers.
 - c. Install piping and tubing plumb and parallel to and at right angles with building construction.
 - d. Install multiple runs of tubing or piping in equally spaced parallel lines.
 - e. Piping and tubing shall not interfere with access to valves, equipment, duct and equipment access doors, or obstruct personnel access and passageways of any kind.
 - f. Coordinate with other trades before installation to prevent proposed piping and tubing from interfering with pipe, duct, terminal equipment, light fixtures, conduit and cable tray space. If changes to Shop Drawings are necessary due to field coordination, document changes on record Drawings.

- k. Thread pipe on a threading machine. Ream inner edges of pipe ends, file, and grind to remove burrs.
 - l. Wrap pipe threads of fittings on pneumatic lines with a single wrap of PTFE tape.
 - m. Protect piping and tubing from entrance of foreign matter.
 7. Conduit in which nonmetallic tubing is installed shall not exceed 50 percent fill. Support conduit according to NFPA 70 unless otherwise indicated.
- B. Below-Grade Pneumatic and Air Signal Piping and Tubing Installation:
 1. Install tubing below grade in a continuous 4-inch (100-mm), Schedule 80, PVC conduit.
 2. Install at a depth of at least 24 inches (600 mm) below finished grade.
 3. Install tubing in raceways dedicated to tubing. Do not combine electrical conductors and tubing in raceways.
- C. Identify piping and tubing as follows:
 1. Every 50 feet (15 m) of straight run.
 2. At least once for each branch within 36 inches (900 mm) of main tee.
 3. At each change in direction.
 4. Within 36 inches (900 mm) of each ceiling, floor, roof and wall penetration.
 5. Where exposed to and where concealed from view, including above ceiling plenums, shafts, and chases.
 6. At each valve.
 7. Mark each instrument tube connection with a number-coded identification. Each unique tube shall have same unique number at instrument connection and termination at opposite end of tube.
- D. Isolation Valves Installation:
 1. Install valves full size of piping and tubing.
 2. Install at the following locations:
 - a. At each branch.
 - b. Before and after each PRV.
 - c. Before and after each air dryer.
 - d. At each control device.
 3. Valves shall be located to be readily accessible from floor.
- E. Process Tubing Installation:
 1. Install process tubing for signal to instruments in liquid and steam systems. Instruments include, but are not limited to, the following:
 - a. Meters.
 - b. Sensors.
 - c. Switches.

d. Transmitters.

2. Support tubing according to MSS SP-69, Table 3, but at intervals no less than 60 inches (1500 mm).
3. Install NPS 1/2 (DN 15) process tubing for industrial-grade sensors, transmitters, and switches. Install stainless-steel bushings where required.
4. Make tubing bends with a bending tool. Flattened or wrinkled bends are unacceptable.
5. Support tubing independent of other trades.
6. Route tubing parallel to and at right angles to building construction.
7. Install tubing concealed in areas with ceilings.
8. Install a dirt leg with an isolation valve and threaded plug in drain valve at each connection to a transmitter and switch.
9. Insulate process piping connected to hot water and steam systems for personnel protection if the surface temperature exceeds 120 deg F (49 deg C). Only insulate piping within maintenance personnel reach from floor, platform, or catwalk.
10. Wrap pipe threads of fitting in process tubing with service temperatures below 350 deg F (177 deg C) with a single wrap of PTFE tape.
11. Coat pipe threads of fittings on process tubing in services with temperatures exceeding 350 deg F (177 deg C) with pipe compound before being made up to reduce the possibility of galling.
12. Do not make tubing connections to a fitting before completing makeup of the connection.
13. Check tubing for correct diameter and wall thickness. Cut the tube ends square and deburred. Exercise care during cutting to keep tubing round.
14. Do not install fittings close to a bend. A length of straight tubing, not deformed by bending, is required for a proper connection.
15. Align tubing with fitting when installed. Avoid springing tube into position.
16. Install tubing with extreme care exercised to keep foreign matter out of system. Open tubing ends shall be kept plugged to keep out dust, dirt and moisture.
17. Do not attach tubing to equipment that may be removed frequently for maintenance or may impart vibration and expansion from temperature change.
18. Protect exposed tubing in mechanical equipment rooms from inadvertent mechanical damage within [76 inches (1800 mm)] [84 inches (2100 mm)] [96 inches (2400 mm)] <Insert dimension> above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.

F. Isolation Valves Installation:

1. Install valves full size of piping and tubing.
2. Install isolation valves at the following locations:
 - a. Process connection.
 - b. Inlet to each instrument including, sensors, transmitters, switches, gages, and other control devices.
3. Locate valves to be readily accessible from floor.

3.21 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

- A. Comply with NECA 1.
- B. Comply with TIA 568-C.1.
- C. Wiring Method: Install cables in raceways and cable trays[**except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used**]. Conceal raceway and cables except in unfinished spaces.
 - 1. Install plenum cable in environmental air spaces, including plenum ceilings.
 - 2. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
 - 3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- D. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- E. Field Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.
- F. Conduit Installation:
 - 1. Install conduit expansion joints where conduit runs exceed **200 feet (60 m)**, and conduit crosses building expansion joints.
 - 2. Coordinate conduit routing with other trades to avoid conflicts with ducts, pipes and equipment and service clearance.
 - 3. Maintain at least **3-inch (75-mm)** separation where conduits run axially above or below ducts and pipes.
 - 4. Limit above-grade conduit runs to **100 feet (30 m)** without pull or junction box.
 - 5. Do not install raceways or electrical items on any "explosion-relief" walls, or rotating equipment.
 - 6. Do not fasten conduits onto the bottom side of a metal deck roof.
 - 7. Flexible conduit is permitted only where flexibility and vibration control is required.
 - 8. Limit flexible conduit to **3 feet (1 m)** long.
 - 9. Conduit shall be continuous from outlet to outlet, from outlet to enclosures, pull and junction boxes, and shall be secured to boxes in such manner that each system shall be electrically continuous throughout.
 - 10. Direct bury conduits underground or install in concrete-encased duct bank where indicated.
 - a. Use rigid, nonmetallic, Schedule 80 PVC.
 - b. Provide a burial depth according to NFPA 70, but not less than **24 inches (600 mm)**.
 - 11. Secure threaded conduit entering an instrument enclosure, cabinet, box, and trough, with a locknut on outside and inside, such that conduit system is

electrically continuous throughout. Provide a metal bushing on inside with insulated throats. Locknuts shall be the type designed to bite into the metal or, on inside of enclosure, shall have a grounding wedge lug under locknut.

12. Conduit box-type connectors for conduit entering enclosures shall have an insulated throat.
13. Connect conduit entering enclosures in wet locations with box-type connectors or with watertight sealing locknuts or other fittings.
14. Offset conduits where entering surface-mounted equipment.
15. Seal conduit runs used by sealing fittings to prevent the circulation of air for the following:
 - a. Conduit extending from interior to exterior of building.
 - b. Conduit extending into pressurized duct and equipment.
 - c. Conduit extending into pressurized zones that are automatically controlled to maintain different pressure set points.
 - d. **<Insert requirement>**.

G. Wire and Cable Installation:

1. Cables serving a common system may be grouped in a common raceway. Install control wiring and cable in separate raceway from power wiring. Do not group conductors from different systems or different voltages.
2. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 90 deg C with no measurable effect on physical and electrical properties of cable.
 - a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.
3. Install lacing bars to restrain cables, to prevent straining connections, and to prevent bending cables to smaller radii than minimums recommended by manufacturer.
4. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIMM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
5. UTP Cable Installation:
 - a. Comply with TIA 568-C.2.
 - b. Do not untwist UTP cables more than **1/2 inch (12 mm)** from the point of termination, to maintain cable geometry.
6. Installation of Cable Routed Exposed under Raised Floors:
 - a. Install plenum-rated cable only.
 - b. Install cabling after the flooring system has been installed in raised floor areas.
 - c. Coil cable [**6 feet (1.8 m)**] **<Insert dimension>** long not less than [**12 inches (300 mm)**] **<Insert dimension>** in diameter below each feed point.

7. Identify each wire on each end and at each terminal with a number-coded identification tag. Each wire shall have a unique tag.
8. Provide strain relief.
9. Terminate wiring in a junction box.
 - a. Clamp cable over jacket in junction box.
 - b. Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.
10. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
11. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
12. Keep runs short. Allow extra length for connecting to terminal boards. Do not bend flexible coaxial cables in a radius less than 10 times the cable OD. Use sleeves or grommets to protect cables from vibration at points where they pass around sharp corners and through penetrations.
13. Ground wire shall be copper and grounding methods shall comply with IEEE C2. Demonstrate ground resistance.
14. Wire and cable shall be continuous from terminal to terminal without splices.
15. Use insulated spade lugs for wire and cable connection to screw terminals.
16. Use shielded cable to transmitters.
17. Use shielded cable to temperature sensors.
18. Perform continuity and meager testing on wire and cable after installation.
19. Do not install bruised, kinked, scored, deformed, or abraded wire and cable. Remove and discard wire and cable if damaged during installation, and replace it with new cable.
20. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
21. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.
22. Protection from Electro-Magnetic Interference (EMI): Provide installation free of (EMI). As a minimum, comply with the following requirements:
 - a. Comply with BICSI TDMM and TIA 569-C for separating unshielded cable from potential EMI sources, including electrical power lines and equipment.
 - b. Separation between open cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
 - 1) Electrical Equipment Rating Less Than 2 kVA: A minimum of **5 inches** (127 mm).
 - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of **12 inches** (300 mm).
 - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of **24 inches** (610 mm).
 - c. Separation between cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:

- 1) Electrical Equipment Rating Less Than 2 kVA: A minimum of **2-1/2 inches** (64 mm).
 - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of **6 inches** (150 mm).
 - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of **12 inches** (300 mm).
- d. Separation between cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
- 1) Electrical Equipment Rating Less Than 2 kVA: No requirement.
 - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of **3 inches** (76 mm).
 - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of **6 inches** (150 mm).
- e. Separation between Cables and Electrical Motors and Transformers, 5 kVA or 5 HP and Larger: A minimum of **48 inches** (1200 mm).
- f. Separation between Cables and Fluorescent Fixtures: A minimum of **5 inches** (127 mm).

3.22 FIBER-OPTIC CABLE SYSTEM INSTALLATION

- A. Comply with TIA 568-C.3, except where requirements indicated are more stringent.
- B. Raceway Installation:
1. Install continuous raceway for routing fiber-optic cables.
 2. Install raceways continuously between pull boxes and junction boxes. Raceways shall enter and be secured to enclosures.
 3. Make bends in raceway using large-radius preformed ells. Field bending shall be according to NFPA 70 minimum radii requirements. Use only equipment specifically designed for material and size involved.
 4. Install no more than the equivalent of two 90-degree bends in any pathway run. Support within **12 inches** (300 mm) of changes in direction. Use long radius elbows for all fiber-optic cables.
 5. Entire raceway shall be complete and raceway interior cleaned before installation of fiber-optic cables.
 6. Securely fasten raceway to building structure using clamps and clips designed for purpose.
 7. Install nylon or polyethylene pulling line in raceways. Clearly label as "pulling line," indicating source and destination.
- C. Fiber-Optic Cable Installation:
1. Route cables as efficiently as possible, minimizing amount of cable required.
 2. Continuously lubricate cables during pulling-in process.

3. Do not exceed maximum pulling tensions provided by cable manufacturer. Monitor cable pulling tension with a mechanical tension meter.
4. Arrange cables passing through pull boxes to obtain maximum clearance among cables within box.
5. As cables emerge from intermediate point pull boxes, coil cable in a figure eight pattern with loops not less than **24 inches (600 mm)** in diameter.
6. Terminate fiber-optic cables in a fiber-optic splice organizer cabinet, unless connected equipment can accept fiber-optic cables directly. Terminate cables with connectors.
7. Install and connect appropriate opto-electronic equipment and fiber jumper cables between opto-electronic equipment and fiber-optic cable system to DDC system fiber-optic cable system. Verify interface compatibility.

D. Cable and Raceway Identification:

1. Label cables at both ends. Labels shall be typed, not handwritten.
2. Mark raceways at each pull box indicating the type and number of cables within.

3.23 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 3. Testing of Pneumatic and Air-Signal Tubing:
 - a. Test for leaks and obstructions.
 - b. Disconnect each pipe and tubing line before a test is performed, and blowout dust, dirt, trash, condensate and other foreign materials with compressed air. Use commercially pure compressed air or nitrogen as distributed in gas cylinders. Air from an oil-free compressor with an air dryer is an acceptable alternative for the test.
 - c. After foreign matter is expelled and line is free from obstructions, plug far end of tubing run.
 - d. Connect a pressure source to near end of run with a needle valve between air supply and tubing run.
 - e. Connect a pressure gage accurate to within 0.5 percent of test between the shutoff needle valve and tubing run under test.
 - f. For system pressures above **30 psig (207 kPa)**, apply a pressure of 1.5 times operating pressure. Record pressure in tubing run every 10 minutes

for one hour. Allowable drop in pressure in one-hour period shall not exceed 1 psig (6.9 kPa).

- g. For system pressures 30 psig (207 kPa) and below, apply a pressure of 2.0 times operating pressure to piping and tubing run. Record pressure in tubing run every 5 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed 0.5 psig (3.5 kPa).

D. Testing:

1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.
2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.
3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by DDC system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.
5. Test Equipment: Use a fiber-optic time domain reflectometer for testing of length and optical connectivity.
6. Test Results: Record test results and submit copy of test results for Project record.

3.24 DDC SYSTEM I/O CHECKOUT PROCEDURES

- A. Check installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
- D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
- E. For pneumatic products, verify that air supply for each product is properly installed.
- F. Control Damper Checkout:
 1. For pneumatic dampers, verify that pressure gages are provided in each air line to damper actuator and positioner.

2. Verify that control dampers are installed correctly for flow direction.
3. Verify that proper blade alignment, either parallel or opposed, has been provided.
4. Verify that damper frame attachment is properly secured and sealed.
5. Verify that damper actuator and linkage attachment is secure.
6. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
7. Verify that damper blade travel is unobstructed.

G. Control Valve Checkout:

1. For pneumatic valves, verify that pressure gages are provided in each air line to valve actuator and positioner.
2. Verify that control valves are installed correctly for flow direction.
3. Verify that valve body attachment is properly secured and sealed.
4. Verify that valve actuator and linkage attachment is secure.
5. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
6. Verify that valve ball, disc or plug travel is unobstructed.
7. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

H. Instrument Checkout:

1. Verify that instrument is correctly installed for location, orientation, direction, and operating clearances.
2. Verify that attachment is properly secured and sealed.
3. Verify that conduit connections are properly secured and sealed.
4. Verify that wiring is properly labeled with unique identification, correct type, and size and is securely attached to proper terminals.
5. Inspect instrument tag against approved submittal.
6. For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
8. For temperature instruments:
 - a. Verify sensing element type and proper material.
 - b. Verify length and insertion.

3.25 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:

- A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.

- C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
- D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
- E. Provide diagnostic and test equipment for calibration and adjustment.
- F. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
- G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
- H. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
- I. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- J. Analog Signals:
 - 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 - 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
 - 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.
- K. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact making or breaking.
- L. Control Dampers:
 - 1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed and 100 percent open at proper air pressure.
 - 3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 4. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- M. Control Valves:

1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
2. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed and 100 percent open at proper air pressures.
3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
4. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

N. Meters: Check sensors at zero, 50, and 100 percent of Project design values.

O. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

P. Switches: Calibrate switches to make or break contact at set points indicated.

Q. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.26 DDC SYSTEM CONTROLLER CHECKOUT

A. Verify power supply.

1. Verify voltage, phase, and hertz.
2. Verify that protection from power surges is installed and functioning.
3. Verify that ground fault protection is installed.
4. If applicable, verify if connected to UPS unit.
5. If applicable, verify if connected to a backup power source.
6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.

B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.

C. Verify that spare I/O capacity is provided.

3.27 DDC CONTROLLER I/O CONTROL LOOP TESTS

A. Testing:

1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
2. Test every I/O point throughout its full operating range.

3. Test every control loop to verify operation is stable and accurate.
4. Adjust control loop proportional, integral, and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
5. Test and adjust every control loop for proper operation according to sequence of operation.
6. Test software and hardware interlocks for proper operation. Correct deficiencies.
7. Operate each analog point at the following:
 - a. Upper quarter of range.
 - b. Lower quarter of range.
 - c. At midpoint of range.
8. Exercise each binary point.
9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller and at field instrument shall match.
10. Prepare and submit a report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desired results.

3.28 DDC SYSTEM VALIDATION TESTS

- A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.
- B. After approval of Test Plan, execute all tests and procedures indicated in plan.
- C. After testing is complete, submit completed test checklist.
- D. Pretest Checklist: Submit the following list with items checked off once verified:
 1. Detailed explanation for any items that are not completed or verified.
 2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
 3. HVAC equipment motors operate below full-load amperage ratings.
 4. Required DDC system components, wiring, and accessories are installed.
 5. Installed DDC system architecture matches approved Drawings.
 6. Control electric power circuits operate at proper voltage and are free from faults.
 7. Required surge protection is installed.
 8. DDC system network communications function properly, including uploading and downloading programming changes.
 9. Using BACnet protocol analyzer, verify that communications are error free.
 10. Each controller's programming is backed up.
 11. Equipment, products, tubing, wiring cable, and conduits are properly labeled.
 12. All I/O points are programmed into controllers.
 13. Testing, adjusting, and balancing work affecting controls is complete.
 14. Dampers and actuators zero and span adjustments are set properly.

15. Each control damper and actuator goes to failed position on loss of power.
16. Valves and actuators zero and span adjustments are set properly.
17. Each control valve and actuator goes to failed position on loss of power.
18. Meter, sensor, and transmitter readings are accurate and calibrated.
19. Control loops are tuned for smooth and stable operation.
20. View trend data where applicable.
21. Each controller works properly in standalone mode.
22. Safety controls and devices function properly.
23. Interfaces with fire-alarm system function properly.
24. Electrical interlocks function properly.
25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
26. Record Drawings are completed.

E. Test Plan:

1. Prepare and submit a validation test plan including test procedures for performance validation tests.
2. Test plan shall address all specified functions of DDC system and sequences of operation.
3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
5. Include a test checklist to be used to check and initial that each test has been successfully completed.
6. Submit test plan documentation [10] [20] <Insert number> business days before start of tests.

F. Validation Test:

1. Verify operating performance of each I/O point in DDC system.
 - a. Verify analog I/O points at operating value.
 - b. Make adjustments to out-of-tolerance I/O points.
 - 1) Identify I/O points for future reference.
 - 2) Simulate abnormal conditions to demonstrate proper function of safety devices.
 - 3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
2. Simulate conditions to demonstrate proper sequence of control.
3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
4. After 24 Hours following Initial Validation Test:
 - a. Re-check I/O points that required corrections during initial test.
 - b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.

5. After 24 Hours of Second Validation Test:
 - a. Re-check I/O points that required corrections during second test.
 - b. Continue validation testing until I/O point is normal on two consecutive tests.
 6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
 7. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.
- G. DDC System Response Time Test:
1. Simulate HLC.
 - a. Heavy load shall be an occurrence of **[50]** <Insert number> percent of total connected binary COV, one-half of which represent an "alarm" condition, and **[50]** <Insert number> percent of total connected analog COV, one-half of which represent an "alarm" condition, that are initiated simultaneously on a one-time basis.
 2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
 3. Measure with a timer having at least 0.1-second resolution and 0.01 percent accuracy.
 4. Purpose of test is to demonstrate DDC system, as follows:
 - a. Reaction to COV and alarm conditions during HLC.
 - b. Ability to update DDC system database during HLC.
 5. Passing test is contingent on the following:
 - a. Alarm reporting at printer beginning no more than **[two]** <Insert number> seconds after the initiation (time zero) of HLC.
 - b. All alarms, both binary and analog, are reported and printed; none are lost.
 - c. Compliance with response times specified.
 6. Prepare and submit a report documenting HLC tested and results of test including time stamp and print out of all alarms.
- H. DDC System Network Bandwidth Test:
1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
 2. To pass, none of DDC system networks shall use more than 70 percent of available bandwidth under normal and HLC operation.

3.29 DDC SYSTEM WIRELESS NETWORK VERIFICATION

- A. DDC system Installer shall design wireless DDC system networks to comply with performance requirements indicated.
- B. Installer shall verify wireless network performance through field testing and shall document results in a field test report.
- C. Testing and verification of all wireless devices shall include, but not be limited to, the following:
 - 1. Speed.
 - 2. Online status.
 - 3. Signal strength.

3.30 FINAL REVIEW

- A. Submit written request to Architect **[and] [Construction Manager]** when DDC system is ready for final review. Written request shall state the following:
 - 1. DDC system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.
 - 2. DDC system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.
 - 3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
 - 4. DDC system is complete and ready for final review.
- B. Review by **[Architect] [and] [Construction Manager]** shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.
- C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.
- D. Should more than two reviews be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews. Estimated cost of each review shall be submitted and approved by DDC system manufacturer and Installer before making the review.
- E. Prepare and submit closeout submittals **[and begin procedures indicated in "Extended Operation Test" Article]** when no deficiencies are reported.
- F. A part of DDC system final review shall include a demonstration to parties participating in final review.

1. Provide staff familiar with DDC system installed to demonstrate operation of DDC system during final review.
2. Provide testing equipment to demonstrate accuracy and other performance requirements of DDC system that is requested by reviewers during final review.
3. Demonstration shall include, but not be limited to, the following:
 - a. Accuracy and calibration of [10] [20] <Insert number> I/O points randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional I/O points may be selected by reviewers until total I/O points being reviewed that satisfy requirements equals quantity indicated.
 - b. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. Up to [10] [20] <Insert number> I/O points shall be randomly selected by reviewers. Additional I/O points may be selected by reviewers to discover problems with operation.
 - c. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
 - d. Operation of randomly selected dampers and valves in normal-on, normal-off and failed positions.
 - e. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
 - f. Trends, summaries, logs, and reports set-up for Project.
 - g. For up to [three] <Insert number> HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20 percent or more.
 - h. Software's ability to communicate with controllers, operator workstations, uploading and downloading of control programs.
 - i. Software's ability to edit control programs off-line.
 - j. Data entry to show Project-specific customizing capability including parameter changes.
 - k. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
 - l. Execution of digital and analog commands in graphic mode.
 - m. Spreadsheet and curve plot software and its integration with database.
 - n. Online user guide and help functions.
 - o. Multitasking by showing different operations occurring simultaneously on four quadrants of split screen.
 - p. System speed of response compared to requirements indicated.
 - q. For Each [Network] [and] [Programmable Application] Controller:
 - 1) Memory: Programmed data, parameters, trend, and alarm history collected during normal operation is not lost during power failure.
 - 2) Operator Interface: Ability to connect directly to each type of digital controller with a portable operator workstation and PDA. Show that

- maintenance personnel interface tools perform as indicated in manufacturer's technical literature.
- 3) Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
 - 4) Electric Power: Ability to disconnect any controller safely from its power source.
 - 5) Wiring Labels: Match control drawings.
 - 6) Network Communication: Ability to locate a controller's location on network and communication architecture matches Shop Drawings.
 - 7) Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators, and devices.
- r. For Each Operator Workstation:
- 1) I/O points lists agree with naming conventions.
 - 2) Graphics are complete.
 - 3) UPS unit, if applicable, operates.
- s. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management.[**Use ASHRAE 135 protocol analyzer to help identify devices, view network traffic, and verify interoperability.**] Requirements must be met even if only one manufacturer's equipment is installed.
- 1) Data Presentation: On each operator workstation, demonstrate graphic display capabilities.
 - 2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
 - 3) Set Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated.[**Modifications are made with messages and write services initiated by an operator using workstation graphics, or by completing a field in a menu with instructional text.**]
 - 4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
 - 5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.
 - 6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
 - 7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.

- 8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
- 9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.
- 10) Device and Network Management:
 - a) Display of network device status.
 - b) Display of BACnet Object Information.
 - c) Silencing devices transmitting erroneous data.
 - d) Time synchronization.
 - e) Remote device re-initialization.
 - f) Backup and restore network device programming and master database(s).
 - g) Configuration management of routers.

t. <Insert additional requirements>.

3.31 EXTENDED OPERATION TEST

- A. Extended operation test is intended to simulate normal operation of DDC system by Owner.
- B. Operate DDC system for an operating period of [14] [21] [28] <Insert number> consecutive calendar days following Substantial Completion. Coordinate exact start date of testing with Owner.
- C. Provide an operator familiar with DDC system installed to man an operator workstation [**while on-site**] during eight hours of each normal business day occurring during operating period.
- D. During operating period, DDC system shall demonstrate correct operation and accuracy of monitored and controlled points as well as operation capabilities of sequences, logs, trends, reports, specialized control algorithms, diagnostics, and other software indicated.
 1. Correct defects of hardware and software when it occurs.
- E. Definition of Failures and Downtime during Operating Period:
 1. Failed I/O point constituting downtime is an I/O point failing to perform its intended function consistently and a point physically failed due to hardware and software.
 2. Downtime is when any I/O point in DDC system is unable to fulfill its' required function.
 3. Downtime shall be calculated as elapsed time between a detected point failure as confirmed by an operator and time point is restored to service.

4. Maximum time interval allowed between DDC system detection of failure occurrence and operator confirmation shall be 0.5 hours.
 5. Downtime shall be logged in hours to nearest 0.1 hour.
 6. Power outages shall not count as downtime, but shall suspend test hours unless systems are provided with UPS and served through a backup power source.
 7. Hardware or software failures caused by power outages shall count as downtime.
- F. During operating period, log downtime and operational problems are encountered.
1. Identify source of problem.
 2. Provide written description of corrective action taken.
 3. Record duration of downtime.
 4. Maintain log showing the following:
 - a. Time of occurrence.
 - b. Description of each occurrence and pertinent written comments for reviewer to understand scope and extent of occurrence.
 - c. Downtime for each failed I/O point.
 - d. Running total of downtime and total time of I/O point after each problem has been restored.
 5. Log shall be available to Owner for review at any time.
- G. For DDC system to pass extended operation test, total downtime shall not exceed [1] [2] <Insert number> percent of total point-hours during operating period.
1. Failure to comply with minimum requirements of passing at end of operating period indicated shall require that operating period be extended one consecutive day at a time until DDC system passes requirement.
- H. Evaluation of DDC system passing test shall be based on the following calculation:
1. Downtime shall be counted on a point-hour basis where total number of DDC system point-hours is equal to total number of I/O points in DDC system multiplied by total number of hours during operating period.
 2. One point-hour of downtime is one I/O point down for one hour. Three points down for five hours is a total of 15 point-hours of downtime. Four points down for one-half hour is 2 point-hours of downtime.
 3. Example Calculation: Maximum allowable downtime for 30-day test when DDC system has 1000 total I/O points (combined analog and binary) and has passing score of 1 percent downtime is computed by 30 days x 24 h/day x 1000 points x 1 percent equals 7200 point-hours of maximum allowable downtime.
- I. Prepare test and inspection reports.
- ### 3.32 ADJUSTING
- A. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit

actual occupied conditions. Provide up to **[two]** **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.33 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three]** **[six]** **[nine]** **[12]** **<Insert number>** months' full maintenance by DDC system manufacturer's authorized service representative. Include **[monthly]** **[quarterly]** **[semiannual]** **[annual]** preventive maintenance, repair, or replacement of worn or defective components, cleaning, calibration, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.34 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for **[one]** **[two]** **<Insert number>** year(s).
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within **[one]** **[two]** **<Insert number>** year(s) from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
1. Upgrade Notice: At least **[30]** **<Insert number>** days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

3.35 DEMONSTRATION

- A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.
- B. Extent of Training:
1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
 2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
 3. Minimum Training Requirements:
 - a. Provide not less than **[five]** **[10]** **[15]** **<Insert number>** days of training total.
 - b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.
 - c. Total days of training shall be broken into not more than **[two]** **[three]** **[four]** **<Insert number>** separate training classes.

- d. Each training class shall be not less than **[one] [two] [three]** <Insert number> consecutive day(s).

C. Training Schedule:

1. Schedule training with Owner **[20]** <Insert number> business days before expected Substantial Completion.
2. Schedule training to provide Owner with at least **[10] [15] [20]** <Insert number> business days of notice in advance of training.
3. Training shall occur within normal business hours at a mutually agreed on time. Unless otherwise agreed to, training shall occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session shall be split in half with **[15] [30]** <Insert number>-minute break between sessions. Morning and afternoon sessions shall be separated by **[30] [60]** <Insert number>-minute lunch period. Training, including breaks and excluding lunch period, shall not exceed **[eight]** <Insert number> hours per day.
4. Provide staggered training schedule as requested by Owner.

D. Training Attendee List and Sign-in Sheet:

1. Request from Owner in advance of training a proposed attendee list with name, phone number, and e-mail address.
2. Provide a preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
3. Preprinted sign-in sheet shall include training session number, date and time, instructor name, phone number and e-mail address, and brief description of content to be covered during session. List attendees with columns for name, phone number, e-mail address and a column for attendee signature or initials.
4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
5. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.

E. Training Attendee Headcount:

1. Plan in advance of training for **[two] [three] [five]** <Insert number> attendees.
2. Make allowance for Owner to add up to **[one] [two]** <Insert number> attendee(s) at time of training.
3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.

F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:

1. **[High school] [High school and technical school] [High school and four-year college]** <Insert level> education and degree.
2. **[Basic] [Intermediate] [Advanced]** user knowledge of computers and office applications.

3. **[Basic] [Intermediate] [Advanced]** knowledge of HVAC systems.
4. **[Basic] [Intermediate] [Advanced]** knowledge of DDC systems.
5. **[Basic] [Intermediate] [Advanced]** knowledge of DDC system and products installed.

G. Attendee Training Manuals:

1. Provide each attendee with a color hard copy of all training materials and visual presentations.
2. Hard-copy materials shall be organized in a three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes a DVD or flash drive with PDF copy of all hard-copy materials.

H. Instructor Requirements:

1. One or multiple qualified instructors, as required, to provide training.
2. Instructors shall have not less than **[five] <Insert number>** years of providing instructional training on not less than **[five] <Insert number>** past projects with similar DDC system scope and complexity to DDC system installed.

I. Organization of Training Sessions:

1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
 - a. Daily operators.
 - b. Advanced operators.
 - c. System managers and administrators.
2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions that cover restricted content for purposes of maintaining DDC system security.

J. Training Outline:

1. Submit training outline for Owner review at least **[10] <Insert number>** business day before scheduling training.
2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.

2. Instructor shall provide training materials, projector, and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration, and service requirements.
5. Operator workstation provided with DDC system shall be used in training. If operator workstation is not indicated, provide a temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables, desks, or tables, chairs, power and data connectivity for each attendee.
2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide a workstation for use by each attendee.

M. Training Content for Daily Operators:

1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.
4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm, and each unique optimization routine.
5. Operating operator workstations, printers and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports, and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.
14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.

20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:
 - a. Operation of HVAC equipment in normal-off, -on and failed conditions while observing individual equipment, dampers, and valves for correct position under each condition.
 - b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
 - c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles and other modes of operation indicated.
 - d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
 - e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
 - f. Each control loop responds to set point adjustment and stabilizes within time period indicated.
 - g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.
26. **<Insert requirement>**.

N. Training Content for Advanced Operators:

1. Making and changing workstation graphics.
2. Creating, deleting, and modifying alarms including annunciation and routing.
3. Creating, deleting, and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
4. Creating, deleting, and modifying reports.
5. Creating, deleting, and modifying points.
6. Creating, deleting, and modifying programming including ability to edit control programs off-line.
7. Creating, deleting, and modifying system graphics and other types of displays.
8. Adding DDC controllers and other network communication devices such as gateways and routers.
9. Adding operator workstations.
10. Performing DDC system checkout and diagnostic procedures.
11. Performing DDC controllers operation and maintenance procedures.

12. Performing operator workstation operation and maintenance procedures.
13. Configuring DDC system hardware including controllers, workstations, communication devices, and I/O points.
14. Maintaining, calibrating, troubleshooting, diagnosing, and repairing hardware.
15. Adjusting, calibrating, and replacing DDC system components.
16. **<Insert requirement>**.

O. Training Content for System Managers and Administrators:

1. DDC system software maintenance and backups.
2. Uploading, downloading, and off-line archiving of all DDC system software and databases.
3. Interface with Project-specific, third-party operator software.
4. Understanding password and security procedures.
5. Adding new operators and making modifications to existing operators.
6. Operator password assignments and modification.
7. Operator authority assignment and modification.
8. Workstation data segregation and modification.
9. **<Insert requirement>**.

P. Video of Training Sessions:

1. Provide a digital video and audio recording of each training session. Create a separate recording file for each session.
2. Stamp each recording file with training session number, session name, and date.
3. Provide Owner with **[two]** **<Insert number>** copies of digital files on DVDs or flash drives for later reference and for use in future training.
4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230923

SECTION 230923.11 - CONTROL VALVES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes control valves and actuators for DDC systems.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230933 "Electric and Electronic Control System for HVAC" for electric/electronic control valves and actuators in electric and electronic control systems.
 - 3. Section 230943 "Pneumatic Control System for HVAC" for pneumatic control valves and actuators in pneumatic control systems.
 - 4. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.11.

1.3 DEFINITIONS

- A. Cv: Design valve coefficient.
- B. DDC: Direct-digital control.
- C. NBR: Nitrile butadiene rubber.
- D. PTFE: Polytetrafluoroethylene
- E. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation, and maintenance instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and[**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for pneumatic signal and main air tubing.

C. Delegated-Design Submittal:

1. Schedule and design calculations for control valves and actuators, including the following:
 - a. Flow at project design and minimum flow conditions.
 - b. Pressure differential drop across valve at project design flow condition.
 - c. Maximum system pressure differential drop (pump close-off pressure) across valve at project minimum flow condition.
 - d. Design and minimum control valve coefficient with corresponding valve position.
 - e. Maximum close-off pressure.
 - f. Leakage flow at maximum system pressure differential.
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Control valve installation location shown in relationship to room, duct, pipe, and equipment.
2. Size and location of wall access panels for control valves installed behind walls.
3. Size and location of ceiling access panels for control valves installed above inaccessible ceilings.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For control valves to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label products to comply with ASME Boiler and Pressure Vessel Code where required by authorities having jurisdiction.
- C. Delegated Design: Engage a qualified professional[**engineer**], as defined in Section 014000 "Quality Requirements," to size products where indicated as delegated design.
- D. Ground Fault: Products shall not fail due to ground fault condition when suitably grounded.
- E. Backup Power Source: Systems and equipment served by a backup power source shall have associated control valve actuators served from a backup power source.
- F. Environmental Conditions:
 - 1. Provide electric control valve actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control valve actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.
 - a. Hazardous Locations: Explosion-proof rating for condition.
- G. Determine control valve sizes and flow coefficients by ISA 75.01.01.
- H. Control valve characteristics and rangeability shall comply with ISA 75.11.01.
- I. Selection Criteria:
 - 1. Control valves shall be suitable for operation at following conditions:
 - a. Chilled Water: **<Insert pressure and coincident temperature requirements>**.
 - b. Condenser Water: **<Insert pressure and coincident temperature requirements>**.
 - c. Heat Recovery: **<Insert pressure and coincident temperature requirements>**.

- d. Heating Hot Water: **<Insert pressure and coincident temperature requirements>**.
 - e. Steam: **<Insert pressure and coincident temperature requirements>**.
 - f. **<Insert system and requirements>**.
2. Control valve shutoff classifications shall be FCI 70-2, Class IV or better unless otherwise indicated.
 3. Valve pattern, three-way or straight through, shall be as indicated on Drawings.
 4. Modulating straight-through pattern control valves shall have equal percentage flow-throttling characteristics unless otherwise indicated.
 5. Modulating three-way pattern water valves shall have linear flow-throttling characteristics. The total flow through the valve shall remain constant regardless of the valve's position.
 6. Modulating butterfly valves shall have **[linear] [or] [equal percentage]** flow-throttling characteristics.
 7. Fail positions unless otherwise indicated:
 - a. Chilled Water: **[Close] [Last position] [Open]**.
 - b. Condenser Water: **[Close] [Last position] [Open]**.
 - c. Heat Recovery: **[Close] [Last position] [Open]**.
 - d. Heating Hot Water: **[Close] [Last position] [Open]**.
 - e. Steam: **[Close] [Last position] [Open]**.
 - f. **<Insert system and fail position>**.
 8. Globe-type control valves shall pass the design flow required with not more than 95 percent of stem lift unless otherwise indicated.
 9. Rotary-type control valves, such as ball and butterfly valves, shall have Cv falling between 65 and 75 degrees of valve full open position and minimum valve Cv between 15 and 25 percent of open position.
 10. Selection shall consider viscosity, flashing, and cavitation corrections.
 11. Valves shall have stable operation throughout full range of operation, from design to minimum Cv.
 12. Minimum Cv shall be calculated at **[10] <Insert number>** percent of design flow, with a coincident pressure differential equal to the system design pump head.
 13. In water systems, select modulating control valves at terminal equipment for a design Cv based on a pressure drop of **[5 psig ((34 kPa))] [7 psig ((48 kPa))] <Insert value>** at design flow unless otherwise indicated.
 14. Modulating valve sizes for steam service shall provide a pressure drop at design flow equal to lesser of the following:
 - a. **[50] <Insert number>** percent of the valve inlet pressure.
 - b. **[50] <Insert number>** percent of the absolute steam pressure at the valve inlet.
 15. Two-position control valves shall be line size unless otherwise indicated.
 16. In water systems, use ball- or globe-style control valves for two-position control for valves **NPS 2 ((DN 50))** and smaller and butterfly style for valves larger than **NPS 2 (DN 50)**.
 17. In steam systems, use ball- or globe-style control valves regardless of size.
 18. Pneumatic, two-position control valves shall provide a smooth opening and

closing characteristic slow enough to avoid water hammer. Valves with pneumatic actuators shall have an adjustable opening time (valve full closed to full open) and an adjustable closing time (valve full open to full closed) ranging from zero to 10 seconds. Opening and closing times shall be independently adjustable.

19. Control valve, pneumatic-control signal shall not exceed **200 feet (60 m)**. For longer distances, provide an electric/electronic control signal to the valve and an electric solenoid valve or electro-pneumatic transducer at the valve to convert the control signal to pneumatic.

2.2 BALL-STYLE CONTROL VALVES

A. Ball Valves with Single Port and Characterized Disk:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Belimo Americas (USA), Inc., Belimo Automation AG**; B2 series.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Pressure Rating for **NPS 1 ((DN 25))** and Smaller: Nominal 600 WOG.
3. Pressure Rating for **NPS 1-1/2 (DN 38)** through **NPS 2 (DN 50)**: Nominal 400 WOG.
4. Close-off Pressure: **200 psig (1379 kPa)**.
5. Process Temperature Range: **Zero to 212 deg F (Minus 18 to plus 100 deg C)**.
6. Body and Tail Piece: Cast bronze ASTM B 61, ASTM B 62, ASTM B 584, or forged brass with nickel plating.
7. End Connections: Threaded (NPT) ends.
8. Ball: **[Chrome-plated brass or bronze] [or] [300 series stainless steel]**.
9. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
10. Ball Seats: Reinforced PTFE.
11. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
12. Flow Characteristic: Equal percentage.

B. Ball Valves with Two Ports and Characterized Disk:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. [Belimo Americas \(USA\), Inc., Belimo Automation AG](#); B3 series.
 - b. <Insert manufacturer's name; product name or designation>.
2. Pressure Rating for NPS 1 (DN 25) and Smaller: Nominal 600 WOG.
 3. Pressure Rating for NPS 1-1/2 (DN 38) through NPS 2 (DN 50): Nominal 400 WOG.
 4. Close-off Pressure: 200 psig (1379 kPa).
 5. Process Temperature Range: Zero to 212 deg F (Minus 18 to plus 100 deg C).
 6. Body and Tail Piece: Cast bronze ASTM B 61, ASTM B 62, ASTM B 584, or forged brass with nickel plating.
 7. End Connections: Threaded (NPT) ends.
 8. Ball: **[Chrome-plated brass or bronze] [or] [300 series stainless steel]**.
 9. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
 10. Ball Seats: Reinforced PTFE.
 11. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
 12. Flow Characteristics for A-Port: Equal percentage.
 13. Flow Characteristics for B-Port: Modified for constant common port flow.
- C. Ball Valves with Single Port and Segmented Ball:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [Valve Solutions, Inc.](#); V series.
 - b. <Insert manufacturer's name; product name or designation>.
 2. Performance:
 - a. Process Temperature Rating: Minus 20 to plus 450 deg F (Minus 29 to plus 232 deg C).
 - b. ASME B16.34, **[Class 150] [or] [Class 300]**.
 - c. Leakage: FCI 70-2, Class IV.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
 3. ASME B16.10 face-to-face dimensions.
 4. Valves NPS 2 (DN 50) and Smaller: Threaded (NPT) ends.
 5. Valves NPS 2-1/2 (DN 65) through NPS 6 (DN 150): Flanged ends suitable for mating to ASME B16.5 flanges.

6. Body: **[Carbon] [or] [stainless]** steel.
7. Ball and Shaft: Stainless steel.
8. Shaft and Segmented Ball: Pinned and welded.
9. Ball Seat: Graphite.
10. Packing: PTFE V-rings and graphite packing follower.
11. Replaceable seat, ball, and shaft packing.
12. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Flow directional arrow.

D. Ball Valves with Segmented Ball, Three-Way Pattern:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Valve Solutions, Inc.;** V series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Arrangement: Two single-port valves mated to a fabricated tee with interconnecting mechanical linkage.
3. Performance:
 - a. Process Temperature Rating: **Minus 20 to plus 450 deg F** (Minus 29 to plus 232 deg C).
 - b. ASME B16.34, **[Class 150] [or] [Class 300]**.
 - c. Leakage: FCI 70-2, Class IV.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
4. Face-to-Face Dimensions: ASME B16.10.
5. Valves **NPS 3 (DN 80)** through **NPS 6 (DN 150)**: Flanged ends suitable for mating to ASME B16.5 flanges.
6. Body: **[Carbon] [or] [stainless]** steel.
7. Ball and Shaft: Stainless steel.
8. Shaft and Segmented Ball: Pinned and welded.
9. Ball Seat: Graphite.
10. Packing: PTFE V-rings and graphite packing follower.
11. Replaceable seat, ball, and shaft packing.
12. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Flow directional arrow.

E. Ball Valves with Full Ball and Characterized V-Notch:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Flow-Tek, a subsidiary of Bray International, Inc.;** Triad and F series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Process Temperature Rating: **Minus 20 to plus 500 deg F** (Minus 29 to plus 232 deg C).
 - b. ASME B16.34, Class 600 for **NPS 2 (DN 50)** and smaller; **[Class 150] [or] [Class 300]** for larger than **NPS 2 (DN 50)**.
 - c. Leakage: FCI 70-2, Class VI, bi-directional.
 - d. Rangeability: Varies from 200 to 1 up to 800 to 1 based on notch pattern of ball.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
 - g. Full port.
3. Face-to-Face Dimension: ASME B16.10 long pattern.
4. Valves **NPS 2 (DN 50)** and Smaller: ASME B1.20.1 threaded (NPT) ends and three-piece body.
5. Valves **NPS 2-1/2 (DN 65)** through **NPS 12 (DN 300)**: Flanged ends suitable for mating to ASME B16.5 flanges and two-piece body.
6. Hole in the stem slot of each ball equalizes pressure between the body cavity and the line media flow.
7. Replaceable seat, ball, and shaft packing.
8. Body: **[Carbon] [or] [stainless]** steel.
9. Ball and Shaft: Stainless steel.
10. Ball Seat: RPTFE.
11. Stem Seals for Valves **NPS 2 (DN 50)** and Smaller: Live-loaded, self-adjusting, primary and secondary sealing using Belleville washers.
 - a. Primary Seal: Combination of thrust washer and thrust washer protector.
 - b. Secondary Seal: Adjustable stem packing composed of RPTFE V-rings.
12. Stem Seals for Valves Larger than **NPS 2 (DN 50)**: Independent packing gland, adjusted without removing mounting hardware or operator, and contoured to uniformly distribute load across packing.
 - a. Primary Seal: Combination of thrust washer and thrust washer protector.
 - b. Secondary Seal: Adjustable stem packing composed of RPTFE V-rings.
13. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Flow directional arrow.

F. Industrial-Grade Ball Valves:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Fisher Valves & Instruments, Emerson Electric Co.; V150 or V300 series.
 - b. <Insert manufacturer's name; product name or designation>.
2. Performance:
 - a. Process Temperature Rating: Minus 20 to plus 450 deg F (Minus 29 to plus 232 deg C).
 - b. ASME B16.34, [Class 150] [or] [Class 300].
 - c. Leakage: FCI 70-2, Class VI.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Modified equal percentage flow characteristic.
3. Face-to-Face Dimensions: Comply with ASME B16.10 short pattern.
4. Body: Cast steel ASTM A 216/A 216M WCB.
5. Flanged Body: Suitable for mating to ASME B16.5 flanges.
6. Shaft: 316 stainless-steel ball, 17-4 PH stainless steel.
7. Ball Seat: Reinforced PTFE.
8. PTFE V-ring packing, 316 stainless-steel packing follower.
9. Replaceable seat, ball, and shaft packings.
10. Replaceable 316 stainless-steel shaft bushings with PTFE linings.
11. Corrosion-resistant nameplate indicating the following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Trim type.
 - e. Body and flange rating.
 - f. Arrow indicating direction of flow.

G. Pressure-Independent Ball Valves NPS 2 (DN 50) and Smaller:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Belimo Americas (USA), Inc., Belimo Automation AG; PICCV series.
 - b. <Insert manufacturer's name; product name or designation>.
2. Performance:
 - a. Pressure Rating: 600 psig (4137 kPa) for NPS 1 (DN 25) and 400 psig (2528 kPa) for NPS 1-1/2 and NPS 2 (DN 38 and DN 50).
 - b. Close-off pressure of 200 psig (1379 kPa).

- c. Process Temperature Range: Between zero to 212 deg F (minus 18 to plus 100 deg C).
 - d. Rangeability: 100 to 1.
3. Integral Pressure Regulator: Located upstream of ball to regulate pressure, to maintain a constant pressure differential while operating within a pressure differential range of 5 to 50 psig ((34 to 345 kPa)).
 4. Body: Forged brass, nickel plated, and with threaded ends.
 5. Ball: Chrome-plated brass.
 6. Stem and Stem Extension: Chrome-plated brass, blowout-proof design.
 7. Stem sleeve or other approved means to allow valve to be opened and closed without damaging field-applied insulation and insulation vapor barrier seal.
 8. Ball Seats: Reinforced PTFE.
 9. Stem Seal: Reinforced PTFE packing ring stem seal with threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if equivalent cycle endurance can be achieved.
 10. Flow Characteristic: Equal percentage.

2.3 BUTTERFLY-STYLE CONTROL VALVES

A. Commercial-Grade, Two-Way Butterfly Valves:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Keystone, a brand of Tyco Flow Control;** Figure 222 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Bi-directional bubble tight shutoff at 250 psig (1724 kPa).
 - b. Comply with MSS SP-67 or MSS SP-68.
 - c. Rotation: Zero to 90 degrees.
 - d. Linear or modified equal percentage flow characteristic.
3. Body: Cast iron ASTM A 126, Class B, ductile iron ASTM A 536 or cast steel ASTM A 216/A 216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
4. Disc: 316 stainless steel.
5. Shaft: 316 or 17-4 PH stainless steel.
6. Seat: Reinforced EPDM or reinforced PTFE with retaining ring.
7. Shaft Bushings: Reinforced PTFE or stainless steel.
8. Replaceable seat, disc, and shaft bushings.
9. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.

- c. Body and trim materials.
- d. Flow arrow.

B. Commercial-Grade, Three-Way Butterfly Valves:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. **Keystone, a brand of Tyco Flow Control;** Figure 222 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Arrangement: Two valves mated to a fabricated tee with interconnecting mechanical linkage.
3. Performance:
 - a. Bi-directional bubble tight shutoff at **250 psig** (1724 kPa).
 - b. Comply with MSS SP-67 or MSS SP-68.
 - c. Rotation: Zero to 90 degrees.
 - d. Linear or modified equal percentage flow characteristic.
4. Body: Cast iron ASTM A 126, Class B, ductile iron ASTM A 536 or cast steel ASTM A 216/A 216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
5. Disc: 316 stainless steel.
6. Shaft: 316 or 17-4 PH stainless steel.
7. Seat: Reinforced EPDM or reinforced PTFE seat with retaining ring.
8. Shaft Bushings: Reinforced PTFE or stainless steel.
9. Replaceable seat, disc, and shaft bushings.
10. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Flow arrow.

C. Industrial-Grade Butterfly Valves:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. **Fisher Valves & Instruments, Emerson Electric Co.;** 8532 and 8580 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Process Temperature Rating: **Minus 200 to plus 849 deg F** (Minus 129 to plus 454 deg C).
 - b. ASME B16.34, [**Class 150**] [or] [**Class 300**] for larger sizes.

- c. Complies with MSS SP-68.
 - d. Leakage: FCI 70-2, Class VI, bi-directional.
 - e. Rangeability: 100 to 1.
 - f. Rotation: Zero to 90 degrees.
 - g. Linear or modified equal percentage flow characteristic.
3. Body: Cast steel ASTM A 216/A 216M WCB, fully lugged, suitable for mating to ASME B16.5 flanges.
 4. Disc: ASTM A 351/A 351M, CF3M or CF8M stainless steel.
 5. Shaft: 17-4 PH stainless steel.
 6. Seat: Reinforced PTFE with retaining ring.
 7. Shaft Bushings: Reinforced PTFE or stainless steel.
 8. Replaceable seat, disc, and shaft bushings.
 9. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Body rating.
 - e. Arrow indicating direction of flow.

2.4 GLOBE-STYLE CONTROL VALVES

A. General Globe-Style Valve Requirements:

1. Globe-style control valve body dimensions shall comply with ISA 75.08.01.
2. Construct the valves to be serviceable from the top.
3. For cage guided valves, trim shall be field interchangeable for different valve flow characteristics, such as equal percentage, linear, and quick opening.
4. Reduced trim for one nominal size smaller shall be available for industrial valves **NPS 1 (DN 25)** and larger.
5. Replaceable seats and plugs.
6. Furnish each control valve with a corrosion-resistant nameplate indicating the following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body and trim size.
 - c. Arrow indicating direction of flow.

B. Two-Way Globe Valves **NPS 2 (DN 50)** and Smaller:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Johnson Controls, Controls Group;** VG7000 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Globe Style: Single port.

3. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
4. End Connections: Threaded.
5. Bonnet: Screwed.
6. Packing: PTFE V-ring.
7. Plug: Top guided.
8. Plug, Seat, and Stem: **[Brass] [or] [stainless steel]**.
9. Process Temperature Range: 35 to 248 deg F (2 to 120 deg C).
10. Ambient Operating Temperature: 35 to 150 deg F (2 to 65 deg C).
11. Leakage: FCI 70-2, Class IV.
12. Rangeability: 25 to 1.
13. Equal percentage flow characteristic.

C. Three-Way Globe Valves **NPS 2 (DN 50)** and Smaller:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Johnson Controls, Controls Group;** VG7000 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Globe Style: Mix flow pattern.
3. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
4. End Connections: Threaded.
5. Bonnet: Screwed.
6. Packing: PTFE V-ring.
7. Plug: Top guided.
8. Plug, Seat, and Stem: **[Brass] [or] [stainless steel]**.
9. Process Temperature Range: 35 to 248 deg F (2 to 120 deg C).
10. Ambient Operating Temperature: 35 to 150 deg F (2 to 65 deg C).
11. Leakage: FCI 70-2, Class IV.
12. Rangeability: 25 to 1.
13. Linear flow characteristic.

D. Two-Way Globe Valves **NPS 2-1/2 to NPS 6 (DN 65 to DN 150):**

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Johnson Controls, Controls Group;** VG2000 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Globe Style: Single port.
3. Body: Cast iron complying with ASME B61.1, Class 125.
4. End Connections: Flanged, suitable for mating to ASME B16.5, Class 150 flanges.
5. Bonnet: Bolted.
6. Packing: PTFE cone-ring.
7. Plug: Top or bottom guided.

8. Plug, Seat, and Stem: Brass or stainless steel.
 9. Process Temperature Rating: **35 to 281 deg F** (2 to 138 deg C).
 10. Leakage: 0.1 percent of maximum flow.
 11. Rangeability: Varies with valve size between 6 and 10 to 1.
 12. Modified linear flow characteristic.
- E. Three-Way Globe Valves **NPS 2-1/2 to NPS 6** (DN 65 to DN 150):
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Johnson Controls, Controls Group;** VG2000 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Globe Style: Mix flow pattern.
 3. Body: Cast iron complying with ASME B61.1, Class 125.
 4. End Connections: Flanged suitable for mating to ASME B16.5, Class 150 flanges.
 5. Bonnet: Bolted.
 6. Packing: PTFE cone-ring.
 7. Plug: Top or bottom guided.
 8. Plug, Seat, and Stem: Brass or stainless steel.
 9. Process Temperature Rating: **35 to 281 deg F** (2 to 138 deg C).
 10. Leakage: 0.1 percent of maximum flow.
 11. Rangeability: Varies with valve size between 6 and 10 to 1.
 12. Modified linear flow characteristic.
- F. Industrial-Grade Straight-Through Globe Valves **NPS 3/4** (DN 20) and Smaller:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Fisher Valves & Instruments, Emerson Electric Co.;** 24000 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Globe Style: Single port.
 3. Body: ASTM B 62 bronze complying with ASME B16.5, Class 250.
 4. End Connections: Threaded.
 5. Bonnet: Screwed or bolted.
 6. Packing: PTFE V-ring.
 7. Plug: Top or cage guided; balanced or unbalanced.
 8. Plug, Seat, and Stem: 316 stainless steel, 17-4 PH stainless-steel cage.
 9. Process Temperature Range: **Minus 20 to plus 400 deg F** (Minus 29 to plus 204 deg C).
 10. Ambient Operating Temperature: **Minus 20 to plus 150 deg F** (Minus 29 to plus 71 deg C).
 11. Leakage: FCI 70-2, Class IV.
 12. Equal percentage flow characteristic.

G. Industrial-Grade Straight-Through Globe Valves **NPS 1 (DN 25)** and Larger:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Fisher Valves & Instruments, Emerson Electric Co.;** ET series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Globe Style: Single port.
3. Body: Cast iron or cast steel.
4. End Connections for **NPS 2 (DN 50):** Threaded.
5. End Connections for **NPS 2-1/2 (DN 65)** and Larger: Raised face flanged.
6. Bonnet: Bolted.
7. Packing: PTFE V-ring.
8. Plug: Cage guided and unbalanced.
9. Plug, Seat, and Stem: 416 stainless-steel plug and seat, 17-4 PH stainless-steel cage and 316 stainless-steel stem.
10. Valve Stem: Thread and pin stem to plug.
11. Valve Stem Finish: Polished to 5 microinches rms or less.
12. Plug and Seat Surfaces: Hardened facing.
13. Process Temperature Range: **Zero to 450 deg F** ((Minus 18 to plus 232 deg C)).
14. Ambient Operating Temperature: **Minus 20 to plus 150 deg F** (Minus 29 to plus 71 deg C).
15. Leakage: FCI 70-2, **[Class IV] [Class V] [Class VI]**.
16. Flow Characteristic: **[Equal percentage] [Linear] [Quick opening]**.

2.5 SOLENOID VALVES

A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. **ASCO Valve, Inc.;** 8210 series.
2. **<Insert manufacturer's name; product name or designation>.**

B. Description:

1. Action: Either normally open or normally closed in the event of electrical power failure as required by the application.
2. Size to close against the system pressure.
3. Manual override capable.
4. Heavy-duty assembly.
5. Body: **[Brass] [or] [stainless steel]**.
6. Seats and Discs: NBR or PTFE.
7. Solenoid Enclosure: NEMA 250, Type 4.

2.6 SELF-CONTAINED TEMPERATURE REGULATING VALVE

A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. Jordan Valve, a division of Richards Industries; Mark 80 series.
2. **<Insert manufacturer's name; product name or designation>**.

B. Description:

1. Self-contained and self-operated temperature regulating valve. Direct acting or reverse acting as required by application.
2. Direct Acting: A rise in temperature at the sensing bulb vaporizes some of the liquid in the bulb, forcing the remaining liquid through a capillary to apply pressure at the diaphragm, in turn closing the valve. The valve shall fail open.
3. Reverse Acting: A rise in temperature at the sensing bulb vaporizes some of the liquid in the bulb, forcing the remaining liquid through a capillary to apply pressure at the diaphragm, in turn opening the valve. The valve shall fail close.
4. Body: Carbon steel.
5. Trim and Seats: 300 series stainless steel.
6. Yoke: Cast iron.
7. Actuator: 300 series stainless steel.
8. End Connections: Threaded.
9. Capillary, Bulb, and Armor: 300 series stainless steel.
10. Thermal Fill Material: Match to the temperature range.
11. Thermowell: Type 316 stainless-steel thermowell sized to fit the bulb and pipe.

C. Operational Characteristics: Control flow from between 5 to 100 percent of rated capacity.

D. Interchangeable trim for one size smaller.

E. Valve Leakage: Comply with FCI 70-2, Class IV.

F. Temperature Range: Match application.

1. Drains from Hot Equipment to Sanitary Sewer System: 105 to 165 deg F ((40 to 74 deg C)).
2. **<Insert description of applications>**.

G. Valve Size: Size to pass the design flow required with not more than 95 percent of the stem lift while operating at design pressure.

2.7 PNEUMATIC CONTROL VALVE ACTUATORS

A. Actuators for Hydronic Control Valves: Shutoff against system pump shutoff head.

B. Actuators for Steam Control Valves: Shutoff against **[1.2] [1.5] <Insert number>** times steam design pressure.

- C. Position indicator and graduated scale on each actuator.
- D. Provide diaphragm action (air-to-open, air-to-close), as required by the sequence of operation, in the event of air supply failure.
- E. For each modulating control valve, provide a positive positioner with the valve actuator. The positioners shall operate on a **3- to 15-psig** (21- to 103-kPa) input signal unless otherwise required to satisfy control sequences of operation. Integrally mount each positioner with an air regulator, air set, and gauges for supply, input, and output. The positioner shall have the following performance characteristics:
 - 1. Linearity: Plus or minus 1 percent of the output signal span.
 - 2. Hysteresis: 0.5 percent of span.
- F. Diaphragms shall be replaceable.
- G. Actuator Construction:
 - 1. Cast-iron or steel diaphragm casing and plate. Cast aluminum is acceptable on valves **NPS 4** ((DN 100)) and smaller.
 - 2. Cast iron or steel yoke. Cast aluminum is acceptable on valves **NPS 4** ((DN 100)) and smaller.
 - 3. Reinforced synthetic rubber or nitrile diaphragm.
 - 4. Steel or steel alloy spring, stem, and spring adjuster.
- H. Rate actuators for not less than 1.2 times the main air pressure to the valve, minimum **30 psig** ((207 kPa)).

2.8 ELECTRIC AND ELECTRONIC CONTROL VALVE ACTUATORS

- A. Actuators for Hydronic Control Valves: Capable of closing valve against system pump shutoff head.
- B. Actuators for Steam Control Valves: Shutoff against **[1.2] [1.5] <Insert number>** times steam design pressure.
- C. Position indicator and graduated scale on each actuator.
- D. Type: Motor operated, with or without gears, electric and electronic.
- E. Voltage: **[Voltage selection delegated to professional designing control system] [24-V ac] [120-V ac] <Insert requirement>**.
- F. Deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
- G. Function properly within a range of 85 to 120 percent of nameplate voltage.
- H. Construction:

1. For Actuators Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
 2. For Actuators from 100 to 400 W: Gears ground steel, oil immersed, shaft hardened steel running in bronze, copper alloy or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
 3. For Actuators Larger Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.
- I. Field Adjustment:
1. Spring Return Actuators: Easily switchable from fail open to fail closed in the field without replacement.
 2. Gear Type Actuators: External manual adjustment mechanism to allow manual positioning when the actuator is not powered.
- J. Two-Position Actuators: Single direction, spring return, or reversing type.
- K. Modulating Actuators:
1. Operation: Capable of stopping at all points across full range, and starting in either direction from any point in range.
 2. Control Input Signal:
 - a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position and other input drives actuator to close position. No signal of either input remains in last position.
 - b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for **[zero- to 10-]** **[or]** **[2- to 10-]**V dc **[and]** **[4- to 20-mA]** signals.
 - c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to pulse duration (length) of signal from a dry contact closure, triac sink, or source controller.
 - d. Programmable Multi-Function:
 - 1) Control Input, Position Feedback, and Running Time: Factory or field programmable.
 - 2) Diagnostic: Feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
 - 3) Service Data: Include, at a minimum, number of hours powered and number of hours in motion.
- L. Position Feedback:
1. **[Equip]** **[Where indicated, equip]** two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of **[open]** **[and]** **[close]** position.
 2. **[Equip]** **[Where indicated, equip]** modulating actuators with a position feedback through **[current]** **[or]** **[voltage]** signal for remote monitoring.
 3. Provide a position indicator and graduated scale on each actuator indicating

open and closed travel limits.

M. Fail-Safe:

1. Where indicated, provide actuator to fail to an end position.
2. Internal spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
3. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

N. Integral Overload Protection:

1. Provide against overload throughout the entire operating range in both directions.
2. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

O. Valve Attachment:

1. Unless otherwise required for valve interface, provide an actuator designed to be directly coupled to valve shaft without the need for connecting linkages.
2. Attach actuator to valve drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.

P. Temperature and Humidity:

1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of [minus 20 to plus 120 deg F ((minus 29 to plus 49 deg C))] <Insert temperature range>.
2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from [5 to 95] <Insert number(s)> percent relative humidity, non-condensing.

Q. Enclosure:

1. Suitable for ambient conditions encountered by application.
2. NEMA 250, Type 2 for indoor and protected applications.
3. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
4. Provide actuator enclosure with heater and control where required by application.

R. Stroke Time:

1. Operate valve from fully closed to fully open within [15] [60] [75] [90] [150] <Insert number> seconds.
2. Operate valve from fully open to fully closed within [15] [60] [75] [90] [150] <Insert number> seconds.
3. Move valve to failed position within [5] [15] [30] <Insert number> seconds.
4. Select operating speed to be compatible with equipment and system operation.

S. Sound:

1. Spring Return: 62 dBA.
2. Non-Spring Return: 45 dBA.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for valves installed in piping to verify actual locations of piping connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CONTROL VALVE APPLICATIONS

- A. Control Valves:
 1. Select from valves specified in "Control Valves" Article to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
 2. **<Insert system> System, <Insert unique application>, Two-Way Applications Controlled by Flow: [Ball valves with single port and characterized disk] [Ball valves with single port and segmented ball] [Ball valves with full ball and characterized V-notch] [Industrial-grade ball valves] [Pressure-independent ball valves] [Butterfly-style valves, commercial-grade, two-way valves] [Butterfly-style valves, industrial-grade valves] [Globe-style, two-way valves] [Globe-style, industrial-grade, straight-through valves].**
 3. **<Insert system> System, <Insert unique application>, Two-Way Applications Controlled by Pressure: [Ball valves with single port and characterized disk] [Ball valves with single port and segmented ball] [Ball valves with full ball and characterized V-notch] [Industrial-grade ball valves] [Pressure-independent ball valves] [Butterfly-style valves, commercial-grade, two-way valves] [Butterfly-style valves, industrial-grade valves] [Globe-style, two-way valves] [Globe-style, industrial-grade, straight-through valves].**
 4. **<Insert system> System, <Insert unique application>, Two-Way Applications Controlled by Temperature: [Ball valves with single port and characterized disk] [Ball valves with single port and segmented ball] [Ball valves with full ball and characterized V-notch] [Industrial-grade ball valves] [Pressure-independent ball valves] [Butterfly-style valves, commercial-grade, two-way valves] [Butterfly-style valves, industrial-grade valves] [Globe-style, two-way valves] [Globe-style, industrial-grade,**

straight-through valves] [Solenoid valves] [Self-contained temperature regulating valves].

5. **<Insert system> System, <Insert unique application>, Three Way, Controlled by Temperature: [Ball valves with two ports and characterized disk] [Ball valves with segmented ball, three-way pattern] [Butterfly-style valves, commercial-grade, three-way valves] [Globe-style, three-way valves].**
6. **Steam System, <Insert unique application>, Two Way, Controlled by Temperature: [Ball valves with single port and segmented ball] [Ball valves with full ball and characterized V-notch] [Industrial-grade ball valves] [Globe-style, two-way valves] [Globe-style, industrial-grade, straight-through valves].**

3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy most stringent requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Properly support instruments, tubing, piping, wiring, and conduits to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- D. Provide ceiling, floor, roof, and wall openings, and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- E. Firestop penetrations made in fire-rated assemblies and seal penetrations made in acoustically rated assemblies.
- F. Fastening Hardware:
 1. Stillson wrenches, pliers, and other tools that will cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for assembling and tightening nuts.
 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- G. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- H. Corrosive Environments:
 1. Use products that are suitable for environment to which they will be subjected.
 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:

- a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
3. Use Type 316 stainless-steel tubing and fittings when in contact with a corrosive environment.
 4. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 5. Where control devices are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 CONTROL VALVES

- A. Install pipe reducers for valves smaller than line size. Position reducers as close to valve as possible but at distance to avoid interference and impact to performance. Install with manufacturer-recommended clearance.
- B. Install flanges or unions to allow drop-in and -out valve installation.
- C. Where indicated, install control valve with three-valve bypass manifold to allow for control valve isolation and removal without interrupting system flow by providing manual throttling valve in bypass pipe.
 1. **<Insert applications>**.
- D. Install drain valves in piping upstream and downstream of each control valve installed in a three-valve manifold and for each control valve larger than [NPS 2 ((DN 50))] [NPS 4 ((DN 100))] **<Insert nominal pipe size>**.
- E. Install pressure temperature taps in piping upstream and downstream of each control valve larger than [NPS 1 (DN 25)] [NPS 2 ((DN 50))] **<Insert nominal pipe size>**.
- F. Valve Orientation:

1. Where possible, install globe and ball valves installed in horizontal piping with stems upright and not more than 15 degrees off of vertical, not inverted.
2. Install valves in a position to allow full stem movement.
3. Where possible, install butterfly valves that are installed in horizontal piping with stems in horizontal position and with low point of disc opening with direction of flow.

G. Clearance:

1. Locate valves for easy access and provide separate support of valves that cannot be handled by service personnel without hoisting mechanism.
2. Install valves with at least **12 inches (300 mm)** of clear space around valve and between valves and adjacent surfaces.

H. Threaded Valves:

1. Note internal length of threads in valve ends, and proximity of valve internal seat or wall, to determine how far pipe should be threaded into valve.
2. Align threads at point of assembly.
3. Apply thread compound to external pipe threads, except where dry seal threading is specified.
4. Assemble joint, wrench tight. Apply wrench on valve end as pipe is being threaded.

I. Flanged Valves:

1. Align flange surfaces parallel.
2. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly with a torque wrench.

3.6 CONNECTIONS

- A. Connect electrical devices and components to electrical grounding system. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with valve identification on valve[**and on face of ceiling directly below valves concealed above ceilings**].

3.8 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.9 CHECKOUT PROCEDURES

- A. Control Valve Checkout:
 - 1. Check installed products before continuity tests, leak tests, and calibration.
 - 2. Check valves for proper location and accessibility.
 - 3. Check valves for proper installation for direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
 - 4. For pneumatic products, verify air supply for each product is properly installed.
 - 5. For pneumatic valves, verify that pressure gauges are provided in each air line to valve actuator and positioner.
 - 6. Verify that control valves are installed correctly for flow direction.
 - 7. Verify that valve body attachment is properly secured and sealed.
 - 8. Verify that valve actuator and linkage attachment are secure.
 - 9. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
 - 10. Verify that valve ball, disc, and plug travel are unobstructed.
 - 11. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

3.10 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.
- B. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed, and 100 percent open at proper air pressures.
- C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.
- D. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF SECTION 230923.11

SECTION 230923.12 - CONTROL DAMPERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes control dampers and actuators for DDC systems.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.12**.

1.3 DEFINITIONS

- A. DDC: Direct-digital control.
- B. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation instructions, including factors affecting performance.
- B. Shop Drawings:

1. Include plans, elevations, sections, and [**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for air and process signal tubing.
5. Include diagrams for pneumatic signal and main air tubing.

C. Delegated-Design Submittal:

1. Schedule and design calculations for control dampers and actuators, including the following.
 - a. Flow at project design and minimum flow conditions.
 - b. Face velocity at project design and minimum airflow conditions.
 - c. Pressure drop across damper at project design and minimum airflow conditions.
 - d. AMCA 500D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
 - e. Maximum close-off pressure.
 - f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Product installation location shown in relationship to room, duct, and equipment.
 2. Size and location of wall access panels for control dampers and actuators installed behind walls.
 3. Size and location of ceiling access panels for control dampers and actuators installed above inaccessible ceilings.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For control dampers to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label products to comply with ASME Boiler and Pressure Vessel Code where required by authorities having jurisdiction.
- C. Delegated Design: Engage a qualified professional[**engineer**], as defined in Section 014000 "Quality Requirements," to size products where indicated as delegated design.
- D. Ground Fault: Products shall not fail due to ground fault condition when suitably grounded.
- E. Backup Power Source: Systems and equipment served by a backup power source shall have associated control damper actuators served from a backup power source.
- F. Environmental Conditions:
 - 1. Provide electric control-damper actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control-damper actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.
 - a. Hazardous Locations: Explosion-proof rating for condition.
- G. Selection Criteria:
 - 1. Control dampers shall be suitable for operation at following conditions:
 - a. Supply Air: **<Insert pressure and coincident temperature requirements>**.
 - b. Return Air: **<Insert pressure and coincident temperature requirements>**.
 - c. Outdoor Air: **<Insert pressure and coincident temperature requirements>**.
 - d. Mixed Air: **<Insert pressure and coincident temperature requirements>**.
 - e. Exhaust Air: **<Insert pressure and coincident temperature requirements>**.
 - f. **<Insert system and requirements>**.
 - 2. Fail positions unless otherwise indicated:
 - a. Supply Air: **[Close] [Last position] [Open]**.
 - b. Return Air: **[Close] [Last position] [Open]**.
 - c. Outdoor Air: **[Close] [Last position] [Open]**.

- d. Mixed Air: **[Close] [Last position] [Open]**.
 - e. Exhaust Air: **[Close] [Last position] [Open]**.
 - f. **<Insert system and requirements>**.
3. Dampers shall have stable operation throughout full range of operation, from design to minimum airflow over varying pressures and temperatures encountered.
 4. Select modulating dampers for a pressure drop of **[2] [5] <Insert number>** percent of fan total static pressure unless otherwise indicated.
 5. Two-position dampers shall be full size of duct or equipment connection unless otherwise indicated.
 6. Pneumatic, two-position control dampers shall provide a smooth opening and closing characteristic slow enough to avoid excessive pressure. Dampers with pneumatic actuators shall have an adjustable opening time (valve full closed to full open) and an adjustable closing time (valve full open to full closed) ranging from zero to 10 seconds. Opening and closing times shall be independently adjustable.
 7. Control-damper, pneumatic-control signal shall not exceed **200 feet (60 m)**. For longer distances, provide an electric/electronic control signal to the damper and an electric solenoid valve or electro-pneumatic transducer at the damper to convert the control signal to pneumatic.

2.2 RECTANGULAR CONTROL DAMPERS

A. General Requirements:

1. Unless otherwise indicated, use parallel blade configuration for two-position control, equipment isolation service, and when mixing two airstreams. For other applications, use opposed blade configuration.
2. Factory assemble multiple damper sections to provide a single damper assembly of size required by the application.
3. Damper actuator shall be factory installed by damper manufacturer as integral part of damper assembly. Coordinate actuator location and mounting requirements with damper manufacturer.

B. Rectangular Dampers with Aluminum Airfoil Blades:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ruskin Company;** CD50 series.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed **3 cfm/sq. ft. (15.2 L/s per sq. m)** against **1-in. wg (250-Pa)** differential static pressure.
 - b. Pressure Drop: **0.05-in. wg (12.5 Pa)** at **1500 fpm (7.6 m/s)** across a

24-by-24-inch (600-by-600-mm) damper when tested according to AMCA 500-D, figure 5.3.

- c. Velocity: Up to 6000 fpm (30 m/s).
- d. Temperature: Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C).
- e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
- f. Damper shall have AMCA seal for both air leakage and air performance.

3. Construction:

a. Frame:

- 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch (1.8 mm) thick.
- 2) Hat-shaped channel with integral flange(s). Mating face shall be a minimum of 1 inch (25 mm).
- 3) Width not less than 5 inches (125 mm).

b. Blades:

- 1) Hollow, airfoil, extruded aluminum.
- 2) Parallel or opposed blade configuration as required by application.
- 3) Material: ASTM B 211, Alloy 6063 T5 aluminum, 0.07 inch (1.8 mm) thick.
- 4) Width not to exceed 6 inches (150 mm).
- 5) Length as required by close-off pressure, not to exceed 48 inches (1200 mm).

c. Seals:

- 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
- 2) Jams: Stainless steel, compression type.

d. Axles: 0.5-inch- (13-mm-) diameter [plated] [or] [stainless] steel, mechanically attached to blades.

e. Bearings:

- 1) Molded synthetic or stainless-steel sleeve mounted in frame.
- 2) Where blade axles are installed in vertical position, provide thrust bearings.

f. Linkage:

- 1) Concealed in frame.
- 2) Constructed of aluminum and [plated] [or] [stainless] steel.
- 3) Hardware: Stainless steel.

g. Transition:

- 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
 - 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
 - 3) Damper size and sleeve shall be connection size plus 2 inches (50 mm).
 - 4) Sleeve length shall be not less than 12 inches (300 mm) for dampers without jackshafts and shall be not less than 16 inches (450 mm) for dampers with jackshafts.
 - 5) Sleeve material shall match adjacent duct.
- h. Additional Corrosion Protection for Corrosive Environments:
- 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch (0.018 mm) thick.
 - 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.
4. Airflow Measurement:
- a. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - 1) **Ruskin Company;** AMS50 series.
 - 2) **<Insert manufacturer's name; product name or designation>.**
 - b. Where indicated, provide damper assembly with integral airflow monitoring.
 - c. Zero- to 10-V dc or 4- to 20-mA scaled output signal for remote monitoring of actual airflow.
 - d. Accuracy shall be within 5 percent of the actual flow rate between the range of minimum and design airflow. For applications with a large variation in range between the minimum and design airflow, configure the damper sections and flow measurement assembly as required to comply with the stated accuracy over the entire modulating range.
 - e. Provide a straightening device as part of the flow measurement assembly to achieve the specified accuracy with configuration indicated.
 - f. Suitable for operation in untreated and unfiltered air.
 - g. Provide temperature and altitude compensation and correction to maintain accuracy over temperature range encountered at site altitude.
 - h. Provide automatic zeroing feature.
5. Airflow Control:
- a. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- 1) [Ruskin Company](#); IAQ50X series.
- 2) **<Insert manufacturer's name; product name or designation>**.

- b. Where indicated, provide damper assembly with integral airflow measurement and control.
- c. A factory-furnished and -calibrated controller shall be programmed, in nonvolatile EPROM, with application-specific airflow set point and range.
- d. The controller and actuator shall communicate to control the desired airflow.
- e. The controller shall receive a zero- to 10-V dc input signal and report a zero- to 20-mA output signal that is proportional to the airflow.
- f. Airflow measurement and control range shall be suitable for operation between **150 to 2000 fpm** (0.8 to 10 m/s).
- g. Ambient Operating Temperature Range: **Minus 40 to plus 140 deg F** (Minus 40 to plus 60 deg C).
- h. Ambient Operating Humidity Range: 5 to 95 percent relative humidity, non-condensing.
- i. Provide unit with control transformer rated for not less than 85 VA. Provide transformer with primary and secondary protection and primary disconnecting means. Coordinate requirements with field power connection.
- j. Provide screw terminals for interface to field wiring.
- k. Factory mount electronics within a NEMA 250, Type 1 painted steel enclosure.

C. Rectangular Dampers with Steel Airfoil Blades:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [Ruskin Company](#); CD60 series.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed **3 cfm/sq. ft.** (15.2 L/s per sq. m) against **1-in. wg** (250-Pa) differential static pressure.
 - b. Pressure Drop: **0.06-in. wg** (15 Pa) at **1500 fpm** (7.6 m/s) across a **24-by-24-inch** (600-by-600-mm) damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to **6000 fpm** (30 m/s).
 - d. Temperature: **Minus 40 to plus 185 deg F** (Minus 40 to plus 85 deg C).
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
3. Construction:
 - a. Frame:

- 1) Material: ASTM A 653/A 653M galvanized-steel profiles, 0.06 inch (1.6 mm) thick.
 - 2) Hat-shaped channel with integral flanges. Mating face shall be a minimum of 1 inch (25 mm).
 - 3) Width not less than 5 inches (125 mm).
- b. Blades:
- 1) Hollow, airfoil, galvanized steel.
 - 2) Parallel or opposed blade configuration as required by application.
 - 3) Material: ASTM A 653/A 653M galvanized steel, 0.05 inch (1.3 mm) thick.
 - 4) Width not to exceed 6 inches (150 mm).
 - 5) Length as required by close-off pressure, not to exceed 48 inches (1200 mm).
- c. Seals:
- 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
 - 2) Jambs: Stainless steel, compression type.
- d. Axles: 0.5-inch- (13-mm-) diameter [plated] [or] [stainless] steel, mechanically attached to blades.
- e. Bearings:
- 1) Stainless steel mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
- f. Linkage:
- 1) Concealed in frame.
 - 2) Constructed of aluminum and [plated] [or] [stainless] steel.
 - 3) Hardware: Stainless steel.
- g. Transition:
- 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
 - 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
 - 3) Damper size and sleeve shall be connection size plus 2 inches (50 mm).
 - 4) Sleeve length shall be not less than 12 inches (300 mm) for dampers without jackshafts and shall be not less than 16 inches (450 mm) for dampers with jackshafts.
 - 5) Sleeve material shall match adjacent duct.
- h. Additional Corrosion Protection for Corrosive Environments:

- 1) Provide epoxy finish for surfaces in contact with airstream.
- 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

D. Industrial-Duty Rectangular Dampers with Steel Airfoil Blades:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ruskin Company;** CD30AF series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Performance:**
 - a. Leakage: Leakage shall not exceed **3 cfm/sq. ft. (15.2 L/s per sq. m)** against **1-in. wg (250-Pa)** differential static pressure.
 - b. Pressure Drop: **0.06-in. wg (15 Pa)** at **2000 fpm (10 m/s)** across a **48-by-48-inch (1200-by-1200-mm)** damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to **4000 fpm (20 m/s)**.
 - d. Temperature: **Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C)**.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, minimum **10-in. wg (2500 Pa)**.
3. **Construction:**
 - a. **Frame:**
 - 1) Material: **[Galvanized] [or] [stainless]** steel, **0.11 inch (2.8 mm)** thick.
 - 2) C-shaped channel. Mating face shall be a minimum of **1 inch (25 mm)**.
 - 3) Width not less than **[3 inches ((75 mm))] [blade width plus 2 inches ((50 mm))]**.
 - b. **Blades:**
 - 1) Hollow, airfoil, **[galvanized] [or] [stainless]** steel.
 - 2) Parallel or opposed blade configuration as required by application.
 - 3) Material: **[Galvanized] [or] [stainless]** steel, **0.06 inch (1.6 mm)** thick.
 - 4) Width not to exceed **[6 inches (150 mm)] [8 inches ((200 mm))]**.
 - 5) Length not to exceed **[36 inches ((900 mm))] [48 inches ((1200 mm))] [60 inches ((1500 mm))]**.
 - c. **Seals:**
 - 1) Blades: Replaceable, mechanically attached EPDM or extruded silicone.
 - 2) Jams: Stainless steel, double compression type.

- d. Axles: **0.5- or 0.75-inch-** ((13- or 19-mm-)) diameter [**plated**] [**or**] [**stainless**] steel, mechanically attached to blades[**and continuous from end to end**].
 - e. Bearings:
 - 1) Stainless-steel sleeve type mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
 - f. Linkage:
 - 1) Face linkage exposed to airstream.
 - 2) Constructed of [**plated**] [**or**] [**stainless**] steel.
 - 3) Hardware: Stainless steel.
- E. Rectangular Dampers with Aluminum Flat Blades:
- 1. **Products:** Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:
 - a. **Ruskin Company**; CD51 series.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - 2. Performance:
 - a. Leakage: Leakage shall not exceed **3.2 cfm/sq. ft.** (16.2 L/s per sq. m) against **1-in. wg** (250-Pa) differential static pressure.
 - b. Pressure Drop: **0.07-in. wg** (17.5 Pa) at **1500 fpm** (7.6 m/s) across a **24-by-24-inch** (600-by-600-mm) damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to **2000 fpm** (10 m/s).
 - d. Temperature: **Minus 50 to plus 250 deg F** (Minus 46 to plus 121 deg C).
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, not to exceed **3-in. wg** (750 Pa).
 - f. Damper shall have AMCA seal for both air leakage and air performance.
 - 3. Construction:
 - a. Frame:
 - 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, **0.12 inch** (3.2 mm) thick.
 - 2) Hat-shaped channel[**with integral flanges**].
 - 3) Width not less than **5 inches** (125 mm).
 - b. Blades:
 - 1) Flat blades of extruded aluminum.
 - 2) Parallel or opposed blade configuration as required by application.

- 3) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, **0.12 inch** (3.2 mm) thick.
- 4) Width not to exceed **6 inches** (150 mm).
- 5) Length as required by close-off pressure, not to exceed **48 inches** (1200 mm).

c. Seals:

- 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
- 2) Jamb: Stainless steel, compression type.

d. Axles: **0.5-inch-** ((13-mm-))diameter [**plated**] [**or**] [**stainless**] steel, mechanically attached to blades.

e. Bearings:

- 1) Molded-synthetic sleeve, mounted in frame.
- 2) Where blade axles are installed in vertical position, provide thrust bearings.

f. Linkage:

- 1) Concealed in frame.
- 2) Constructed of [**plated**] [**or**] [**stainless**] steel.
- 3) Hardware: Stainless steel.

g. Transition:

- 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
- 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
- 3) Damper size and sleeve shall be connection size plus **2 inches** (50 mm).
- 4) Sleeve length shall be not less than **12 inches** (300 mm) for dampers without jackshafts and shall be not less than **16 inches** (450 mm) for dampers with jackshafts.
- 5) Sleeve material shall match adjacent duct.

h. Additional Corrosion Protection for Corrosive Environments:

- 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of **0.0007 inch** (0.018 mm) thick.
- 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

F. Rectangular Dampers with Steel Flat Blades:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ruskin Company;** CD36 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Performance:**
 - a. Leakage: Leakage shall not exceed **4.8 cfm/sq. ft. (24.3 L/s per sq. m)** against **1-in. wg (250-Pa)** differential static pressure.
 - b. Pressure Drop: **0.1-in. wg (25 Pa)** at **1500 fpm (7.6 m/s)** across a **24-by-24-inch (600-by-600-mm)** damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to **1500 fpm (7.6 m/s)**.
 - d. Temperature: **Minus 25 to plus 180 deg F (Minus 32 to plus 82 deg C)**.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, not to exceed **4-in. wg (1000 Pa)**.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
3. **Construction:**
 - a. **Frame:**
 - 1) Material: **[Galvanized] [or] [stainless]** steel, **0.06 inch (1.6 mm)** thick.
 - 2) Hat-shaped channel **[with integral flanges]**.
 - 3) Width not less than **5 inches (125 mm)**.
 - b. **Blades:**
 - 1) Flat blades with multiple grooves positioned axially for reinforcement.
 - 2) Parallel or opposed blade configuration as required by application.
 - 3) Material: **[Galvanized] [or] [stainless]** steel, **0.06 inch (1.6 mm)** thick.
 - 4) Width not to exceed **6 inches (150 mm)**.
 - 5) Length as required by close-off pressure, not to exceed **48 inches (1200 mm)**.
 - c. **Seals:**
 - 1) Blades: Replaceable, mechanically attached, PVC-coated polyester.
 - 2) Jams: Stainless steel, compression type.
 - d. Axles: **0.5-inch- (13-mm-)** diameter **[plated] [or] [stainless]** steel, mechanically attached to blades.
 - e. **Bearings:**
 - 1) Molded-synthetic sleeve, mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.

- f. Linkage:
- 1) Concealed in frame.
 - 2) Constructed of **[plated] [or] [stainless]** steel.
 - 3) Hardware: Stainless steel.

G. Insulated Rectangular Dampers:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **TAMCO;** 9000ECT series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Performance:**
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed **3 cfm/sq. ft. (15.2 L/s per sq. m)** against **1-in. wg (250-Pa)** differential static pressure and shall not exceed **4.9 cfm/sq. ft. (25 L/s per sq. m)** against **4-in. wg (1000-Pa)** differential static pressure at **minus 40 deg F (minus 40 deg C)**.
 - b. Pressure Drop: **0.1-in. wg (25 Pa)** at **1500 fpm (7.6 m/s)** across a **24-by-24-inch (600-by-600-mm)** damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to **4000 fpm (20 m/s)**.
 - d. Temperature: **Minus 100 to plus 185 deg F (Minus 73 to plus 85 deg C)**.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
3. **Construction:**
 - a. **Frame:**
 - 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, **0.08 inch (2.0 mm)** thick.
 - 2) C-shaped channel with integral flange(s). Mating face shall be a minimum of **1 inch (25 mm)**.
 - 3) Width not less than **4 inches (100 mm)**.
 - 4) Entire frame shall be thermally broken by means of polyurethane resin pockets, complete with thermal cuts.
 - 5) Damper frame shall be insulated with polystyrafoam on four sides.
 - b. **Blades:**
 - 1) Hollow shaped, extruded aluminum.
 - 2) Blades shall be internally insulated with expanded polyurethane foam and shall be thermally broken. Complete blade shall have an insulating factor of R-2.29 and a temperature index of 55.
 - 3) Parallel or opposed blade configuration as required by application.

- 4) Material: ASTM B 211, Alloy 6063 T5 aluminum, **0.08 inch** (2.0 mm) thick.
 - 5) Width not to exceed **6 inches** (150 mm).
 - 6) Length as required by close-off pressure, not to exceed **48 inches** (1200 mm).
- c. Seals: Blade and frame seals shall be of flexible silicone and secured in an integral slot within the aluminum extrusions.
- d. Axles: **0.44-inch-** (11-mm-) diameter **[plated] [or] [stainless]** steel, mechanically attached to blades.
- e. Bearings:
- 1) Bearings shall be composed of a Celcon inner bearing fixed to axle, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
- f. Linkage:
- 1) Concealed in frame.
 - 2) Constructed of aluminum and **[plated] [or] [stainless]** steel.
 - 3) Hardware: Stainless steel.
- g. Transition:
- 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
 - 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
 - 3) Damper size and sleeve shall be connection size plus **2 inches** (50 mm).
 - 4) Sleeve length shall be not less than **12 inches** (300 mm) for dampers without jackshafts and shall be not less than **16 inches** (450 mm) for dampers with jackshafts.
 - 5) Sleeve material shall match adjacent duct.
- h. Additional Corrosion Protection for Corrosive Environments:
- 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of **0.0007 inch** (0.018 mm) thick.
 - 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

2.3 ROUND CONTROL DAMPERS

A. Round Dampers, Sleeve Type:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ruskin Company;** CDRS25 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Leakage: Leakage shall not exceed **0.15 cfm/in.** (0.0028 L/s per mm) of perimeter blade at **4-in. wg** (1000-Pa) differential static pressure.
 - b. Pressure Drop: **0.02-in. wg** (5 Pa) at **1500 fpm** (7.6 m/s) across a **12-inch** (300-mm) damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to **4000 fpm** (20 m/s).
 - d. Temperature: **Minus 25 to plus 200 deg F** (Minus 32 to plus 93 deg C).
 - e. Pressure Rating: **8-in. wg** (2000 Pa) for sizes through **12 inches** (300 mm), **6-in. wg** (1500 Pa) for larger sizes.
3. Construction:
 - a. Frame:
 - 1) Material: **[Galvanized] [or] [stainless]** steel, **0.04 in** (1.0 mm) thick.
 - 2) Outward rolled stiffener beads positioned approximately **1 inch** (25 mm) inboard of each end.
 - 3) Sleeve-type connection for mating to adjacent ductwork.
 - 4) Size Range: **4 to 24 inches** (100 to 600 mm).
 - 5) Length not less than **7 inches** (175 mm).
 - 6) Provide **2-inch** (50-mm) sheet metal standoff for mounting actuator.
 - b. Blade: Double-thickness circular flat blades sandwiched together and constructed of **[galvanized] [or] [stainless]** steel.
 - c. Blade Seal: Polyethylene foam seal sandwiched between two sides of blades and fully encompassing blade edge.
 - d. Axle: **0.5-inch-** (13-mm-) diameter **[plated] [or] [stainless]** steel, mechanically attached to blade.
 - e. Bearings: Stainless-steel sleeve pressed into frame.

B. Round Dampers, Flanged Type:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ruskin Company;** CDR82 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:

- a. Leakage: Leakage shall not exceed 0.15 cfm/in. (0.0028 L/s per mm) of perimeter blade at 4-in. wg (1000-Pa) differential static pressure.
 - b. Pressure Drop: 0.03-in. wg (7.5 Pa) at 1500 fpm (7.6 m/s) across a 12-inch (300-mm) damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 4000 fpm (20 m/s).
 - d. Temperature: Minus 25 to plus 250 deg F (Minus 32 to plus 121 deg C).
 - e. Pressure Rating: 8-in. wg (2000 Pa) for sizes through 36 inches (900 mm) in diameter, 6-in. wg (1500 Pa) for larger sizes.
3. Construction:
- a. Frame:
 - 1) Size Range: 4 to 60 inches (100 to 1500 mm).
 - 2) Material: [Galvanized] [or] [stainless] steel.
 - a) Sizes through 24 Inches (600 mm) in Diameter: 0.15 inch (4 mm) thick.
 - b) Sizes 26 through 48 Inches (650 through 1200 mm) in Diameter: 0.25 inch (6 mm) thick.
 - c) Larger Sizes: 0.31 inch (8 mm) thick.
 - 3) Flanges:
 - a) Outward rolled with bolt holes on each end of frame for mating to adjacent ductwork.
 - b) Face: Not less than 1.25 inch (31 mm) for damper sizes through 12 inches (300 mm) in diameter, 1.5 inch (38 mm) for damper sizes 14 through 24 inches (350 through 600 mm) in diameter, and 2 inches (50 mm) for larger sizes.
 - 4) Length (Flange Face to Face): Not less than 8 inches (200 mm).
 - 5) Provide 3-inch (75-mm) sheet metal standoff for mounting actuator.
 - b. Blade: Reinforced circular flat blade constructed of [galvanized] [or] [stainless] steel.
 - 1) Sizes through 24 Inches (600 mm): 0.15 inch (4 mm) thick.
 - 2) Sizes 26 through 48 Inches ((650 through 1200 mm)): 0.19 inch ((5 mm)) thick.
 - 3) Larger Sizes: 0.25 inch (6 mm) thick.
 - c. Blade Stop: Full circumference, located in airstream, minimum 0.5 by 0.25 inch (13 by 6 mm) [galvanized-] [or] [stainless-] steel bar.
 - d. Blade Seal: Neoprene, mechanically attached to blade and fully encompassing blade edge.
 - e. Axle: [Plated] [or] [stainless] steel, mechanically attached to blade.
 - 1) Sizes through 14 Inches ((350 mm)): 0.5 inch (13 mm) in diameter.
 - 2) Sizes 16 through 42 Inches (400 through 1050 mm): 0.75 inch (19 mm)

- in diameter.
- 3) Larger Sizes: 1 inch (25 mm) in diameter.

f. Bearings: Stainless-steel sleeve pressed into frame.

2.4 GENERAL CONTROL-DAMPER ACTUATORS REQUIREMENTS

- A. Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which the damper is subjected.
- B. Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
- C. The total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
- D. Provide one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
- E. Avoid the use of excessively oversized actuators which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.
- F. Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
- G. Provide mounting hardware and linkages for connecting actuator to damper.
- H. Select actuators to fail in desired position in the event of a power failure.
- I. Actuator Fail Positions: [**See Drawings.**][**As indicated below:**]
 - 1. Exhaust Air: [Close] [Last position] [Open].
 - 2. Outdoor Air: [Close] [Last position] [Open].
 - 3. Supply Air: [Close] [Last position] [Open].
 - 4. Return Air: [Close] [Last position] [Open].
 - 5. <Insert system and fail position>.

2.5 PNEUMATIC ACTUATORS

- A. Where two or more actuators are installed for interrelated operation in unison, such as dampers used for mixing, provide the dampers with a positive positioner.
- B. Equip pneumatic modulating actuators with a positive positioner, having the following performance characteristics:
 - 1. Linearity: Plus or minus 1 percent of output signal span.

2. Hysteresis: 0.5 percent of the span.
- C. Provide each positioner with an integrally mounted air set and pressure gauges for supply, input and output. Positioners shall operate on a 3- to 15-psig (21- to 103-kPa) input signal unless otherwise required to satisfy the control sequences of operation.
- D. Rate actuators for a pressure of at least 25 psig (172 kPa).
- E. Provide actuators with replaceable diaphragms.
- F. Actuator Construction:
 1. Construct the diaphragm casing and plate of cast iron, steel, or cast aluminum.
 2. Construct the yoke of cast iron, steel, or cast aluminum.
 3. Construct the diaphragm of reinforced synthetic rubber or nitrile.
 4. Construct the spring, stem, and spring adjuster of steel or steel alloy.
- G. Provide actuator with adjustable stops for both maximum and minimum positions.
- H. Provide a position indicator and graduated scale on each actuator. Indicate open and closed travel limits.

2.6 ELECTRIC AND ELECTRONIC ACTUATORS

- A. Type: Motor operated, with or without gears, electric and electronic.
- B. Voltage:
 1. **[See Drawings] [Voltage selection is delegated to professional designing control system] [24 V] [120 V] <Insert requirement>.**
 2. Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
 3. Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.
- C. Construction:
 1. Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
 2. 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
 3. Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.
- D. Field Adjustment:
 1. Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
 2. Provide gear-type actuators with an external manual adjustment mechanism to

allow manual positioning of the damper when the actuator is not powered.

- E. Two-Position Actuators: Single direction, spring return, or reversing type.
- F. Modulating Actuators:
1. Capable of stopping at all points across full range, and starting in either direction from any point in range.
 2. Control Input Signal:
 - a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position, and other input drives actuator to close position. No signal of either input remains in last position.
 - b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for **[zero- to 10-]** **[or]** **[2- to 10-]**V dc **[and]** **[4- to 20-mA]** signals.
 - c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to a pulse duration (length) of signal from a dry-contact closure, triac sink or source controller.
 - d. Programmable Multi-Function:
 - 1) Control input, position feedback, and running time shall be factory or field programmable.
 - 2) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
 - 3) Service data, including at a minimum, number of hours powered and number of hours in motion.
- G. Position Feedback:
1. **[Equip]** **[Where indicated, equip]** two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of **[open]** **[and]** **[close]** position.
 2. **[Equip]** **[Where indicated, equip]** modulating actuators with a position feedback through **[current]** **[or]** **[voltage]** signal for remote monitoring.
 3. Provide a position indicator and graduated scale on each actuator indicating open and closed travel limits.
- H. Fail-Safe:
1. Where indicated, provide actuator to fail to an end position.
 2. Internal spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
 3. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.
- I. Integral Overload Protection:
1. Provide against overload throughout the entire operating range in both directions.
 2. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or

magnetic clutches are acceptable methods of protection.

J. Damper Attachment:

1. Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
2. Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.

K. Temperature and Humidity:

1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of [minus 20 to plus 120 deg F ((minus 29 to plus 49 deg C))] <Insert temperature range>.
2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from [5 to 95] <Insert numbers> percent relative humidity, non-condensing.

L. Enclosure:

1. Suitable for ambient conditions encountered by application.
2. NEMA 250, Type 2 for indoor and protected applications.
3. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
4. Provide actuator enclosure with a heater and controller where required by application.

M. Stroke Time:

1. Operate damper from fully closed to fully open within [15] [60] [75] [90] [150] <Insert number> seconds.
2. Operate damper from fully open to fully closed within [15] [60] [75] [90] [150] <Insert number> seconds.
3. Move damper to failed position within [5] [15] [30] <Insert number> seconds.
4. Select operating speed to be compatible with equipment and system operation.
5. Actuators operating in smoke control systems comply with governing code and NFPA requirements.

N. Sound:

1. Spring Return: 62 dBA.
2. Non-Spring Return: 45 dBA.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for dampers and instruments installed in duct systems to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CONTROL-DAMPER APPLICATIONS

- A. Control Dampers:
- B. Select from damper types indicated in "Control Dampers" Article to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
 - 1. Rectangular Exhaust Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: **[Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type]**.
 - 2. Round Exhaust Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: **[Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type]**.
 - 3. Rectangular Outdoor Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: **[Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type]**.
 - 4. Round Outdoor Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: **[Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type]**.
 - 5. Rectangular Return Air Duct Applications with SMACNA Construction Class

- <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
6. Round Return Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 7. Rectangular Supply Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 8. Round Supply Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].

3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy most stringent requirements indicated.
- B. Properly support dampers and actuators, tubing, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a <Insert valve> force.
- C. Provide ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- D. Seal penetrations made in fire-rated and acoustically rated assemblies.
- E. Fastening Hardware:
 1. Stillson wrenches, pliers, or other tools that will cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for assembling and tightening nuts.
 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.

- F. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- G. Corrosive Environments:
1. Use products that are suitable for environment to which they will be subjected.
 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - c. **<Insert applications>**.
 3. Use Type 316 stainless-steel tubing and fittings when in contact with a corrosive environment.
 4. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 5. Where actuators are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 CONTROL DAMPERS

- A. Install smooth transitions, not exceeding **[15] [30] <Insert number>** degrees, to dampers smaller than adjacent duct. Install transitions as close to damper as possible but at distance to avoid interference and impact to performance. Consult manufacturer for recommended clearance.
- B. Clearance:
1. Locate dampers for easy access and provide separate support of dampers that cannot be handled by service personnel without hoisting mechanism.
 2. Install dampers with at least **24 inches (600 mm)** of clear space on sides of

dampers requiring service access.

C. Service Access:

1. Dampers and actuators shall be accessible for visual inspection and service.
2. Install access door(s) in duct or equipment located upstream of damper to allow service personnel to hand clean any portion of damper, linkage, and actuator. Comply with requirements in Section 233300 "Air Duct Accessories."

D. Install dampers straight and true, level in all planes, and square in all dimensions. Install supplementary structural steel reinforcement for large multiple-section dampers if factory support alone cannot handle loading.

E. Attach actuator(s) to damper drive shaft.

F. For duct-mounted and equipment-mounted dampers installed outside of equipment, install a visible and accessible indication of damper position from outside.

3.6 CONNECTIONS

A. Connect electrical devices and components to electrical grounding system. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

B. Install engraved phenolic nameplate with damper identification on damper[**and on face of ceiling where damper is concealed above ceiling**].

3.8 CHECKOUT PROCEDURES

A. Control-Damper Checkout:

1. Check dampers for proper location and accessibility.
2. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
3. For pneumatic products, verify air supply for each product is properly installed.
4. For pneumatic dampers, verify that pressure gages are provided in each air line to damper actuator and positioner.
5. Verify that control dampers are installed correctly for flow direction.
6. Verify that proper blade alignment, either parallel or opposed, has been provided.
7. Verify that damper frame attachment is properly secured and sealed.
8. Verify that damper actuator and linkage attachment are secure.
9. Verify that actuator wiring is complete, enclosed, and connected to correct power source.

10. Verify that damper blade travel is unobstructed.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING:

- A. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.
- B. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed, and 100 percent open at proper air pressure.
- C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.
- D. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF SECTION 230923.12

SECTION 230923.13 - ENERGY METERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes thermal and electric power energy meters that connect to DDC systems.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.13**.

1.3 DEFINITIONS

- A. DDC: Direct-digital control.
- B. Ethernet: Local area network based on IEEE 802.3.1 standards.
- C. Firmware: Software (programs or data) that has been written onto read-only memory (ROM). Firmware is a combination of software and hardware. Storage media with ROMs that have data or programs recorded on them are firmware.
- D. I/O: Input/output.
- E. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.
- F. RS-232: A TIA standard for asynchronous serial data communications between terminal devices.
- G. RS-485: A TIA standard for multipoint communications using two twisted pairs.
- H. RTD: Resistance temperature detector.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 2. Operating characteristics, electrical characteristics, and furnished accessories indicating electrical power requirements.
 3. Product description with complete technical data, performance curves, and product specification sheets.
- B. LEED Submittals: Product data for energy instruments for use in showing compliance with measurement and verification credit.
- C. Shop Drawings:
1. Include plans, elevations, sections, and[**mounting**] details.
 2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each product requiring a certificate.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For energy meters to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 THERMAL ENERGY METERS

- A. Performance Requirements: Manufacturer shall certify that each energy meter indicated complies with specified performance requirements and characteristics.
1. Product certificates are required.
- B. Insertion-Type Thermal Energy Meters:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated**; System 10 series.

- b. **<Insert manufacturer's name; product name or designation>.**
2. Description:
 - a. Factory-packaged meter consisting of supply and return temperature sensors, flow sensor, digital display, keypad user interface, installation hardware, color-coded interconnecting cabling, and installation instructions.
 - b. Each thermal energy meter shall be individually calibrated and provided with calibration certification traceable to NIST.
3. Alphanumeric display of the following on face of enclosure:
 - a. Total energy consumption.
 - b. Energy rate.
 - c. Flow rate.
 - d. Supply temperature.
 - e. Return temperature.
 - f. Visual indication of power status (on/off) on face of enclosure.
4. Electronics Enclosure:
 - a. Remote from temperature and flow sensors.
 - b. NEMA 250, Type 12 or Type 13 for indoor applications and NEMA 250, Type 4 or Type 4X for outdoor applications.
 - c. Labeled terminal strip for field wiring connections.
5. Programming:
 - a. Factory programmed for specific application and field programmable through keypad on face of enclosure.
 - b. Programmed parameters and total energy consumption shall be stored in non-volatile EEPROM memory.
6. Output Signals:
 - a. Total Energy Consumption: Isolated solid-state dry contact with 100 mA, 50-V rating and contact duration of 0.5, 1, 2, or 6 seconds.
 - b. Energy Rate, Flow Rate, Supply Temperature, Return Temperature: 4 to 20 mA or zero- to 10-V dc for each.
 - c. In lieu of hardwired analog signals, a serial communication interface may be used.
7. Serial Communication Interface: Compatible with host to share total energy consumption, energy rate, flow rate, and supply and return temperature data.
8. Temperature Sensors:
 - a. Temperature range matched to application.
 - b. Differential temperature accuracy within **0.15 deg F (0.08 deg C)** over the calibrated range.
 - c. NEMA 250, Type 4 junction box with thermal isolation.

- d. Stainless-steel thermowell with **NPS 1/2 (DN 15) NPT** connection for each sensor.
9. Flow Sensor:
- a. Suitable for an operating pressure of at least **200 psig (1378 kPa)**.
 - b. Meters in hot-water systems shall be suitable for maximum system temperatures encountered, but not less than **250 deg F (121 deg C)**.
 - c. Pressure drop not to exceed **1 psig (6.89 kPa)** at **20-fps (6.1-m/s)** flow velocity in **NPS 2 (DN 50)** pipe and decreasing in large pipe with lower velocity.
 - d. Sensor Accuracy:
 - 1) Within 1 percent of actual flow between the flow velocity range of **3 to 30 fps (0.9 to 9 m/s)**.
 - 2) Within 2 percent of actual flow between the flow velocity range of **0.4 to 20 fps (0.1 to 6.1 m/s)**.
 - 3) Within 0.5 percent of actual reading at the calibrated velocity.
 - e. Wet calibrate and tag each sensor to standards traceable to NIST, and provide each sensor with a certificate of calibration.
 - f. Provide single turbine sensors for pipe size **NPS 2 (DN 50)** and smaller. Provide dual turbine sensors for pipe size **NPS 2-1/2 (DN 65)** and larger. Provide bidirectional dual turbine sensors where installed in bypass piping.
 - g. For sensors with dual contra-rotating turbine elements, provide each turbine element with its own rotational sensing system and an averaging circuit to reduce measurement errors due to a poor flow profile.
 - h. Rotational sensing of each turbine shall be accomplished electronically by sensing impedance change. The sensor shall have an integral frequency output linear with flow rate and individual top and bottom turbine outputs for diagnostic purposes.
 - i. Provide the flow sensor complete with installation hardware necessary to enable insertion and removal from the pipe without system shutdown.
 - j. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts. Construct wetted metal components of Type 316 stainless steel, including the installation hardware.
 - k. House the sensor electronics in a NEMA 250, Type 4 weathertight aluminum enclosure with a gasketed cover. Housing shall include connection for field-installed conduit.
 - l. Sensor cable length shall be sufficient to connect to display module.
 - m. Sensor housing shall have full-port [**Type 316 stainless-steel**] ball valve for system isolation.
10. Power Supply:
- a. Field Power: 120-V ac, 60 Hz unless otherwise required by the application.
 - b. Internal Power: As required by flow meter.

C. In-Line, Compact-Type Thermal Energy Meters:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated;** System 30 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Description:**
 - a. Factory-packaged meter consisting of supply and return temperature sensors, flow sensor, digital display, operator interface, installation hardware, interconnecting cabling, and installation instructions.
 - b. Each thermal energy meter shall be individually calibrated and provided with calibration certifications traceable to NIST.
 - c. Meter limited to flow rates between **0.8 and 38 gpm** (0.05 to 2.4 L/s).
 - d. Meter mode of operation shall be field configurable to accommodate two pipe systems that change from between heating and cooling.
3. **Alphanumeric display of the following on face of enclosure:**
 - a. Total energy consumption.
 - b. Energy rate.
 - c. Flow rate.
 - d. Supply temperature.
 - e. Return temperature.
4. **Diagnostic Lights:**
 - a. Meter equipped with diagnostic indicator lights that confirm the operation of the microprocessor and its input circuitry.
 - b. Red LED labeled "BTU" shall flash as energy is transferred.
 - c. Red LED labeled "FLOW" shall flash at a rate that is proportional to the liquid flow rate. An unlit LED indicates no flow signal.
5. **Programming:**
 - a. Meter shall be factory programmed for specific application.
 - b. Programmed parameters and total energy consumption shall be stored in non-volatile memory.
6. **Output Signals:**
 - a. Mode 1 and Mode 2 Total Energy Consumption: Isolated solid-state dry contact with 100 mA, 50-V rating and contact duration of 0.5, 1, 2, or 6 seconds.
 - b. Factory-set isolated analog output for energy rate, flow rate, or temperature difference: 4 to 20 mA, zero to 5 or 10 V.
 - c. In lieu of hardwired output signals, a serial communication interface may be used.

7. Serial Communication Interface: Compatible with host to share total energy consumption, energy rate, flow rate, and supply and return temperature data.
8. Temperature Sensors:
 - a. Temperature range matched to application.
 - b. Differential temperature accuracy within 0.15 deg F (0.08 deg C) over the calibrated range.
 - c. One temperature sensor shall be built into the body of the flow sensor.
 - d. Second sensor shall be provided with brass thermowell with NPS 1/2 ((DN 15)) sweat fitting or NPS 1/4 ((DN 6)) NPT connection.
9. Flow Sensor:
 - a. Ambient Temperature: 40 to 120 deg F (4 to 49 deg C).
 - b. Process Temperature: 32 to 200 deg F (0 to 93 deg C).
 - c. Maximum Process Pressure: 400 psig (2758 kPa).
 - d. Pressure Drop: 3 psig (20 kPa) at 38 gpm (2.4 L/s).
 - e. Accuracy:
 - 1) Within 1 percent of actual flow over flow rate range of 5.7 to 38 gpm (0.4 to 2.4 L/s).
 - 2) Within 2 percent of actual flow over flow rate range of 0.8 to 38 gpm (0.05 to 2.4 L/s).
 - 3) Within 0.5 percent of actual reading at the calibrated velocity.
 - f. Construct flow sensor body of brass.
 - g. Furnish with two tail pieces to facilitate connection to the piping system. One end of each tail piece shall be a compression fitting with retaining nut, and the other end shall either be a sweat fitting for copper or a threaded nipple with NPT threads.
 - h. Process Connections: NPS 3/4 or NPS 1 (DN 20 or DN 25).
 - i. House electronics in a NEMA 250, Type 4 weathertight aluminum enclosure with a gasketed cover. Housing shall include connection for field-installed conduit.
 - j. Sensor cable length shall be sufficient to connect to display module.
10. Power Supply:
 - a. Field Power: 24-V ac, 50 or 60 Hz unless otherwise required by the application.

2.2 ELECTRIC POWER METERS

- A. Performance Requirements: Manufacturer shall certify that each energy meter indicated complies with specified performance requirements and characteristics.
 1. Product certificates are required.
- B. Fully Programmable Multifunction Electric Power Meter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Siemens Building Technologies, Inc.;** 9330 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Hardware:**
 - a. **Voltage Inputs:** Three voltage inputs, capable of measuring from zero- to 347-V rms (line to neutral) or from zero- to 600-V rms (line to line). The device shall have provisions for direct connection for wye (Star) systems up to 347/600-V ac. For higher voltage systems, PTs with 120-, 277-, or 347-V ac secondary shall be supported. Voltage inputs shall provide the following:
 - 1) 1500-V ac continuous surge protection.
 - 2) 25 percent of full-scale voltage over range capability.
 - b. **Current Inputs:** Three 5-A nominal (10-A full-scale) current inputs. Current inputs shall be transformer coupled and accept CTs with 5-A nominal (10-A full-scale) outputs. Current inputs shall provide the following:
 - 1) 300-A surge protection for one second.
 - 2) 25 percent of full-scale current continuous over range capability.
 - c. **Power Supply:** 95- to 240-V ac (within 10 percent) at 47 to 440 Hz, 110- to 300-V dc, or 20- to 60-V dc power source. Load shall not exceed 12 W.
 - d. **On-board I/O:**
 - 1) Four digital (status) inputs.
 - 2) Four optically isolated, Darlington transistor digital (status) outputs with the following features:
 - a) Outputs shall have the ability to be used to provide pulse outputs according to any energy consumption levels.
 - b) Outputs shall be scalable to within 1,000,000,000 units per pulse.
 - 3) Four analog I/O operator selectable from:
 - a) Milliamp inputs.
 - b) Zero- to 20-mA inputs.
 - c) Four zero- to 1-mA outputs.
 - d) Four zero- to 20-mA outputs.
 - e) Four zero- to 1-mA inputs and four zero- to 1-mA outputs.
 - f) Four zero- to 20-mA inputs and four zero- to 20-mA outputs.
 - 4) Analog inputs and outputs shall be accurate to within 0.3 percent of full scale.

- e. Provisions for future external I/O: Instrument shall support the following provisions for I/O for future applications. The external I/O shall support up to four digital output devices and shall support the following devices:
- 1) 120-V ac, 3.5 A, N.O. solid-state relay.
 - 2) 120-V ac, 3.5 A, zero voltage turn-on, manual override relay.
 - 3) 240-V ac, 3.5 A, N.O. solid-state relay.
 - 4) 240-V ac, 3.5 A, zero voltage turn-on, manual override relay.
 - 5) 60-V dc, 3.5 A, N.O. solid-state relay.
 - 6) 60-V dc, 1.5 mA, zero voltage turn-on, manual override relay.
 - 7) 60-V dc, 1.0 A, low-leakage, N.O. solid-state relay.
 - 8) 200-V dc, 1.0 A, N.O. solid-state relay.
 - 9) 100-V dc, 0.5 A, N.O. mechanical relay.
- f. Communications:
- 1) Provide the following built-in communication ports of standard technology, as defined by IEEE:
 - a) Two optically isolated RS-485 communication ports, supporting data rates from 1200 to 19200 bits per second.
 - b) One front-panel infrared optical port for RS-232 communications, supporting data rates from 1200 to 19200 bits per second. This port shall support an ANSI Type II optocoupler.
 - c) Ethernet port that has a gateway that allows the host system to communicate through the Ethernet port to additional metering devices connected to the card's COM2 RS-485 port. The device shall have provisions for an internal Ethernet port compatible with 10Base-T Ethernet. The Ethernet port shall be terminated using an RJ-45 connector.
 - d) Internal 33.6-kbps modem that has a gateway that allows the host system to communicate through the modem port to additional metering devices connected to the card's COM1 RS-485 port. The internal modem shall be certified for use on North American telephone systems only. The modem port shall be terminated using either an RJ11 or a captured wire connector.
 - 2) Communication ports shall support the following communication capabilities, independently configurable:
 - a) SEAbus/ION protocol.
 - b) Modbus RTU protocol.
 - c) DNP 3.0 protocol.
 - d) Simultaneous access through all communication ports to any measured or derived parameter.
 - e) Protocols shall be field configurable from the front display, or via communication ports, and be capable of being accomplished without resetting the meter or interrupting its

- operation in any way.
- f) Provisions for flash firmware that can be field upgraded through any communication port, without de-commissioning the instrument or de-energizing the circuit or equipment. The firmware-upgrade procedure shall be robust and able to recover from power failure during an upgrade.
 - g) Support time synchronization broadcast messages from a host computer system.
- g. Mounting Options:
- 1) **3.6-by-3.6-inch** (92-by-92-mm) panel cutout, using sliding clamps tightened by thumbscrews.
 - 2) Transducer-type base unit with a remote backlit digital display, with cable for remote display applications.
 - 3) Transducer-type base unit with no display, locally mounted.
 - 4) Allow operator to remove and replace the display panel without removing the instrument from the equipment in which it is mounted.
- h. Front-Panel Display:
- 1) Programmable buttons that allow access to eight data display screens.
 - 2) Display measured parameter with its corresponding label.
 - 3) Display any four parameters simultaneously using alphanumeric characters.
 - 4) Display any two parameter simultaneously using large alphanumeric characters.
 - 5) Display any parameter using very large alphanumeric characters.
 - 6) Display basic voltage, current, and power readings using extra-large alphanumeric characters.
 - 7) Allow the operator to change parameter labels.
 - 8) Feature a programmable time-out interval and adjustable contrast.
- i. Enclosure: If installation requires meter to be installed in a dedicated enclosure, install meter in an NRTL-listed enclosure suitable for operating environment at meter location.
- 1) Indoors: NEMA 250, **[Type 1]** [or] **[Type 12]**.
 - 2) Outdoors: NEMA 250, **[Type 4]** [or] **[Type 4X]**.
- j. Memory: 512 kBs of non-volatile RAM to store the following:
- 1) Setup data.
 - 2) A time-stamped event log with the following features:
 - 3) Support at least 500 events.
 - a) Number of records in the log shall be programmable.
 - b) Each event record shall record the date and time of the event, the cause and effect of the event, and the priority of the event.

- c) Events relating to set-point activity, relay operation, and self-diagnostics shall be recorded in the event log.
 - d) Time stamps shall have a resolution of one millisecond.
 - e) Time stamps shall be able to be synchronized to within 100 ms between devices on the same serial communication medium.
 - f) Minimum event recording response time shall be one second.
 - g) The priority of set-point events shall be programmable.
 - 4) Two programmable data recorders that can each store up to 16 channels of historical trend data with the following features:
 - a) Each data recorder shall be able to record any parameter, either measured or derived.
 - b) Each data recorder shall be enabled and triggered manually or through internal operating conditions, including periodic timer or set-point activity.
 - c) The number of records (depth) of each data recorder and the overflow conditions (stop-when-full or circular) shall be programmable.
 - d) Memory shall be dynamically allocated between data recorders and event log to allow storage of any 16 parameters at 15-minute intervals for not less than 30 days.
 - 5) Min/Max data for any monitored parameter.
3. Instrument:
 - a. Display Web pages over a standard Internet browser. Web pages shall include real-time instantaneous values, accumulated energy values, and total harmonic distortion.
 - b. Automatically e-mail alarm notifications or scheduled system status updates. E-mail messages sent shall be received as ordinary e-mail message.
 - c. Data logs shall be sent on an event-driven or scheduled basis.
 - d. Accommodate high-speed Modbus TCP communications when connected to Ethernet port.
4. Instrument shall measure and calculate the following information at one-second intervals:
 - a. Voltage line-to-neutral and line-to-line for each phase and average of all three phases.
 - b. Percent voltage unbalance.
 - c. Current for each phase and average of three phases.
 - d. Percent current unbalance.
 - e. kW for each phase and total of three phases.
 - f. kVAR for each phase and total of three phases.
 - g. kVA for each phase and total of three phases.
 - h. kWh for total of three phases, provided as accumulating import, export, net, and total readings.

- i. kVARh for total of three phases, provided as accumulating import, export, net, and total readings.
 - j. kVAh for total of three phases, provided as an accumulating net reading.
 - k. Power factor for each phase and total of three phases.
 - l. Frequency.
 - m. Harmonic distortion for each voltage and current input, provided as individual harmonic magnitudes up to the 15th harmonic and as total odd, total even, and total overall harmonic distortion; readings given as a percentage of fundamental.
 - n. K-Factor calculations of the first 15 harmonics for all current inputs.
5. Operator interface features are as follows:
- a. Capable of calculating the following information for any reading at one-second intervals:
 - 1) Thermal demand calculations for any parameter, with operator-programmable length of demand period to match local utility billing method.
 - 2) Sliding window demands for any parameter with operator-programmable length of demand period and number of subperiods to match local utility billing method.
 - 3) Predicted Demand calculations of sliding window demand parameters, with operator-programmable predictive response characteristics.
 - 4) Minimum value for any measured parameter.
 - 5) Maximum value for any measured parameter.
 - 6) Derived values for any combination of measured or calculated parameter, using the following arithmetic, trigonometric, and logic functions (equivalent PLC capabilities):
 - a) Arithmetic functions: division, multiplication, addition, subtraction, power, absolute value, square root, average, max, min, rms, sum, sum-of-squares, unary minus, integer ceiling, integer floor, modulus, exponent, PI.
 - b) Trigonometric Functions: COS, SIN, TAN, ARCCOS, ARCSIN, ARCTAN, LN, and LOG10.
 - c) Logic Functions: Equal to, equal to or more than, equal to or less than, more than or less than, less than, more than, and, "OR," "NOT," and "IF."
 - d) Thermocouple Linearization Functions: Type J, Type K, Type R, Type RTD, or Type T.
 - e) Temperature Conversion Functions: C to F, F to C.
 - b. Support direct display of all parameters on the front panel or remote display in user-programmable groups, using plain language labels. Simultaneous access to all parameters shall be available through any communication port.
 - c. Field programmable as follows:

- 1) Basic Parameters: Voltage input scale, voltage mode (wye, delta, single phase), current input scale, auxiliary input and output scales, and communication setup parameters are programmable from the front panel.
 - 2) Parameters described above, plus additional set-point/relay and data log setup parameters, shall be programmed via the communication port using a portable or remotely located computer terminal.
 - 3) Using ION modules, support customized configurations of all operating parameters.
 - 4) Provisions to ensure that programming through a computer can be secured by user ID and password.
 - 5) Provisions to ensure that programming through the front panel is secured by password.
- d. Provisions for creating periodic or non-periodic schedules for up to two years. Schedules may be used to perform the following functions:
- 1) Demand control.
 - 2) Load scheduling.
 - 3) Logging.
 - 4) Periodic resetting.
6. Alarming and set-point control shall include following minimum requirements:
- a. Set-point control of internal recording mechanisms and all digital output relays as follows:
 - 1) 12 programmable set points, each of which shall respond to out-of-range and alarm conditions for any measured parameter.
 - a) Each set point shall have one-second minimum response time.
 - b) Each set point shall have programmable pick-up and dropout levels (high and low limits) and time delays on operate and release.
 - c) Activity of each set point shall generate an event of a programmable priority. Priority levels shall support up to 256 levels of alarm severity.
 - d) Any set point shall be programmable to any operating condition, and any number of available set points shall be concurrently programmable to operate on a particular condition to support multiple threshold conditions.
 - 2) Set points shall be programmable to operate on any over or under condition for the following:
 - a) Any voltage or current input or average.
 - b) Voltage or current imbalance.
 - c) kW or kVAR forward or reverse.
 - d) kVA.
 - e) Power factor lag or lead.

- f) Frequency.
 - g) kW or current demand on any phase or total or average.
 - h) Individual harmonic distortion on any phase input.
 - i) Total harmonic distortion on any phase input.
 - j) Total even or odd harmonic distortion on any phase input.
 - k) Any maximum or minimum value.
 - l) Multiple energy accumulation conditions.
 - m) Phase reversal.
 - n) Pulse count levels.
 - o) Any internally derived value.
- 3) Any set-point condition shall be able to control any number of digital output relays in an AND or an OR configuration, using pulse mode or latch mode operation, for control and alarm purposes. Digital outputs shall also be operable remotely via any communication port.
 - 4) Any set-point condition shall be able to provide breaker trip relay operation.
 - 5) Consecutive alarm conditions and triggers shall be supported with no "dead" time between events. There shall be no need for a rearming delay time between events.
 - 6) It shall be possible to use any logical combination of any number of available set-point conditions to control any internal or external function or event.
 - 7) Digital outputs shall support pulse output relay operation for kWh total, kWh imported, kWh exported, kVARh total, kVARh imported, kVARh exported, and kVAh values.

C. Multifunction Electric Power Meter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Siemens Building Technologies, Inc.;** 9200 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Hardware:**
 - a. **Voltage Inputs:** Three voltage inputs capable of measuring from zero- to 400-V rms (line to neutral) or from zero- to 690-V rms (line to line). The instrument shall have provisions for direct connection for wye (Star) systems up to 347/600-V ac. For higher-voltage systems, PTs with 120-, 277-, or 347-V ac secondaries shall be supported. Voltage inputs shall provide the following:
 - 1) 1500-V ac continuous surge protection.
 - 2) 25 percent of full-scale voltage over range capability.

- b. Current Inputs: Three 5-A nominal (6-A full-scale) current inputs. Current inputs shall be transformer coupled and accept CTs with 5-A nominal (6-A full-scale) outputs. Current inputs shall provide the following:
 - 1) 120-A surge protection for one second.
 - 2) 20 percent of nominal current continuous over range capability.
- c. Power Supply: 100- to 240-V ac (within 10 percent) at 50 to 60 Hz, 110- to 300-V dc, or 20- to 60-V dc power source. Load shall not exceed 15 W.
- d. Onboard I/O:
 - 1) Two Form A solid-state digital (status) outputs with the following features:
 - a) The ability to be used to provide pulse outputs according to any energy consumption levels.
 - b) Rated 200-V ac/dc with a maximum current of 100 mA.
- e. Communications:
 - 1) Provide the following built-in communication ports of standard technology, as defined by the IEEE:
 - a) One optically isolated RS-485 communication port, supporting data rates from 1200 to 19200 bits per second.
 - 2) Communication ports shall support the following communication capabilities, independently configurable:
 - a) PML protocol.
 - b) Modbus RTU protocol.
 - c) Shall provide simultaneous access through all communication ports to any measured or derived parameter.
 - d) Protocols shall be field configurable from the front display, or via communication ports, and be capable of being accomplished without resetting the meter or interrupting its operation in any way.
 - e) Support time synchronization broadcast messages from a host computer system.
- f. Mounting and Display:
 - 1) The instrument shall support the following mounting options:
 - a) 3.6-by-3.6-inch (92-by-92-mm) panel cutout, using sliding clamps tightened by thumbscrews.
 - b) ANSI 4-inch (100-mm) round cut-out.
 - c) Transducer-type base unit with a remote LED display with cable for remote display applications.
 - d) Transducer-type base unit only with no display locally mounted.

- e) Allow the operator to remove and replace the display panel without removing the instrument from the equipment in which it is mounted.
 - g. Enclosure: If installation requires meter to be installed in a dedicated enclosure, install meter in an NRTL-listed enclosure suitable for operating environment at meter location.
 - 1) Indoors: NEMA 250, **[Type 1]** [or] **[Type 12]**.
 - 2) Outdoors: NEMA 250, **[Type 4]** [or] **[Type 4X]**.
 - h. Memory: Sufficient non-volatile (RAM) to store setup data and accumulated energy values.
3. The instrument shall measure and calculate the following information:
- a. Voltage line-to-neutral and line-to-line for each phase and average of three phases.
 - b. Current for each phase and average of three phases.
 - c. Peak current demand.
 - d. Neutral current.
 - e. Power (kW).
 - f. Peak power demand (kW).
 - g. Energy (kWh) import/export.
 - h. Power factor total.
 - i. Frequency.
4. Operator interface features are as follows:
- a. Capable of calculating the following information for any reading at one-second intervals:
 - 1) Sliding window demands for any parameter with operator-programmable length of demand period and number of subperiods to match local utility billing method.
 - b. Support direct display of all parameters on the front panel or remote display in user-programmable groups, using plain language labels. Simultaneous access to all parameters shall be available through any communication port.
 - c. Field programmable as follows:
 - 1) Basic Parameters: Voltage input scale, voltage mode (wye, delta, single phase), current input scale, auxiliary input and output scales, and communication setup parameters are programmable from the front panel.
 - 2) Using ION modules, support customized configurations of all operating parameters.
 - 3) Provisions to ensure that programming through a computer can be secured by user ID and password.

- 4) Provisions to ensure that programming through the front panel is secured by password.
- 5) Digital outputs shall support pulse output relay operation for kWh total, kWh imported, kWh exported, kVARh total, kVARh imported, kVARh exported, and kVAh values.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 THERMAL ENERGY METER APPLICATIONS

- A. **<Insert equipment type>, <Insert service>.**

3.3 ELECTRIC POWER METER APPLICATIONS

- A. **<Insert equipment type>: [Fully programmable, multifunction, electric power meter] [Multifunction, electric power meter].**

3.4 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- C. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

3.5 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.6 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of systems and equipment Installer] [manufacturer's authorized service representative]**. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, lubrication, cleaning, and adjusting as required for proper **<Insert equipment>** operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.7 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.13

SECTION 230923.14 - FLOW INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Airflow sensors.
2. Airflow switches.
3. Airflow transmitters.
4. Liquid flow meters.
5. Liquid flow sensors.
6. Liquid flow switches.
7. Liquid flow transmitters.

- B. Related Requirements:

1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.14**.

1.3 DEFINITIONS

- A. Ethernet: Local area network based on IEEE 802.3 standards.
- B. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.
- C. PEEK: polyetheretherketone.
- D. PTFE: Polytetrafluoroethylene.
- E. PPS: Polyphenylene sulfide.

- F. RS-485: A TIA standard for multipoint communications using two twisted pairs.
- G. RTD: Resistance temperature detector.
- H. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation instructions, including factors affecting performance.
- B. LEED Submittals: Product data for flow instruments for use in showing compliance with requirements in ASHRAE 62.1.
- C. Shop Drawings:
 - 1. Include plans, elevations, sections, and [**mounting**] details.
 - 2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
 - 4. Include diagrams for air and process signal tubing.
 - 5. Number-coded identification system for unique identification of wiring, cable, and tubing ends.
- D. Delegated-Design Submittal:
 - 1. Schedule and design calculations for flow instruments, including the following.
 - a. Flow at Project design and minimum flow conditions.
 - b. Pressure drop at Project design and minimum flow conditions.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each product requiring a certificate.
- B. Product Test Reports: For each product, for tests performed by [**manufacturer and witnessed by a qualified testing agency**] [**a qualified testing agency**].

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For instruments to include in operation and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Provide parts, as indicated by manufacturer's recommended parts list, for product operation during [one] [two] <Insert number>-year period following warranty period.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Select and size products to achieve specified performance requirements.
- B. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 GENERAL REQUIREMENTS FOR FLOW INSTRUMENTS

- A. Air sensors and transmitters shall have an extended range of [10] [20] <Insert number> percent above Project design flow and [10] [20] <Insert number> percent below minimum Project flow to signal abnormal flow conditions and to provide flexibility for changes in operation.
- B. Liquid and steam sensors, meters, and transmitters shall have an extended range of [10] [20] <Insert number> percent above Project design flow and [10] [20] <Insert number> percent below Project minimum flow to signal abnormal flow conditions and to provide flexibility for changes in operation.

2.3 AIRFLOW SENSORS:

- A. Performance Requirements:
 - 1. Adjustable for changes in system operational parameters.
 - 2. Airflow Sensor and Transmitter Range: Extended range of [10] [20] <Insert number> percent above Project design flow and [10] [20] <Insert number> percent below minimum Project flow to signal abnormal flow conditions.
 - 3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.

- a. Product certificates are required.
- B. Pitot-Tube Airflow Sensor Station:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Air Monitor Corporation;** Fan Evaluator.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Description: Multiple total- and static-pressure sensors positioned at the center of equal area of the station cross section and interconnected by respective averaging manifolds.
 - a. Stations **4 sq. ft. (0.4 sq. m)** and Smaller: One total-pressure sensor and one static-pressure sensor for every **16 sq. in. (103 sq. cm)** of station area.
 - b. Stations Larger than **4 sq. ft. (0.4 sq. m)**: One total-pressure sensor and one static-pressure sensor for every **36 sq. in. (232 sq. cm)** of station area.
 3. Casing: Galvanized sheet steel at least **0.079 inch (2.0 mm)** thick with coating complying with ASTM A 653/A 653M, **G90 ((Z275))**. Casings shall be stainless steel, **0.0781 inch (2.0 mm)** thick, when connected to stainless duct and aluminum, **0.063 inch (1.6 mm)** thick, when connected to aluminum duct.
 - a. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with aluminum paint.
 - b. Casing Depth: At least **8 inches (200 mm)**.
 - c. Casing Flanges: Outward flange, minimum flange face **1.5 inches (38 mm)**.
 - d. Casing Configuration and Size: Match shape (rectangular, round, flat oval) and same size as adjacent duct unless otherwise indicated.
 4. Include an open parallel cell air straightener or air equalizer honeycomb mechanically fastened to casing.
 - a. Construct straightener or equalizer from Type 3003 aluminum or Type 316 stainless steel, depending on casing material. Use stainless steel for units with stainless-steel casings.
 5. Construct pressure sensor array from drawn copper or stainless-steel tubing. Use stainless steel for units with stainless-steel casings. Copper tubing shall comply with ASTM B 75 and ASTM B 280. Minimum tube wall thickness shall be **0.030 inch (0.8 mm)**. Include internal piping and external pressure transmitter ports.
 6. Station Labeling: Identification label on each station casing indicating model number, size, area, and application-specific airflow range.
 7. Performance:
 - a. Pressure Loss: **0.015-inch wg (3.8 Pa)** at **1000 fpm (5 m/s)**, or **0.085-inch wg (22.5 Pa)** at **2000 fpm (10 m/s)**.

- b. Accuracy: Within 2 percent of actual airflow.
- c. Self-Generated Sound: NC 40 and sound level within the duct shall not be amplified.
- d. Performance rated and tested according to AMCA 610. Each station shall bear the AMCA seal.

C. Pitot-Tube Fan Inlet Airflow Traverse Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Air Monitor Corporation;** Volu-probe/ **[FI] [or] [FI/SS]**.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Traverse manifold designed for mounting in fan inlets.
3. Contain multiple total- and static-pressure sensors placed at concentric area centers along the exterior surface of cylindrical manifold and internally connected to their respective averaging manifolds. Sensors shall not protrude beyond the surface of the manifold nor be adversely affected by particle contamination present in airstream.
4. Manifold (two per inlet) shall have dual end support swivel brackets suitable for mounting in the fan inlet bell and symmetrical averaging signal takeoffs and fittings.
5. Sensors shall be capable of producing steady, non-pulsating signals of standard total- and static-pressure without need for flow corrections or factors, with an accuracy of 3 percent of actual flow over a turndown range of 6 to 1.
6. Manifold Materials: **[Copper or anodized aluminum] [or] [Type 316 stainless steel]**.
7. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter copper and aluminum manifolds shall be the following:
 - a. For Fan Inlets Smaller than **20 Inches** (500 mm): **0.375 inch** (9 mm).
 - b. For Fan Inlets **20 Inches** (500 mm) and Larger: **0.75 inch** (19 mm).
8. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter stainless-steel manifolds shall be the following:
 - a. For Fan Inlets Smaller than **20 Inches** (500 mm): **0.375 inch** (9 mm).
 - b. For Fan Inlets **20 through 48 Inches** (500 through 1200 mm): **0.75 inch** (19 mm).
 - c. For Fan Inlets Larger than **48 Inches** (1200 mm): **1.0 inch** (25 mm).

D. Piezometer Ring Fan Inlet Airflow Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. Twin City Fan & Blower; Piezometer Ring.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. In lieu of externally mounted fan inlet airflow sensors, option to provide fans with airflow measurement integral to fan inlet cones for continuous measurement of air volume flow rate.
 3. Multiple pressure sensor points strategically placed along the circumference of the inlet cone and internally connected to an averaging ring manifold located behind the inlet cone.
 4. Sensor points shall not protrude beyond the surface of the inlet cone nor be adversely affected by particle contamination present in the airstream.
 5. Sensor shall produce steady, non-pulsating signals to achieve accuracy within 5 percent of actual airflow.
 6. Sensor shall be non-intrusive and not impact fan performance.
 7. Product shall be a standard offering of the fan manufacturer and include published literature with supporting test data to validate sensor performance.

E. Thermal Airflow Station:

1. Products: Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]**:
 - a. Ebtron, Inc.; Gold Series.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Source Limitations: Obtain airflow and temperature measuring sensors and transmitters from single manufacturer.
3. Description: Airflow station shall consist of one or more sensor probes **[mounted in a casing,]**and a remotely mounted microprocessor-based transmitter.
4. Performance:
 - a. Capable of independently processing up to **[16] <Insert number>** independently wired sensor assemblies.
 - b. Airflow rate of each sensor assembly shall be equally weighted and averaged by transmitter prior to output.
 - c. Temperature of each sensor assembly shall be velocity weighted and averaged by transmitter prior to output.
 - d. Listed and labeled by an NRTL as successfully tested as an assembly according to UL 873, "Temperature-Indicating and Regulating Equipment."
 - e. Components shall be interconnected by exposed NRTL-listed plenum-rated cable or non-listed cable placed in conduit.
 - f. Each flow station shall be factory calibrated at a minimum of **[16] <Insert number>** airflow rates and **[three] <Insert number>** temperatures to standards that are traceable to NIST.
 - g. Airflow Accuracy: Within **[2] [3] [5] <Insert number>** percent of reading over the entire operating airflow range.

- 1) Devices whose accuracy is combined accuracy of transmitter and sensor probes must demonstrate that total accuracy meets the performance requirements throughout the measurement range.
 - h. Temperature Accuracy: Within **0.2 deg F** (0.11 deg C) over entire operating range of **minus 20 to plus 140 deg F** (minus 29 to plus 60 deg C).
 - i. Sensor Ambient Operating Temperature Range: **Minus 20 to plus 160 deg F** (Minus 29 to plus 71 deg C).
 - j. Transmitter Ambient Operating Temperature Range: **Minus 20 to plus 120 deg F** (Minus 29 to plus 49 deg C).
 - k. Sensor and Transmitter Ambient Operating Humidity Range: Zero to 99 percent, non-condensing.
 - l. Instrument shall compensate for changes in air temperature and density throughout calibrated velocity range for seasonal extremes at Project location.
 - m. Pressure Drop: **0.05-inch wg** (12.5 Pa) at **2000 fpm** (10.2 m/s) across a **24-by-24-inch** (600-by-600-mm) area.
 - n. Instruments mounted in throat or face of fan inlet cone shall not negatively influence fan performance by reducing flow more than **[1] [2] <Insert number>** percent of Project design flow or negatively impact fan-generated sound. Losses in performance shall be documented with submittal data, and adjustments to compensate for performance impact shall be made to fan in order to deliver Project design airflow indicated.
5. Sensor Assemblies:
- a. Each sensor probe shall contain two individually wired, hermetically sealed bead-in-glass thermistors.
 - b. Mount thermistors in sensor using a marine-grade, waterproof epoxy.
 - c. Thermistor leads shall be protected and not exposed to the environment.
 - d. Each sensor assembly shall independently determine airflow rate and temperature at each measurement point.
 - e. Each sensor probe shall have an integral cable for connection to remotely mounted transmitter.
 - f. Sensor Probe Material: Gold anodized, extruded 6063 aluminum tube or Type 304 stainless steel.
 - g. Probe Assembly Mounting Brackets Material: Type 304 stainless steel.
6. Casing:
- a. Factory mount sensor probes in an airflow station casing to create a single assembly for field mounting.
 - b. Material: Galvanized sheet steel at least **0.079 inch** (2.0 mm) thick with coating complying with ASTM A 653/A 653M, **G90** ((Z275)). Casings shall be stainless steel, **0.0781 inch** (2.0 mm) thick, when connected to stainless duct and aluminum, **0.063 inch** (1.6 mm) thick, when connected to aluminum duct.
 - c. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with zinc-rich paint.
 - d. Casing Depth: At least **8 inches** (200 mm).

- e. Include casing inlet and discharge connections with a minimum [1.5-inch (40-mm)] [2-inch ((50-mm))] <Insert dimension> face flange.

7. Transmitter:

- a. Integral digital display capable of simultaneously displaying total airflow and average temperature, individual airflow, and temperature readings of each independent sensor assembly.
- b. Capable of field configuration and diagnostics using an onboard push-button interface and digital display.

- 1) Include an integral power switch to operate on 24-V ac (isolation not required) and include the following:

- a) Integral protection from transients and power surges.
- b) Circuitry to ensure reset after power disruption, transients, and brownouts.
- c) Integral transformer to convert field power source to operating voltage required by instrument.

- c. Remote Signal Interface:

- 1) Linear Analog Signals for Airflow[**and Temperature**]: Fuse protected and isolated, [field selectable,] [zero- to 10-V dc] [or] [4 to 20 mA].
- 2) RS-485: BACnet-ARCNET, BACnet-MS/TP, and Modbus-RTU.
- 3) 10 Base-T Ethernet: BACnet Ethernet, BACnet-IP, Modbus-TCP, and TCP/IP.
- 4) LonWorks free topology.

2.4 AIRFLOW SWITCHES

A. Polymer Film Sail Switch:

- 1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

- a. [Honeywell International Inc., Building Solutions](#); Model S688A.
- b. <Insert manufacturer's name; product name or designation>.

- 2. Performance:

- a. Suitable for applications operating at velocities up to 400 fpm (2.0 m/s).
- b. Suitable for mounting with air direction in horizontal, vertical up or down.
- c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- d. Voltage: 24-, 120-, 240-V ac.
- e. Normally Open Full Load Current: 2 A at 120-V ac.
- f. Normally Closed Full Load Current: 1 A at 120-V ac.
- g. Normally open switch actuates at 250 fpm (1.3 m/s) and opens at 75 fpm

- (0.4 m/s).
 - h. Normally closed switch actuates at 75 fpm (0.4 m/s) and closes at 250 fpm (1.3 m/s).
 - i. Maximum Process Temperature: 170 deg F (77 deg C).
 - j. Maximum Ambient Temperature: 125 deg F (52 deg C).
- 3. Construction:
 - a. Polyester film sail encasing a wire frame.
 - b. Sail actuates a SPDT snap switch.
 - c. Enclosure Material: Zinc-plated steel.
 - d. Enclosure with removable cover.
 - e. NEMA 250, Type 1 enclosure.
 - f. Removable spring counterbalances sail to allow mounting in either vertical (up or down) or horizontal airflow.
 - g. Electrical Connections: Screw terminals.
 - h. Conduit Connections: 1/2-inch (16-mm) trade size conduit knock outs on top and bottom.

B. Stainless-Steel Single Vane Switch:

- 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Model 530.
 - b. **<Insert manufacturer's name; product name or designation>.**
- 2. Description:
 - a. Velocities up to 2000 fpm (10.2 m/s).
 - b. Suitable for mounting with air direction in horizontal.
- 3. Performance:
 - a. Voltage: 125-, 240-, and 480-V ac.
 - b. Full Load Current: 9.8 A at 125-V ac.
 - c. Field-Adjustable Velocity Set Point: 400 to 1600 fpm (2.0 to 8.2 m/s).
 - d. Maximum Process Temperature: 180 deg F (82 deg C).
 - e. Maximum Ambient Temperature: 125 deg F (52 deg C).
- 4. Construction:
 - a. Stainless-steel vane.
 - b. Vane actuates a SPDT snap switch.
 - c. Enclosure Material: Die-cast metal.
 - d. Enclosure with removable cover.
 - e. NEMA 250, Type 1 enclosure.
 - f. Screw set-point adjustment.
 - g. Electrical Connections: Screw terminals.

- h. Conduit Connections: 1-inch (27-mm) trade size conduit knockouts on top and bottom.

2.5 AIRFLOW TRANSMITTERS

A. Airflow Transmitter with 0.10 Percent Accuracy and Auto-Zero Feature:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Air Monitor Corporation; Veltron II.
 - b. <Insert manufacturer's name; product name or designation>.
2. Transmitter shall receive total- and static-pressure signals from a primary element, amplify signals, extract the square root, and scale the signals to produce 4- to 20-mA dc output signals linear to airflow.
3. NEMA 250, Type 1 enclosure.
4. Construct assembly so that shock, vibration, and pressures surges of up to 1 psig (6.9 kPa) will neither harm transmitter, nor affect its accuracy.
5. Transmitter with automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. The automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
6. Performance:
 - a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
 - b. Calibrated Span: Field adjustable, minus 40 percent of the range.
 - c. Accuracy: Within 0.10 percent of natural span.
 - d. Repeatability: Within 0.15 percent of calibrated span.
 - e. Linearity: Within 0.2 percent of calibrated span.
 - f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.
7. Integral digital LED or digital display for continuous indication of airflow.

B. Airflow Transmitters with 0.25 Percent Accuracy and Auto-Zero Feature:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Air Monitor Corporation; DPT 2500 Plus.
 - b. <Insert manufacturer's name; product name or designation>.
2. Transmitter shall receive total- and static-pressure signals from a flow element, amplify signals, extract the square foot, and scale the signals to produce 4- to 20-mA dc output signals linear to airflow.
3. NEMA 250, Type 1 enclosure.

4. Construct assembly so shock, vibration, and pressures surges of up to 1 psig (6.9 kPa) will neither harm transmitter, nor affect its accuracy.
 5. Transmitter with automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. The automatic zeroing circuit shall re-zero the transmitter to within 0.1 percent of true zero.
 6. Performance:
 - a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
 - b. Calibrated Span: Field adjustable, minus 40 percent of the range.
 - c. Accuracy: Within 0.25 percent of natural span.
 - d. Repeatability: Within 0.15 percent of calibrated span.
 - e. Linearity: Within 0.2 percent of calibrated span.
 - f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.
 7. Integral digital display for continuous indication of airflow.
- C. Pressure Differential Transmitters for Airflow Measurement:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [Setra Systems, Inc.](#); Model 267.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Performance:
 - a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
 - b. Accuracy: Within [1] [0.5] [0.4] [0.25] percent of the full-scale range.
 - c. Hysteresis: Within 0.10 percent of full scale.
 - d. Repeatability: Within 0.05 percent of full scale.
 - e. Stability: Within one percent of span per year.
 - f. Overpressure: 10 psig (69 kPa).
 - g. Temperature Limits: Zero to 150 deg F (Minus 18 to plus 66 deg C).
 - h. Compensate Temperature Limits: 40 to 150 deg F (4 to 66 deg C).
 - i. Thermal Effects: 0.033 percent of full scale per degree F.
 - j. Shock and vibration shall not harm the transmitter.
 3. Output Signals:
 - a. Analog Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 800-ohm load.
 - b. Analog Voltage Signal:

- 1) Three wire, zero to **[5] [10]** V.
 - 2) Minimum Load Resistance: 1000 ohms.
4. Display: Four-digit digital with minimum **0.4-inch-** (10-mm-) high numeric characters.
 5. Operator Interface:
 - a. Zero and span adjustments located behind cover.
 6. Construction:
 - a. Plastic casing with removable plastic cover.
 - b. Fittings: Swivel fittings for connection to copper tubing or barbed fittings for connection to polyethylene tubing. Fittings on bottom of instrument case.
 - c. Screw terminal block for wire connections.
 - d. Vertical plane mounting.
 - e. NEMA 250, Type 4.
 - f. Mounting Bracket: Appropriate for installation.
- D. Pressure Differential Indicating Transmitter, Switch, and Controller for Airflow Measurement:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series DH3 Digihelic.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Description:
 - a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
 - b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
 - c. Select instrument range based on application.
 3. Performance:
 - a. Accuracy including hysteresis and repeatability:
 - 1) Ranges Less than **5-Inch wg** (1250 Pa): Within 1 percent.
 - 2) Other Ranges: Within 0.5 percent at **77 deg F** (25 deg C).
 - b. Stability: Within 1 percent per year.
 - c. Response Time: 250 ms.
 - d. Overpressure:
 - 1) Ranges Less than **50-Inch wg** (12.5 kPa): **5 psi** ((34.5 kPa).)
 - 2) Range of **100-Inch wg** (25 kPa): **9 psi** (62 kPa).

- e. Temperature Limits: 32 to 140 deg F (Zero to 60 deg C).
 - f. Thermal Effects: 0.020 percent per deg F ((deg C)).
 - g. Warm-up Period: One hour.
4. Controller: Programming through menu keys to access five menus.
 - a. Security level.
 - b. Pressure, velocity, or flow application.
 - c. Engineering units.
 - d. K-factor for use with flow application.
 - e. Set-point control only; set-point and alarm operation; alarm operation as high, low, or high/low with manual; or automatic reset and delay.
 - f. View high and low readings.
 - g. Digital dampening for smoothing erratic applications.
 - h. Scaling of analog output to fit range and field calibration.
 5. Display:
 - a. Four-digit digital, with minimum 0.4-inch- (10-mm-) high alphanumeric characters.
 - b. Four LED indicators; two LEDs for set point and two LEDs for alarm status.
 6. Operator Interface:
 - a. Set-point adjustment through keypad on face of instrument.
 - b. Zero and span adjustments accessible through menu.
 - c. Programming through keypad.
 7. Output Analog Signal: Two-wire, 4- to 20-mA dc current source; capable of operating into a 900-ohm load.
 8. Output Digital Signal: Two, SPDT relays; each rated for 1 A at 30-V ac or 30-V dc.
 9. Construction:
 - a. Die-cast aluminum casing and bezel.
 - b. Connections on side and back.
 - c. Vertical plane mounting.
 - d. NEMA 250, Type 1 rating.
 - e. Nominal 4-inch- (100-mm-) diameter face.
 - f. Mounting Bracket: Appropriate for installation.

2.6 LIQUID FLOW METERS

A. General Requirements for Liquid Flow Meters:

1. Adjustable for changes in system operational parameters.
2. Liquid and Steam Sensors, Meters, and Transmitters: Extended range of [10] [20] <Insert number> percent above Project design flow and [10] [20] <Insert number> percent below Project minimum flow to signal abnormal flow

- conditions.
3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
 4. Product certificates are required.
- B. Insertion Paddle Wheel Flow Meter, **NPS 2 (DN 50)**:
1. **Products**: Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]**:
 - a. **Data Industrial, Badger Meter, Inc.**; Series 200 Sensor with Series 500 Transmitter.
 - b. **<Insert manufacturer's name; product name or designation>**.
 2. Description: Insertion-type meter with a non-magnetic spinning paddle wheel.
 3. Performance:
 - a. Range: **0.5 to 30 fps** (0.15 to 9.1 mps).
 - b. Accuracy: Within 1 percent of full scale over flow range.
 - c. Linearity: Within 0.2 percent of full scale over flow range.
 - d. Repeatability: Within 0.3 percent of full scale over flow range.
 - e. Ambient Temperature: **14 to 150 deg F** (Minus 10 to plus 66 deg C).
 - f. Maximum Process Temperature: **[221 deg F ((105 deg C))] [285 deg F ((141 deg C))]**.
 - g. Maximum Pressure: **400 psig at 100 deg F** (2758 kPa at 38 deg C).
 4. Output Signal: Frequency pulse.
 5. Construction:
 - a. Wetted Metal Parts, Including Sensor Sleeve, Mounting Adapter, and Isolation Valve: **[Brass] [Type 316 stainless steel]**.
 - b. Shaft: **[Tungsten carbide] [Titanium] [Hastalloy C] [Monel] [Type 316 stainless steel]**.
 - c. Impeller: **[Nylon] [Tefzel]**.
 - d. Process Connection: **NPS 2 ((DN 50))**.
 - e. Instrument Isolation Valve: **[Gate] [Full port ball]** valve for system isolation.
 - f. Insertion Depth: Threaded positioning nut for accurate sensor depth in the pipe.
 - g. Electronics Enclosure:
 - 1) Polyphenylene sulfide (PPS) with Viton seal.
 - 2) Electrical Connection: Cable furnished with sensor.
 6. Transmitter:
 - a. User-adjustable scale to refine resolution of flow range over 4- to 20-mA signal.
 - b. Enclosure Material: Polycarbonate with tongue and groove, with neoprene sealed cover.

- c. NEMA 250, Type 4X enclosure.
 - d. Electrical Connection: Screw terminals.
 - e. Linearity less than one percent.
 - f. Output Response Time: 6 seconds for 10 to 90 percent step.
 - g. Load resistance of 650 ohms at 24-V dc.
 - h. Operating Temperature: **Minus 32 to plus 122 deg F** (Minus 36 to plus 50 deg C).
 - i. Digital display of flow rate.
- C. Insertion Paddle Wheel Flow Meter, **NPS 1** (DN 25):
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Data Industrial, Badger Meter, Inc.**; SDI Series.
 - b. **<Insert manufacturer's name; product name or designation>**.
 2. Description:
 - a. Insertion-type meter with a non-magnetic spinning paddle wheel.
 - b. Each meter shall be wet calibrated at factory to standards traceable to NIST and provided with a certificate of calibration.
 - c. Programming kit including cable connector and Microsoft-Windows-compatible software.
 - d. Where indicated, provide meter with bi-directional flow measurement.
 3. Performance:
 - a. Range: **0.33 to 20 fps** (0.1 to 6.1 m/s).
 - b. Accuracy: Within **[0.5] [1]** percent of flow rate.
 - c. Repeatability: Within 0.5 percent.
 - d. Ambient Temperature: **14 to 150 deg F** ((Minus 10 to plus 66 deg C)).
 - e. Maximum Process Temperature: **300 deg F** (149 deg C) with PEEK sensor tip.
 - f. Maximum Pressure: **350 psig at 300 deg F** (2413 kPa at 149 deg C) with PEEK sensor tip.
 - g. Pressure Drop: Up to **0.5 psig at 10 fps** (3.5 kPa at 3 m/s) for pipe sizes **NPS 1-1/2** (DN 20) and larger.
 4. Output Signal:
 - a. Unidirectional Flow Meter: Frequency pulse.
 - b. Unidirectional Flow Meter: Analog, two wire, loop-powered, 4- to 20-mA signal.
 - c. Unidirectional Flow Meter: Scaled pulse.
 - d. Bi-directional Flow Meter: Analog 4- to 20-mA signal plus direction.
 - e. Bi-directional Flow Meter: Scaled pulse.
 5. Operator Interface:

- a. Programming: Instrument programming through computer and programming kit.
 - b. Digital Display: Eight-character digital display of flow rate, flow totalization, input, output, and flow direction for bi-directional meters.
6. Construction:
- a. Wetted Metal Parts (Including Sensor Stem, Mounting Adapter, and Isolation Valve): Type 316 stainless steel.
 - b. Sensor Tip: PPS or PEEK.
 - c. Shaft: Tungsten carbide.
 - d. Impeller: Stainless steel.
 - e. Process Connection: **NPS 1 (DN 25)**.
 - f. Instrument Isolation Valve: Full port ball valve for system isolation.
 - g. Insertion Depth: Threaded positioning nut for accurate sensor depth in the pipe.
 - h. Electronics Enclosure:
 - 1) Polypropylene with Viton-sealed acrylic cover.
 - 2) Removable cover.
 - 3) NEMA 250, Type 4X.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: **1/2-inch ((16-mm))**trade size.

D. Insertion Turbine Flow Meter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated;** F-1100 Series Sensor with D-1200 Series Remote Display Module for pipe sizes **NPS 1-1/4 to NPS 2 (DN 32 to DN 50)**, Onicon F-1200 Series Sensor with D-1200 Series Remote Display Module for pipe sizes **NPS 2-1/2 (DN 65)** and larger.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Description:
 - a. Operating pressure of **300 psig (2068 kPa)** with a temperature of **200 deg F (93 deg C)**.
 - b. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than **250 deg F (121 deg C)**.
 - c. Pressure drop not to exceed **1 psig (6.9 kPa)** at **20-fps (6.1-m/s)** flow velocity in a **NPS 2 (DN 50)** pipe and decreasing in large pipe with lower velocity.
 - d. Sensor Accuracy:
 - 1) Within 1 percent of actual flow between the flow velocity range of **3 to 30 fps (0.9 to 9.1 m/s)**.
 - 2) Within 2 percent of actual flow between the flow velocity range of **0.4 to 20 fps (0.1 to 6.1 m/s)**.

- 3) Within 0.5 percent of actual reading at the calibrated velocity.
 - e. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.
3. Sensor:
- a. For Pipe Sizes **NPS 2 (DN 50)** and Smaller: Single turbine sensors.
 - b. For Pipe Sizes **NPS 2-1/2 (DN 65)** and Larger: Dual turbine sensors.
 - c. Piping with Bi-directional Flow: Bi-directional dual turbine sensors.
 - d. Dual turbine sensors shall have dual, contra-rotating turbine elements, each turbine element with its own rotational sensing system, and an averaging circuit.
 - e. Rotational sensing of each turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
 - f. Sensor shall have an integral frequency output linear with flow rate. For dual turbine units, with individual top and bottom turbine outputs for diagnostic purposes.
 - g. Bi-directional sensors shall have isolated solid-state dry contacts with a contact rating of 100 mA at 50 V. The contacts shall close when the flow in direction of arrow is **0.18 fps (0.05 m/s)** or more.
 - h. Flow sensor shall be complete with installation hardware necessary to enable insertion and removal from pipe without system shutdown.
 - i. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts. Construct wetted metal components of Type 316 stainless steel, including installation hardware.
 - j. House sensor electronics in a NEMA 250, Type 4 enclosure.
 - k. Enclosure shall include connection(s) for field-installed conduit.
 - l. Sensor shall have cable of length sufficient to connect to display module.
 - m. Sensor housing shall have full port [**Type 316 stainless-steel**] ball valve for system isolation.
4. Display Module:
- a. Remote from sensor.
 - b. House in a NEMA 250, Type 4X enclosure.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow sensor.
 - e. Remote Interface:
 - 1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
 - 2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
 - 3) Outputs linear to within 0.1 percent of calibrated span.
 - f. Digital display for flow rate and totalized flow.
 - 1) At least eight display digits for totalization.

- 2) Bi-directional units with separate digital display for flow and totalization in each direction.
- g. Local reset of flow totalization.
- h. Program and data shall be stored in nonvolatile memory in event of power loss.
- i. For bi-directional units, with display of flow direction (contacts open or closed).

E. Inline Turbine Flow Meter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated;** F-1300 Series Sensor with D-1200 Series Remote Display Module.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Description:**
 - a. Available in **NPS 3/4 and NPS 1** (DN 20 and DN 25).
 - b. Operating pressure of **300 psig** (2068 kPa) with a temperature of **200 deg F** (93 deg C).
 - c. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than **250 deg F** (121 deg C).
 - d. Pressure drop not to exceed **3 psig at 38 gpm** (21 kPa at 2.4 L/s).
 - e. **Sensor Accuracy:**
 - 1) Within 2 percent of actual flow between the flow range of **0.8 to 38 gpm** (0.05 to 2.4 L/s).
 - 2) Within 0.5 percent of actual reading at the calibrated velocity.
 - f. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.
3. **Sensor:**
 - a. Rotational sensing of turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
 - b. Sensor shall have an integral frequency output linear with flow rate.
 - c. Sensor shall have threaded union on each end.
 - d. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts.
 - e. Construct wetted metal components of brass or stainless steel.
 - f. House sensor electronics in a NEMA 250, Type 4 enclosure.
 - g. Enclosure shall include connection(s) for field-installed conduit.
 - h. Sensor shall have cable of length sufficient to connect to display module.

4. Display Module:

- a. Remote from sensor.
- b. Enclosure: NEMA 250, Type 4X.
- c. Label terminal strip for all wiring connections.
- d. 120-V ac power supply with 24-V dc output to power the flow sensor.
- e. Remote Interface:
 - 1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
 - 2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
 - 3) Outputs linear to within 0.1 percent of calibrated span.
- f. Digital display of flow rate and totalized flow.
- g. At least eight display digits for totalization.
- h. Local reset of flow totalization.
- i. Program and data shall be stored in nonvolatile memory in the event of power loss.

F. In-line Body Electromagnetic Flow Meter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated;** F-3200 Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Description:**
 - a. No moving parts.
 - b. Suitable for flow measurement of fluids with electrical conductivity more than 5 microsiemens per cm.
 - c. Inherent bi-directional flow measurement.
 - d. Flow measurement with three pipe diameters upstream and two pipe diameters downstream.
 - e. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
 - f. Transmitter **[integral to] [remote from]** meter.
3. **Performance:**
 - a. Accuracy for Velocities between **3.3 and 33 fps** (1 and 10 m/s): Within 0.2 percent of reading.
 - b. Accuracy for Velocities between **1.0 and 3.3 fps** (0.3 and 1 m/s): Within 0.75 percent of reading.
 - c. Accuracy for Velocities Less than **1.0 fps** ((0.3 m/s)): Within **0.0075 fps** (0.0023 m/s).
 - d. Ambient Temperature: **Minus 4 to plus 140 deg F** (Minus 20 to plus 60 deg C).

- e. Process Temperature: **Minus 4 to 212 deg F** (Minus 20 to plus 100 deg C).
 - f. Pressure: **[225 psig (1551 kPa)] [580 psig (3999 kPa)]**.
4. Analog Output Current Signal:
- a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Isolated.
5. Digital Output Signal: Two, programmable, digital/pulse outputs configurable for frequency, pulse, or directional flow.
6. Operator Interface:
- a. Keypad.
 - b. Digital Display: Multiple-line digital display of alphanumeric characters.
 - c. LED for normal and alarm operation.
7. Construction:
- a. Body: **[Epoxy-coated carbon steel] [Type 316 stainless steel]**.
 - b. Body Liner Material: **[PTFE] [Ebonite] [Polypropylene]**.
 - c. Flow Tube: Type 304 stainless steel.
 - d. Connection: **[150 Class flange] [300 Class flange] [Threaded] [Wafer]**.
 - e. Electrodes: Type 316 stainless steel. Quantity determined by manufacturer based on application.
 - f. Electronics Enclosure:
 - 1) Painted aluminum.
 - 2) Removable cover.
 - 3) NEMA 250, Type 6.
- G. Insertion Electromagnetic Flow Meter:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated;** F-3500 Series[**with D/B-1200 Series remote display module**].
 - b. **<Insert manufacturer's name; product name or designation>**.
 2. Description:
 - a. No moving parts.
 - b. Suitable for flow measurement of fluids with electrical conductivity between 20 to 60000 microsiemens per centimeter.
 - c. Suitable for pipe sizes **NPS 3 through NPS 72** (DN 80 through DN 1800).
 - d. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
 - e. Continuous auto-zero function.

- f. Transmitter integral to meter.
3. Performance:
- a. Flow Range: 0.25 to 20 fps (0.08 to 6.1 m/s).
 - b. Accuracy for Velocities between 2 and 20 fps (0.6 to 6.1 m/s): Within 1 percent of reading.
 - c. Accuracy for Velocities Less than 2 fps (0.6 m/s): Within 0.02 fps (0.006 m/s).
 - d. Ambient Temperature: Minus 5 to 150 deg F (Minus 21 to plus 66 deg C).
 - e. Process Temperature: 15 to 250 deg F (Minus 9 to plus 121 deg C).
 - f. Pressure: 400 psig (2758 kPa).
4. Output Signals:
- a. Field-selectable analog signals.
 - 1) Current Signal (Isolated): 4 to 20 mA.
 - 2) Voltage Signal (Isolated): Zero- to [5] [10]-V dc.
 - b. Digital Signal: Dry-contact closure signaling fault condition.
 - c. Frequency Signal: Zero- to 15-V peak pulse, zero to 500 Hz.
 - d. Scalable Pulse Output:
 - 1) Isolated solid-state dry contact.
 - 2) Contact Rating: 100 mA at 50-V dc.
 - 3) Pulse Duration: 0.5, 1, 2, or 6 seconds.
5. Construction:
- a. Wetted Metal Parts: Type 316 stainless steel.
 - b. Sensor Head: Polysulfone.
 - c. Process Connection: 1-inch (25-mm).
 - d. Instrument Isolation Valve: Full port Type 316 stainless-steel ball valve for system isolation.
 - e. Electrodes: Type 316 stainless steel.
 - f. Electronics Enclosure:
 - 1) Painted aluminum.
 - 2) Removable cover.
 - 3) NEMA 250, Type 4.
 - 4) Electrical Connection: PVC-jacketed cable, 10 feet (3 m) long.
 - 5) Conduit Connection: 1/2-inch ((16 mm))trade size.
6. Display Module:
- a. Remote from meter.
 - b. House in a NEMA 250, Type 4X enclosure.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow sensor.
 - e. Input Signal from Meter: Zero- to 15-V pulse output.

- f. Output Signals: Additional output signals furnished with flow meter connected to display module terminal strip.
- g. Auxiliary Output Signals: Analog current output (isolated) shall be 4 to 20 mA.
- h. Auxiliary Output Signals: Analog voltage output (isolated) shall be zero to [5] [10] V.
- i. Auxiliary Output Signals: Digital output (isolated) shall be solid-state dry contacts rated for 100 mA at 50 V.
- j. Digital Display:
 - 1) Flow rate.
 - 2) Totalized flow.
 - 3) At least six display digits for flow rate and eight display digits for totalization.
 - 4) Bi-directional units with separate digital display for flow and totalization in each direction.
- k. Local reset of flow totalization.
- l. Program and data shall be stored in nonvolatile memory in the event of power loss.
- m. For bi-directional units, provide LED display of flow direction (contacts open or closed).

H. Vortex Shedding Flow Meter with Integral Temperature Measurement:

- 1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. **Onicon Incorporated;** F-2200 Series[with D-2100 Series remote display].
 - b. <Insert manufacturer's name; product name or designation>.
- 2. Description:
 - a. Flow measurement using vortex shedder body with integral 1000-ohm platinum RTD.
 - b. Meter **NPS 3/8 through NPS 8** (DN 10 through DN 200).
 - c. Each meter shall be factory calibrated at five points from **zero to 250 fps** (zero to 76 m/s) and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
 - d. Each meter shall be programmed using project-specific application data.
 - e. Meter shall include integral diagnostics to verify installation conditions and proper operation.
- 3. Performance:
 - a. Volumetric Flow Accuracy: Within 1 percent of reading for meter **NPS 1** (DN 25) and larger; within 2 percent of reading for smaller sizes.
 - b. Mass Flow Accuracy: Within 1.5 percent of reading for **NPS 1** (DN 25) and

- larger; within 2.5 percent of reading for smaller sizes.
- c. Ambient Temperature: **Zero to 132 deg F** (Minus 18 to plus 56 deg C).
 - d. Process Temperature: **25 to 464 deg F** (Minus 4 to plus 240 deg C).
 - e. Pressure: Equal to flange rating.
4. Output Signals:
- a. Analog Current Signal of Flow Rate:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Digital Signal: Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.
5. Operator Interface:
- a. Keypad.
 - b. Digital Display: Two-line digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, and temperature and support field programming of all parameters.
6. Construction:
- a. Material: Type 316L stainless steel for sizes through **NPS 4 (DN 100)**; Type 304 stainless steel for larger sizes.
 - b. Connection: **[Class 300] [Class 600]** flange.
 - c. Vortex Shedder: Unalloyed titanium.
 - d. Shedder Seal: Nickel-plated Inconel.
 - e. Enclosure:
 - 1) Epoxy-painted cast aluminum.
 - 2) Removable screw-on cover.
 - 3) NEMA 250, Type 4X.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: Two, **1/2-inch ((16-mm))**trade size.
7. Remote Display Module:
- a. Remote from meter.
 - b. House in a NEMA 250, Type 4 enclosure.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow meter.
 - e. Input Signal from Meter: Analog current, 4 to 20 mA.
 - f. Output Signals:
 - 1) Analog Current Output: Two wire, 4 to 20 mA, maximum loop resistance 275 ohms.
 - 2) Digital Output (Isolated): Solid-state dry contacts rated for 100 mA at 50-V dc.

- g. Digital Display:
 - 1) Flow rate.
 - 2) Totalized flow.
 - 3) Display Digits: 3.5 for flow rate and 8 for totalization.
 - h. Local reset of flow totalization.
 - i. Program and data shall be stored in nonvolatile memory in the event of power loss.
8. Upstream Flow Straightener:
- a. Flow straightener where required by installation.
 - b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
 - c. Straightener size shall match meter size.
- I. Vortex Shedding Flow Meter with Integral Pressure and Temperature Measurement:
- 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Onicon Incorporated**; F-2500 Series.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - 2. Description:
 - a. Mass flow measurement corrected for density using vortex shedder body with integral piezoelectric pressure sensors and 1000-ohm platinum RTD.
 - b. Meter **NPS 1/2 through NPS 12 (DN 15 through DN 300)**.
 - c. Each meter shall be factory calibrated at five points from **Zero to 250 fps (0 to 76 m/s)** and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
 - d. Each meter shall be programmed using project-specific application data.
 - e. Meter shall include integral diagnostics to verify installation conditions and proper operation.
 - 3. Performance:
 - a. Volumetric Flow Accuracy for Liquid: Within 0.75 percent of reading for Reynolds numbers 20000 and larger.
 - b. Volumetric Flow Accuracy for Steam and Gas: Within 1 percent of reading for Reynolds numbers 20000 and larger.
 - c. Mass Flow Accuracy for Steam and Gas: Within 1.5 percent of reading for Reynolds numbers 20000 and larger.
 - d. Repeatability: Within 0.1 percent.
 - e. Long-Term Stability: Within 0.1 percent per year.
 - f. Ambient Temperature: **Minus 40 to plus 185 deg F** (Minus 40 to plus 85 deg

- C).
 - g. Process Temperature: **Minus 40 to plus 464 deg F** (Minus 40 to plus 240 deg C).
 - h. Pressure: Equal to flange rating.
- 4. Output Signals:
 - a. Analog Current Signal of Flow Rate:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Analog Current Signals for Pressure and Temperature: Separate 4- to 20-mA signals for gage pressure and temperature.
 - c. Digital Signal:
 - 1) Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.
 - 2) HART, FSK protocol.
- 5. Operator Interface:
 - a. Keypad.
 - b. Digital Display: Two-line digital display of alphanumeric characters. The meter shall display flow rate, flow totalization, pressure, temperature, and support field programming of all parameters.
- 6. Construction:
 - a. Material: Type 316L stainless steel.
 - b. Connection: **[Class 150] [Class 300] [Class 600]** flange.
 - c. Enclosure:
 - 1) Epoxy-painted cast aluminum.
 - 2) Removable screw-on cover.
 - 3) NEMA 250, Type 6.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: Two, **1/2-inch** (16-mm) trade size.
- 7. Upstream Flow Straightener:
 - a. Meter manufacturer shall provide flow straightener where required by installation to comply with manufacturer's installation recommendations.
 - b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
 - c. Straightener size shall match meter size.
- J. Vortex Shedding Flow Meter for Hazardous Environments:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Rosemount, Inc., Emerson Electric Co.;** 8800C Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Standard: ASME MFC-6M.
3. Description:
 - a. FM Approved for hazardous environments.
 - 1) Intrinsically safe for Class I, Division 1, Groups A, B, C, and D; Class II and III, Division 1, Groups E, F, and G.
 - 2) Explosion-Proof for Class I, Division 1, Groups B, C, and D.
 - 3) Dust-Ignition-Proof for Class II and III, Division 1, Groups E, F, and G.
 - b. Sensor shall be isolated from process and replaceable without breaking process seals.
 - c. Meter immune to vibration.
 - d. Clog-free design eliminates gaskets and ports.
 - e. Meter **NPS 1/2 through NPS 12 (DN 15 through DN 300).**
 - f. Each meter shall be factory calibrated and provided with a certificate of calibration.
 - g. Meter shall be furnished with a permanently attached stainless-steel tag.
 - h. Meter shall include integral diagnostics to verify proper operation.
4. Performance:
 - a. Flow Accuracy: Within 0.65 percent of reading plus 0.025 percent of span for Reynolds numbers 20000 and larger.
 - b. Repeatability: Within 0.1 percent of flow rate.
 - c. Long-Term Stability: Within 0.1 percent of flow rate per year.
 - d. Response Time: Greater of three vortex shedding cycles or 0.2 seconds.
 - e. Dampening: Adjustable between 0.2 to 255 seconds.
 - f. Ambient Temperature: **Minus 58 to plus 250 deg F (Minus 50 to plus 121 deg C).**
 - g. Humidity: Zero to 95 percent noncondensing.
 - h. Process Temperature: **Minus 40 to plus 450 deg F (Minus 40 to plus 232 deg C).**
 - i. Pressure: Equal to flange rating.
5. Output Signals:
 - a. Analog Current Signal of Flow Rate:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.

- b. Digital Signal:
 - 1) Pulse output for flow totalization.
 - 2) HART protocol.
- 6. Digital Display: Digital display of alphanumeric characters. The meter shall display flow rate, flow totalization, percent of range, and current output.
- 7. Body and Flanges:
 - a. Material: Type 316L stainless steel.
 - b. Connection: ASME B16.5, **[Class 150]** **[Class 300]** **[Class 600]** flange.
 - c. Enclosure:
 - 1) Polyurethane-painted cast aluminum.
 - 2) Removable screw-on cover.
 - 3) NEMA 250, Type 4X.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: 1/2-inch (16-mm) trade size.

2.7 LIQUID FLOW SENSORS (PRIMARY ELEMENTS)

A. Averaging Pitot Tubes:

- 1. **Products:** Subject to compliance with requirements, **[provide the following]** **[provide one of the following]** **[available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Rosemount, Inc., Emerson Electric Co.;** Model 485 Annubar.
 - b. **<Insert manufacturer's name; product name or designation>.**
- 2. Standards: ASME MFC-12M.
- 3. Description:
 - a. Sensor shall include isolation valves and connections that are suitable for connecting to a remote pressure instrument.
 - b. Sensor shall consist of high- and low-pressure plenums and be able to accommodate an integral RTD.
 - c. Sensor's cross-sectional tee shape shall allow flow separation at a fixed point independent of flow rate, pressure, or temperature with a stable flow coefficient maintained over a wide range of Reynolds numbers.
 - d. Sensor shape shall promote less-turbulent zones on the backside of the sensor. Individual sensing ports shall be located in this less-turbulent region to measure low pressure. Number of sensing ports shall be a function of the pipe size.
 - e. High pressure shall be measured by a frontal slot design extending full length of sensor. Number of slots shall be a function of pipe size.
 - f. Manufacturer shall submit on request independent testing documentation (product test reports), demonstrating compliance with specified performance.

4. Performance:[**Product test reports are required.**]
 - a. Discharge Coefficient Factor: Within 0.75 percent of flow rate.
 - b. Repeatability: Within 0.1 percent.
 - c. Flow Turndown: 10:1.
 - d. Sensor Size for Pipe Size **NPS 2 through NPS 8** (DN 50 through DN 200): Minimum rod Reynolds number of 6000; probe width of **0.59 inch** ((15 mm)).
 - e. Sensor Size for Pipe Size **NPS 6 through NPS 36** (DN 150 through DN 900): Minimum rod Reynolds number of 12500; probe width of **1.060 inch** ((27 mm)).
 - f. Sensor Size for Pipe Size **NPS 12 through NPS 72** (DN 300 through DN 1800): Minimum rod Reynolds number of 25000; probe width of **1.953 inches** (50 mm).
 - g. Process Temperature Limit: **500 deg F** (260 deg C).
 - h. Process Pressure Limit: Equal to flange rating.

5. Construction:
 - a. Sensor Surface Finish: Front surface textured for high-Reynolds-number applications to create a more turbulent boundary layer on front surface of sensor and produce a more predictable and repeatable separation of flow at edge of sensor.
 - b. Sensor Material: Type 316 stainless steel.
 - c. Packing Gland:
 - 1) Wetted Parts: Type 316 stainless steel.
 - 2) Packing Material: Graphite.
 - d. Isolation Valve: Type 316 stainless-steel full port ball valve configured to remove sensor while isolating process.
 - e. Flanged In-line Pipe Spool:
 - 1) Mount sensor in a flanged section of pipe.
 - 2) Pipe material to match adjacent pipe.
 - 3) Flanges to match adjacent pipe.

B. Venturis:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Preso Meters, Division of Racine Federated, Inc.**; Model VB, CV and SSM Series.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. On request, submit independent testing documentation (product test reports), demonstrating compliance with specified performance.
3. Standard: ASME MFC-3M.
4. Performance:

- a. Accuracy within 0.5 percent of measured flow throughout flow range from design to 10 percent of design flow.
 - b. Accuracy with five pipe diameters of straight pipe upstream and two pipe diameters downstream.
 - c. Size and beta ratio shall be matched with transmitter to provide accuracy of entire assembly within 1 percent of design flow rate, when the flow rate is allowed to vary between 10 to 100 percent of the design.
5. Construction:
- a. One-piece bronze or brass construction with threaded connections for pipe sizes **NPS 1/2 through NPS 2** ((DN 15 to DN 50)).
 - b. One-piece plated cast steel with flanged connections for pipe sizes **NPS 2-1/2 through NPS 8** ((DN 65 to DN 200)), and fabricated steel with flanged connections for larger sizes.
 - c. Sensing Taps: Two, accurately located built-in sensing taps, nipples, shut-off valves, and quick connect coupling.
 - d. Identification Tag: Attached to each venturi with a chain and label indicating pipe size, venturi series, station identification, and meter reading at flow rate and pressure differential.
 - e. Use venturi with pressure differential transmitter.

C. Orifice Plates:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Rosemount, Inc., Emerson Electric Co.;** Model 405 Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Standards: ASME MFC-3M or ASME MFC-14M.
3. Performance:
 - a. Orifice plates shall be sharp, square-edged concentric type.
 - b. Shop fabricate and calibrate orifice meter runs through **NPS 2** (DN 50).
 - c. Field fabricate orifice runs **NPS 3** (DN 80) and larger.
 - d. Meter run piping or tubing shall be uniform internal surface, which is free of internal grooves and striations, but is not polished. Out of roundness shall not exceed 0.5 percent. A reduction of the pipe diameter or distortion caused by welding is unacceptable.
 - e. Size orifice plates for **100-inch wg** (24.9-kPa) pressure differential, except that the absolute value of the meter range shall not exceed the absolute value of the flowing pressure.
 - f. Ratio of orifice diameter to actual internal pipe diameter d/B (beta) shall be between 0.70 and 0.30.
 - g. Locate orifice plates in horizontal or vertical lines in accordance with good metering practice.
 - h. Minimum upstream and downstream straight pipe shall comply with ASME Fluid Meters Research Committee Reports.

4. Construction:
 - a. Fabricate the orifice plate and matching companion flanges of Type 316 stainless steel.
 - b. Transmitter connection shall be at least **NPS 1/2 (DN 15)**.
 - c. Stamp the orifice plates with the number and the orifice bore on the handle of the plate.
5. Use orifice plate with pressure differential transmitter.
6. Calibration information and calculations shall comply with either of the referenced standards for each orifice plate.

D. Segmented Wedge Flow Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Preso Meters, Division of Racine Federated, Inc.**; COIN Series.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Description: Pressure differential design using a segmented or segmental wedge installed in a straight section of pipe.
3. Performance: **[Product test reports are required.]**
 - a. Accuracy within 0.5 percent of the measured flow over flow range from design flow to 10 percent of design flow.
 - b. Accuracy with 10 pipe diameters of straight pipe upstream and five pipe diameters downstream.
 - c. Repeatability shall be within 0.2 percent over flow range.
 - d. Discharge coefficient shall be linear and stable throughout the flow range.
 - e. Determine H/ID ratios to meet specified performance.
 - f. Capable of bi-directional flow measurement with no degradation of performance, with flow in either direction.
 - g. Suitable for working pressure of **200 psig at 200 deg F** (1379 kPa at 93 deg C).
4. Construction:
 - a. Pipe: Type 316 stainless steel with inside diameter to match adjacent pipe. Length determined by manufacturer.
 - b. Wedge: Type 316 stainless-steel segmented angled wedge equal on both sides.
 - c. Flanges: Class 150 **[weld neck] [raised face]**, Type 316 stainless steel.
 - d. Instrument Connections: **NPS 1/2 (DN 15)**, Class 3000, Type 316 stainless-steel half couplings.
 - e. Identification Tag: Stamped or engraved stainless steel.
5. Use with a pressure differential transmitter.

E. Portable Meter Package for Liquid Flow Sensors:

1. Metal-reinforced-plastic carrying case.
2. Waterproof meter with nominal **6-inch (150-mm)** round dial face.
3. Meter with dual rupture-proof liquid-filled bellows having integral temperature compensation.
4. Meter with external range and zero adjustment.
5. Multiple meters in package, if required to accommodate venturis with a wide range of pressure signals.
6. Two connecting hoses, [**10-feet (3-m)**] **<Insert dimension>** long, with quick connect couplings compatible with venturi couplings.
7. Two brass blowdown valves with Buna-N seals and blowdown hoses.
8. Instruction book with flow versus differential curves.
9. Suitable for working pressure of **200 psig (1380 kPa)** at **200 deg F (93.3 deg C)**.
10. Portable meter package to connect to flow sensor without disturbing connection to pressure differential transmitter. Provide isolation valves at connections.
11. Turn over to Owner at Project completion.

2.8 LIQUID FLOW SWITCHES

A. Liquid Flow Switch (Bellows Type):

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **W. E. Anderson, Division of Dwyer Instruments, Inc.**; Series FS-2.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Description:
 - a. Field-adjustable four-vane combinations.
 - b. Field-adjustable set-point adjustment screw.
 - c. Suitable for pipe sizes **NPS 1 through NPS 8 (DN 25 through DN 200)**.
 - d. Switch mounted vertically in horizontal pipe.
3. Performance:
 - a. Flow Rate Actuation and De-actuation: Varies with vane combination and set-point adjustment.
 - b. Pressure Limit: **145 psig (1000 kPa)**.
 - c. Temperature Limit: **230 deg F (110 deg C)**.
 - d. Electrical Rating: 10 A resistive, 3 A conductive at 250-V ac.
 - e. Switch Type: SPDT snap switch.
4. Wetted Parts Construction:
 - a. Bellows: Tin-bronze.
 - b. Vanes: Stainless steel.

- c. Body: Forged brass.
 - d. Process Connection: **NPS 1** (DN 25)).
 5. Enclosure:
 - a. Die-cast aluminum alloy.
 - b. NEMA 250, Type 4.
 - c. Electrical Connection: Cable gland with attached wire leads.
- B. Liquid Flow Switch (Magnetic Type):
 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **W. E. Anderson, Division of Dwyer Instruments, Inc.**; Series V4.
 - b. **<Insert manufacturer's name; product name or designation>**.
 2. Description:
 - a. Field-adjustable five-vane combinations.
 - b. Suitable for pipe sizes **NPS 1-1/2 through NPS 20** (DN 40 to DN 500).
 - c. Mounting Suitable for Application: Switch vertically mounted in horizontal pipe, or switch horizontally mounted in vertical pipe with flow up.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous-environment Class I, Groups C and D; Class II, Groups E, F, and G.
 3. Performance:
 - a. Flow Rate Actuation and De-actuation: Varies with vane combination.
 - b. Pressure Limit: **1000 psig** (6895 kPa) for brass body, **2000 psig** (13790 kPa) for Type 316 stainless-steel body.
 - c. Temperature Range: **Minus 4 to plus 275 deg F** (Minus 20 to plus 135 deg C).
 - d. Electrical Rating: 10 A at 125/250-V ac.
 - e. Switch Type: **[SPDT] [DPDT]** snap switch.
 4. Wetted Parts Construction:
 - a. Vanes: Type 316 stainless steel.
 - b. Body: **[Brass] [Type 316 stainless steel]**.
 - c. Magnetic Keeper: **[Type 430 stainless steel] [Type 316 stainless steel]**.
 - d. Process Connection: **NPS 1-1/2** (DN 40).
 5. Enclosure:
 - a. Die-cast aluminum alloy.
 - b. Threaded cover.
 - c. NEMA 250, Type 4.
 - d. Electrical Connection: Terminal block.
 - e. Conduit Connection: **3/4-inch** (21-mm) trade size.

C. Liquid Flow Switch (Magnetic Type) for Small-Diameter Pipe:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. W. E. Anderson, Division of Dwyer Instruments, Inc.; Series V6.
 - b. <Insert manufacturer's name; product name or designation>.
2. Description:
 - a. Suitable for pipe sizes **NPS 1/2 through NPS 2** (DN 15 through DN 50).
 - b. Mounting Suitable for Application: Switch vertically mounted in horizontal pipe, or switch horizontally mounted in vertical pipe with flow up.
 - c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous-environment Class I, Groups A, B, C, and D; Class II, Groups E, F, and G.
3. Performance:
 - a. Flow Rate Actuation and De-actuation: Not adjustable.
 - b. Pressure Limit of Body: **1000 psig** (6895 kPa) for brass, **2000 psig** (13790 kPa) for Type 303 stainless-steel body.
 - c. Pressure Limit of Tee: **250 psig** (1724 kPa) for brass, **1000 psig** (6895 kPa) for malleable iron, and **2000 psig** (13790 kPa) for forged carbon steel and stainless steel.
 - d. Temperature Range: **Minus 4 to plus 220 deg F** (Minus 20 to plus 104 deg C).
 - e. Electrical Rating: 5 A at 125/250-V ac.
 - f. Switch Type: [**SPDT**] [**DPDT**] snap switch.
4. Wetted Parts Construction (Lower Body):
 - a. Vanes: Type 301 stainless steel.
 - b. Body: [**Brass**] [**Type 303 stainless steel**].
 - c. Magnet: Ceramic.
 - d. Process Connection: **NPS 1/2** (DN 15).
5. Enclosure (Upper Body):
 - a. [**Brass**] [**Type 303 stainless steel**].
 - b. NEMA 250, Type 4.
 - c. Electrical Connection: Terminal block.
 - d. Conduit Connection: **3/4-inch** (21-mm) trade size.
6. Integral Mounting Tee Furnished with Switch:
 - a. [**Brass**] [**Forged carbon steel**] [**Malleable iron**] [**Stainless steel**].
 - b. Size: [**Match adjacent pipe**] <Insert size>.
 - c. Connection: Threaded pipe.

2.9 LIQUID FLOW TRANSMITTERS

A. Pressure Differential Transmitter with 0.07 Percent Accuracy for Flow Measurement [in Hazardous Environment]:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. **Rosemount, Inc., Emerson Electric Co.;** Model 3051CD.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
 - b. Explosion-Proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust-Ignition-Proof for Class II, Division 1, Groups E, F, and G.
 - d. Dust-Ignition-Proof for Class III, Division 1.
3. Performance:
 - a. Range: **Minus 250- to 250-inch wg** (Minus 62.5 to 62.5 kPa).
 - b. Span: Field adjustable.
 - c. Minimum Span: **2.5-inch wg** (500 Pa).
 - d. Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: **3626 psig** (25000 kPa).
 - g. Process Temperature Limits: **Minus 40 to plus 250 deg F** (Minus 40 to plus 121 deg C).
 - h. Ambient Temperature Limits: **Minus 40 to plus 185 deg F** (Minus 40 to plus 85 deg C).
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
4. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable zero to 30 seconds.
5. Operator Interface: Zero and span adjustments located behind cover.
6. Display: Five-digit, two-line digital display with **0.4 inch** (10 mm) high alphanumeric characters.
7. Construction:
 - a. Nonwetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.

- c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. **NPS 1/2 (DN 15)** process connections on bottom of instrument.
 - e. Drain/vent valve on low- and high-pressure connections.
 - f. Two **1/2-inch (16-mm)** trade size conduit connection on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting bracket suitable for installation.
 8. Five-Valve Manifold:
 - a. Each transmitter shall have integrally mounted manifold.
 - b. Construct manifold body of Type 316 stainless steel.
 - c. Manifold shall have **NPS 1/2 (DN 15)** process connections.
- B. Liquid Pressure Differential Transmitter for Flow Measurement:
 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series 645.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Performance:
 - a. Range: Approximately 2 times the set point.
 - b. Span: Adjustable plus or minus 1 mA, non-interactive.
 - c. Accuracy: Within 0.25 percent of full scale.
 - d. Maximum Operating Pressure: 2.5 times range.
 - e. Temperature Limits: **Zero to 175 deg F** (Minus 18 to plus 79 deg C).
 - f. Compensate Temperature Limits: **30 to 150 deg F** (Minus 1 to plus 66 deg C).
 - g. Thermal Effects: 0.02 percent of full scale per degree F.
 - h. Response Time: 30 to 50 ms.
 - i. Shock and vibration shall not harm the transmitter.
 3. Analog Output Current Signal:
 - a. Two wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 4. Operator Interface:
 - a. Zero and span adjustments located behind cover.
 - b. Bleed screws on side of body, two screws on low-pressure side, and one screw on high-pressure side, for air in line and pressure cavity.
 5. Construction:
 - a. Aluminum and stainless-steel enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH or 300 series stainless

- steel.
 - c. NPS 1/4 (DN 8) process connections on side of instrument enclosure.
 - d. Knock out for 1/2-inch (15-mm) trade size conduit connection on side of instrument enclosure.
 - e. Screw terminal block for wire connections.
 - f. NEMA 250, Type 4X.
 - g. Mounting bracket shall be suitable for installation.
6. Transmitter shall have three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Manifold shall have NPS 1/4 (DN 8) process connections.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Provide the services of an independent inspection agency to confirm that proposed mounting locations comply with requirements indicated and approved submittals.
 - 1. Indicate dimensioned locations with mounting height for all surface-mounted products to walls and ceilings on shop drawings.
 - 2. Do not begin installation without submittal approval of mounting location.
- E. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.
- F. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- G. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTRUMENT APPLICATIONS

- A. Select from instrument types to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
- B. Duct-Mounted Airflow Sensors:

1. Measured Velocities [500 fpm (2.5 m/s)] <Insert value> and Less: Thermal airflow station.
 2. Measured Velocities Greater than [500 fpm (2.5 m/s)] <Insert value>: [Pitot-tube airflow sensor station] [Thermal airflow station].
- C. Damper-Mounted Airflow Sensors:
1. Measured Velocities [400 fpm (2.0 m/s)] <Insert value> and Less: Thermal airflow station.
 2. Measured Velocities Greater than [500 fpm (2.5 m/s)] <Insert value>: [Pitot-tube airflow sensor station] [Thermal airflow station] [Damper with integral flow measurement] [Damper with integral flow control].
- D. Fan-Mounted Airflow Sensors:
1. Measured Velocities [500 fpm (2.5 m/s)] <Insert value> and Less: Thermal airflow station.
 2. Measured Velocities Greater than [500 fpm (2.5 m/s)] <Insert value>: [Pitot-tube fan inlet airflow sensor station] [Piezometer ring fan inlet airflow sensor] [Thermal airflow station].
- E. Airflow Switches:
1. Measured Velocities 400 fpm (2.0 m/s) and Less: Polymer film sail switch.
 2. Measured Velocities Greater than 400 fpm (2.0 m/s): Stainless-steel single-vane switch.
- F. Airflow Transmitters for Use with Pitot-Tube-Type Sensors:
1. Exhaust Air Airflow: [Airflow transmitter with 0.10 percent accuracy and auto-zero feature] [Airflow transmitter with 0.25 percent accuracy and auto-zero feature] [Pressure differential transmitter for airflow measurement] [Pressure differential indicating transmitter, switch, and controller for airflow measurement].
 2. Outdoor Air Airflow: [Airflow transmitter with 0.10 percent accuracy and auto-zero feature] [Airflow transmitter with 0.25 percent accuracy and auto-zero feature] [Pressure differential transmitter for airflow measurement] [Pressure differential indicating transmitter, switch and controller for airflow measurement].
 3. Return Air Airflow: [Airflow transmitter with 0.10 percent accuracy and auto-zero feature] [Airflow transmitter with 0.25 percent accuracy and auto-zero feature] [Pressure differential transmitter for airflow measurement] [Pressure differential indicating transmitter, switch, and controller for airflow measurement].
 4. Supply Air Airflow: [Airflow transmitter with 0.10 percent accuracy and auto-zero feature] [Airflow transmitter with 0.25 percent accuracy and auto-zero feature] [Pressure differential transmitter for airflow measurement] [Pressure differential indicating transmitter, switch, and controller for airflow measurement].

G. Liquid Flow Sensors (Primary Elements):

1. **<Insert system> System, <Insert unique application>: [Averaging pitot tubes] [Venturis] [Orifice plates] [Segmented wedge].**

H. Liquid Flow Meters:

1. **<Insert system> System, <Insert unique application>: [Insertion paddle wheel transmitter] [Turbine flow meter] [Electromagnetic flow meter] [Vortex shedding flow meter with integral temperature measurement] [Vortex shedding flow meter with integral pressure and temperature measurement] [Vortex shedding flow meter for hazardous environments].**

I. Liquid Flow Switches:

1. **<Insert system> System, <Insert unique application>: [Bellows type] [Magnetic type].**

J. Liquid Flow Transmitters:

1. **<Insert system> System, <Insert unique application>: [Pressure differential transmitter with 0.07 percent accuracy for flow measurement] [Liquid pressure differential transmitter].**

3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- D. Install ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- E. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- F. Corrosive Environments:
1. Use products that are suitable for environment to which they will be subjected.
 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:

- a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - c. **<Insert requirement>**.
3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings with a corrosive-resistant coating that is suitable for environment.
 4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 INSTRUMENTS, GENERAL INSTALLATION REQUIREMENTS

- A. Mounting Location:
 1. Rough-in: Outline instrument-mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
 2. Install switches and transmitters for air and liquid flow associated with individual air-handling units and connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
 3. Install liquid and steam flow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 4. Install airflow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
 6. Install instruments in steam, liquid, and liquid-sealed-piped services below their process connection point. Slope tubing down to instrument with a slope of [2] [3] **<Insert number>** percent.

7. Install instruments in dry gas and non-condensable-vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of [2] [3] <Insert number> percent.

B. Mounting Height:

1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
2. Mount switches and transmitters, located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements, within a range of 42 to 72 inches (1050 to 1800 mm) above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches (1500 mm).

- C. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

3.6 FLOW INSTRUMENTS INSTALLATION

A. Airflow Sensors:

1. Install sensors in straight sections of duct with manufacturer-recommended straight duct upstream and downstream of sensor.
2. Installed sensors shall be accessible for visual inspection and service. Install access door(s) in duct or equipment located upstream of sensor, to allow service personnel to hand clean sensors.

B. Liquid and Steam Sensors:

1. Install sensors in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Alert manufacturer where installation cannot accommodate recommended clearance, and solicit recommendations for field modifications to installation, such as flow straighteners, to improve condition.
3. Install pipe reducers for in-line sensors smaller than line size. Position reducers at distance from sensor to avoid interference and impact on accuracy.
4. Install in-line sensors with flanges or unions to provide drop-in and -out installation.

C. Liquid Flow Meters:

1. Install meters in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Install pipe reducers for in-line meters smaller than line size. Install reducers at distance from meter to avoid interference and impact on accuracy.
3. Install in-line meters with flanges or unions to provide drop-in and -out

installation.

4. Insertion Meters:

- a. Install system process connections full size of meter connection, but not less than [NPS 1 (DN 25)] [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] **<Insert pipe size>**. Provide [stainless-steel] bushing if required to mate to system connection.
- b. Install meter in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
- c. In applications where top-dead-center location is not possible due to field constraints, install meter at location along top half of pipe if acceptable by manufacturer for mounting orientation.

D. Liquid Switches:

1. Install system process connection full size of switch connection, but not less than [NPS 1 ((DN 25))] [NPS 1-1/2 ((DN 40))] [NPS 2 ((DN 50))] **<Insert pipe size>**. Install [stainless-steel] bushing if required to mate switch to system connection.
2. Install switch in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
3. In applications where top-dead-center location is not possible due to field constraints, install switch at location along top half of pipe if switch is acceptable by manufacturer for mounting orientation.

E. Transmitters:

1. Install airflow transmitters serving an air system in a single location adjacent to or within system control panel.
2. Install liquid flow transmitters, not integral to sensors, in vicinity of sensor. Where multiple flow transmitters serving same system are located in same room, co-locate transmitters by system to provide service personnel a single and convenient location for inspection and service.

3.7 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.8 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.

- C. Polish glossy surfaces to a clean shine.

3.9 CHECKOUT PROCEDURES

A. Description:

1. Check out installed products before continuity tests, leak tests, and calibration.
2. Check instruments for proper location and accessibility.
3. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
4. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.

B. Flow Instrument Checkout:

1. Verify that sensors are installed correctly with respect to flow direction.
2. Verify that sensor attachment is properly secured and sealed.
3. Verify that processing tubing attachment is secure and isolation valves have been provided.
4. Inspect instrument tag against approved submittal.
5. Verify that recommended upstream and downstream distances have been maintained.

3.10 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
4. Equipment and procedures used for calibration shall meet instrument manufacturer's recommendations.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If after-calibration-indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of

specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.11 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of systems and equipment Installer] [manufacturer's authorized service representative]**. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.12 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without

paying royalties.

END OF SECTION 230923.14

SECTION 230923.16 - GAS INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes the Following Gas Instruments:
 - 1. Carbon-dioxide sensors and transmitters.
 - 2. Combination carbon dioxide and VOC sensors and transmitters.
 - 3. Single-point oxygen monitoring system.
 - 4. Multipoint carbon-monoxide monitoring system.
 - 5. VOC sensors and transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.16**.

1.3 DEFINITIONS

- A. NDIR: Nondispersive infrared.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Installation instructions, including factor affecting performance.
 - 3. Product description with complete technical data, performance curves, product specification sheets.

- B. LEED Submittals: Product data of carbon dioxide instruments for use in showing compliance with requirements in ASHRAE 62.1.
- C. Shop Drawings:
 - 1. Include plans, elevations, sections, and **[mounting]**details.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Number-coded identification system for unique identification of wiring, cable, and tubing ends.
- D. Samples: For each exposed product installed in finished space.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which wall-mounted instruments located in finished space are shown and coordinated with each other, showing relationship to light switches, fire alarm devices, and other installed devices using input from installers of the items involved.
- B. Product Test Reports: For each product, for tests performed by **[manufacturer and witnessed by a qualified testing agency] [a qualified testing agency]**.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For gas instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 CARBON-DIOXIDE SENSORS AND TRANSMITTERS

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - 1. **Vaisala Inc.;** GMW 20 series for wall-mounted space applications and GMD 20 series for duct-mounted applications.
 - 2. **<Insert manufacturer's name; product name or designation>.**
- B. Description:
 - 1. NDIR technology or equivalent technology providing long-term stability and reliability.
 - 2. Two-wire, 4-20 mA output signal, linearized to carbon-dioxide concentration in ppm.

C. Construction:

1. House electronics in an ABS plastic enclosure. Provide equivalent of NEMA 250, Type 1 enclosure for wall-mounted space applications and NEMA 250, Type 4 for duct-mounted applications.
2. Equip with digital display for continuous indication of carbon-dioxide concentration.

D. Performance:

1. Measurement Range: Zero to 2000 ppm.
2. Accuracy: Within 2 percent of reading, plus or minus 30 ppm.
3. Repeatability: Within 1 percent of full scale.
4. Temperature Dependence: Within 0.05 percent of full scale over an operating range of 25 to 110 deg F (minus 4 to 43 deg C).
5. Long-Term Stability: Within 5 percent of full scale after more than five years.
6. Response Time: Within 60 seconds.
7. Warm-up Time: Within five minutes.

E. Provide calibration kit. Turn over to Owner at start of warranty period.

2.2 COMBINATION CARBON-DIOXIDE AND VOC SENSORS AND TRANSMITTERS

A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. [Siemens Building Technologies, Inc.](#); QPA20 series.
2. **<Insert manufacturer's name; product name or designation>.**

B. Description:

1. NDIR technology or equivalent technology that provides long-term stability and reliability.
2. Senses and responds to combined concentration of more than 30 contaminants commonly found in indoor environments.

C. Output Signal: Zero to 10-V dc.

D. Performance:

1. Carbon-Dioxide Range: Zero to 2000 ppm.
2. Carbon-Dioxide Accuracy: Within 50 ppm, plus 2 percent measured value.
3. VOC Range: Zero to 2000 ppm.
4. VOC Sensitivity Ranges: Field selectable, low, normal, high.
5. Ambient Temperature: 32 to 122 degrees F.
6. Ambient Relative Humidity: 5 to 95 percent non-condensing.

E. Enclosure: White plastic.

- F. Electrical Connections: Screw terminals.
- G. Display: Digital, LCD.

2.3 SINGLE-POINT OXYGEN MONITORING SYSTEM

- A. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - 1. [MSA Instrument Division, Inc.](#); Toxgard II Monitor System.
 - 2. <Insert manufacturer's name; product name or designation>.
- B. Description:
 - 1. System shall measure and display a single gas concentration, provide local audio and visual alarms when preset limits are exceeded, and send output signals of gas concentration and detected alarms.
 - 2. System shall require no periodic maintenance other than periodic checking of sensor response to a known concentration of gas.
 - 3. System shall be designed to provide for installation, setup, and start-up from outside of unit enclosure without need to open the enclosure door.
 - 4. System shall be factory calibrated and ready for operation after installation.
 - 5. Monitor shall be internally wired to accommodate a single-point field power connection.
- C. Performance:
 - 1. Range: Full scale, zero to 25 percent oxygen.
 - 2. Zero Drift: Within 1 percent per year.
 - 3. Span Drift: Within 10 percent per year.
 - 4. Repeatability: Within 1 percent of full scale.
 - 5. Linearity: Within 2 percent of full scale.
 - 6. Step Change Response Time: Within 12 seconds.
- D. Enclosure:
 - 1. NEMA 250, Type 4X.
 - 2. Access to the inside of enclosure, as well as to controller, display, and wiring connections, shall be through full-length door on front of enclosure.
 - 3. Door with shatterproof window sized to provide viewing of visual display and indicator lights.
 - 4. Equip enclosure with mounting brackets for the purpose of attaching the unit to a flat surface.
 - 5. Provide door with key lock access to inside enclosure.
- E. Controller:
 - 1. Password-protected access through full-function keypad.
 - 2. Set:

- a. Real-time clock.
 - b. Alarm levels.
 - c. Change span-gas values.
 - d. Display date of last calibration.
 - e. Display minimum, maximum, and average gas values.
 - f. Change address, future calibration time, and date.
3. Automatic return-to-normal-operation feature after calibration.
 4. Date stamps last successful calibration.
 5. Time and date stamps events.
 6. Selectable lockout of output signals during calibration.
 7. Logs minimum, maximum, and average gas concentrations over selected time intervals.
- F. Visual Display:
1. Four-digit LED or backlight LCD display visible from front face of enclosure.
 2. Value displayed shall be a direct reading of gas concentration.
 3. Displays system status indicators.
 4. Visual Alarm Indication:
 - a. Three separate alarm levels: Caution, Warning, and Alarm.
 - b. Separate strobes for Warning and Alarm conditions. Externally mount the two strobes on top of enclosure.
 5. Indication of sensor nearing end of its useful life based on the sensor output, not on the time the sensor was in service.
 6. Displays average, minimum, and maximum gas concentrations of the sensor over selected time.
 7. Malfunction Indication Alarm: Displays a separate unique character when an over range or under range condition exists, a sensor signal sensor is lost, or a set-point error or memory failure occurs.
- G. Audible Alarm:
1. Provides an audible horn when an alarm condition occurs.
 2. Horn shall be rated for 95 dB with selectable output tones.
 3. Mount horn inside or on exterior of enclosure.
 4. Activate horn through a horn relay. Horn relay shall be form "A" contacts and set as normally open and common.
- H. Operator Interface:
1. Door Audible Alarm Acknowledge Switch:
 - a. Push-button switch located on front door shall silence audible alarm.
 - b. Switch shall reset latched alarms if normal gas conditions exist. Visual alarms shall remain on as long as alarms are exceeded.

2. Operating Modes and Parameters Selection: Selections listed shall be accomplished by the use of switches, jumpers, or remote control not involving the use of tools.
 - a. Display range value.
 - b. Latching or nonlatching mode for the alarm set points.
 - c. Upscale or downscale acting alarms.
- I. Output Signal:
1. Relays:
 - a. Provide one relay for each set-point level for each of the three alarm levels.
 - b. Provide one relay for fault conditions.
 - c. Alarm and fault relays shall be form "C," SPDT. Contacts shall be rated for 5 A resistive at 250-V ac or 30-V dc.
 - d. Contacts shall be capable of being selected normally open or normally closed.
 - e. Alarm relays shall be normally de-energized. The fault relay shall be normally energized.
 2. Analog Output:
 - a. Two-wire, 4- to 20-mA, **[isolated] [nonisolated] [isolated or nonisolated]** current source.
 - b. Signal capable of operating into a 600-ohm load.
 3. Digital Communication:
 - a. Bidirectional sending and receiving of digital signals.
 - b. Digital signals shall comply with FTT-10-based communication.
 - c. Protocol shall be LonTalk supported by Lon Works.
 - d. Signal speed shall be no greater than 78.1 kBs per second.
- J. Sensor:
1. Electrochemical fuel-cell type does not require periodic addition of reagents.
 2. Sensor shall be replaceable without the need for tools.
 3. Sensors shall have a minimum useful life of one year. Replace failed sensors at no charge within first year.
 4. Mount sensor externally on the side or bottom of enclosure. Where indicated on Drawings, mount sensor remote from enclosure.
 5. Remote Mounting:
 - a. Provide sensor in a separate enclosure. Enclosure shall be NEMA 250, Type 4X, except when sensor is installed in a hazardous location, then enclosure shall be an explosion-proof type suitable for the application.
 - b. Provide sensor with cable for connecting to monitor.
 - c. Provide sensor with mounting hardware suitable for application.
 - d. For duct-mounted applications, the sensor installation shall provide kit for

calibration of the sensor without removing sensor from duct.

K. Gas Sampling Pump:

1. Where required by application, provide a pump mounted inside the enclosure to provide a motive force to induce flow of gas sample across the sensor.
2. Signal to the sensor from the pump shall be in digital communication format to eliminate radio-frequency interference (RFI) and electromagnetic interference (EMI).
3. A flow sensor shall activate a relay when the gas sample falls below the acceptable flow rate to the sensor and shall indicate a loss of gas flow on the display.
4. Introduction of a calibration gas to the gas sensor shall be through an integral push-button valve. This push-button valve shall return to monitoring the sampled area when released.

L. Battery Backup:

1. Provide battery backup power supply to continue normal operation if normal power source is interrupted.
2. Transfer to battery backup shall be automatic and shall be indicated on the display.
3. Mount battery backup power supply inside enclosure.
4. Battery backup shall be continuously charged during normal operation.
5. Battery life shall be at least 0.5 hours with strobes flashing, alarm conditions asserted, and horn sounding.

M. Calibration:

1. Calibrate and adjust functions through nonintrusive hand-held wireless remote control without opening enclosure door.
2. Enter calibration mode through hand-held wireless remote control unit. The display of the monitor shall instruct the user on when to apply zero and span gas. The system shall automatically adjust its internal settings to the proper calibration values without further intervention by the user. On completion of a successful calibration, the system shall exit the calibration mode. Date stamp of last successful calibration is retained in the system internal memory, with capability to be indicated on display. If calibration is unsuccessful for any reason, the display shall show an unsuccessful calibration attempt and revert to its previous calibration settings.
3. Wireless method shall employ a digitally encoded infrared light beam.
4. Hand-held wireless remote control shall let the user perform sensor zeroing and calibration.
5. Hand-held wireless remote control shall let the user perform sensor zeroing and calibration, as well as activate all functions and features of the monitor.
6. The monitor infrared link shall not be affected by natural and man-made low-level ambient light.

N. Automatic Calibration System:

1. Provide automatic calibration of all oxygen monitors installed. Number of automatic calibration systems shall be determined by supplier based on location and quantity of oxygen monitors.
2. Automatic calibration system shall, without manual intervention, periodically perform a complete calibration of the sensor.
3. System shall exchange digital signals with sensor.
4. Automatic calibration shall be adjustable from as many as three times per day to only once every 30 days.
5. Sensor alarms shall be suppressed or disabled until the automatic calibration cycle is completed.
6. Manual calibration of the sensor shall be initiated at any time with a hand-held infrared remote control without the need to disable or turn off the automatic calibration system.
7. House the system in a separate NEMA 250, Type 4X enclosure from the oxygen monitoring system. Enclosure shall have provisions for wall mounting.
8. Digital displays shall indicate zero and when span gas is being applied to the sensor, the status, and any fault condition.
9. Provide with a separate valve condulet to monitor the condition of the calibration cylinders attached to the calibration system. Insufficient gas pressure to calibrate the sensor shall light the fault indicator.

2.4 MULTIPOINT CARBON-MONOXIDE MONITORING SYSTEM

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. [MSA Instrument Division, Inc.](#); MultiGard.
2. **<Insert manufacturer's name; product name or designation>.**

- B. Description:

1. Each sampling point shall monitor any variation in the carbon-monoxide concentration level.
2. Each sampling point shall be individually piped to the monitoring system.
3. Provide **[each]** sampling point with a 0.3-micron filter.
4. Each sampling point shall be an alarm point.
5. A dual-head diaphragm pump shall draw an air sample through piping system and through a microprocessor-controlled sequencer feeding an analyzer with a new sample every **[15] <Insert number>** seconds.
6. Sample time shall be adjustable in 1 second increments from zero to 60 minutes.
7. Span and zero calibration gas shall be automatically initiated by the microprocessor. System shall also provide manual initiation of span and zero calibration gas.
8. Analyzer output shall be corrected by the microprocessor.
9. Monitoring system shall have **[8] [16] [24] [32]** sample points.
10. System shall operate on 120-V ac, single-phase, 60-Hz power.
11. Final adjustment; calibration, testing, and startup of the system shall be performed by a trained representative of manufacturer.

C. Analyzer:

1. Analyzer shall operate using principle of nondispersive infrared absorption.
2. Sampling response time shall be within 10 seconds.
3. Zero drift and span drift shall be less than 1 percent of full scale within a 24-hour period.
4. Repeatability shall be within 1 percent of full scale.
5. Accuracy shall be within 1 percent of full scale.
6. Calibration range shall be zero to 500 ppm.
7. Digital display on analyzer face with scale shall be in ppm.
8. Temperature shall be compensated from 30 to 120 deg F ((minus 1 to 49 deg C)) ambient temperature.

D. Control and Display:

1. Each sample shall send a 4-20 mA output signal proportional to the highest concentration.
2. Alphanumeric visual display of current analyzer concentration reading shall be in ppm or another industry-accepted measurement.
3. Visual indication for sample analyzing, sample high-concentration alarm, analyzer malfunction, and calibration.
4. Any number and configuration of sample points shall be capable of being bypassed.
5. Each sample point shall be capable of being manually sampled through an override feature.
6. System parameters shall be stored in nonvolatile memory.
7. Provide at least an eight-hour battery backup of current alarm status. Battery shall be rechargeable.

E. Enclosure:

1. NEMA 250, **[Type 1] [or] [Type 12]**.
2. Hinged and locking door, full size of face.
3. House all system components. Multiple adjoining enclosures are acceptable if joined to a common support structure.

F. Calibration Equipment:

1. Provide equipment necessary to automatically and manually calibrate the system, including, but not be limited to, the following:
 - a. Regular assembly.
 - b. Zero cap.
 - c. Calibration cap.
 - d. Two cylinders filled with calibration gas.
 - e. Instruction book.
 - f. Carrying case.

2.5 VOC SENSORS AND TRANSMITTERS

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
1. **Building Automation Products Inc.;** BA/AQS.
 2. **<Insert manufacturer's name; product name or designation>.**
- B. Description:
1. VOC sensor shall use an oxidizing element that varies resistance with contaminant gases.
 2. Senses and responds to combined concentration of more than 30 contaminants commonly found in indoor environments.
- C. Output Signal: Zero to **[5] [or] [10]**-V dc with minimum load resistance of 4000 ohms.
- D. Performance:
1. Measurement Range: Zero to 100 percent.
 2. Ambient Temperature: **32 to 140 deg F** (zero to 60 deg C).
 3. Ambient Relative Humidity: 5 to 95 percent non-condensing.
- E. Enclosure: Lexan.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Properly support instruments, tubing, piping, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to seismic loads.
- D. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- E. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- F. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - c. **<Insert requirements>**.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."

- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 INSTRUMENTS, GENERAL INSTALLATION REQUIREMENTS

A. Mounting Location:

1. Install transmitters for gas associated with individual air-handling units and associated connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
2. Install gas switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
3. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
4. Install instruments in dry gas and non-condensable vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of [2] [3] <Insert number> percent.

B. Mounting Height:

1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements within a range of 42 to 72 inches (1.1 to 1.6 m) above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches ((1.5 m)).

- C. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated, using neoprene gaskets or grommets.

3.5 CARBON-MONOXIDE MONITORING SYSTEM

- A. Install sample points in monitored area to provide accurate measurement of gas concentration.
- B. Install exposed sampling points with a finished appearance consistent with other materials in space. Submit proposed products to be installed for review and approval.

- C. Individually install each sample point to the carbon-monoxide monitoring system.
- D. Install tubing in a minimum size of **NPS 3/8 (DN 10)**.
- E. Use compression fittings at connections to equipment.
- F. If not indicated on Drawings, locate carbon-monoxide monitoring system in a secured and serviceable location accessible to authorized personnel.
- G. Support carbon-monoxide monitoring system from floor or wall. Support floor-mounted systems using a structural channel frame. Provide mounting brackets.

3.6 OXYGEN MONITORING SYSTEM

- A. Install monitor in space to provide an accurate measurement of gas concentration.
- B. Support oxygen monitoring system from wall.

3.7 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification on face.

3.8 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.
- D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and

- adjustment.
3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
 4. Equipment and procedures used for calibration shall comply with instrument manufacturer's written recommendations.
 5. Provide diagnostic and test equipment for calibration and adjustment.
 6. Field instruments and equipment used to test and calibrate installed instruments shall have an accuracy of at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.
 9. Comply with field-testing requirements and procedures in ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- B. Analog Signals:
1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.
- C. Digital Signals:
1. Check digital signals using a jumper wire.
 2. Check digital signals using an ohmmeter to test for contact.
- D. Meters: Check sensors at zero, 50, and 100 percent of Project design values.
- E. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.
- F. Switches: Calibrate switches to make or break contact at set points indicated.
- G. Transmitters:
1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
 2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.
- 3.10 MAINTENANCE SERVICE
- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of**

gas system and equipment installer] [manufacturer's authorized service representative]. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.11 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate gas instrument demonstration video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.16

SECTION 230923.17 - LEVEL INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes liquid-level switches, sensors, and transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.17**.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Include product description with complete technical data, performance curves, and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For level instruments, to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Environmental Conditions:
- Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - If instrument alone cannot comply with requirement, install instrument in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[**and cooled**], filtered, and ventilated as required by instrument and application.

2.2 LEVEL SWITCHES

- A. Liquid-Level Switch (Magnetic Type with Float):
- Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - [W. E. Anderson Division, Dwyer Instruments, Inc.](#); Series L4.
 - <Insert manufacturer's name; product name or designation>**.
 - Description:
 - Mounting Suitable for Application: Horizontal or vertical switch mounting.
 - Float arm with hinge design limits vertical movement to prevent sticking.
 - Replaceable float with threaded connection.
 - Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments (Class I, Groups C and D; Class II, Groups E, F, and G).
 - Performance:
 - Level Actuation and De-Actuation: **0.75-inch (20-mm)** deadband.
 - Body Pressure Limit: **1000 psig ((6895kPa))** for brass body; **2000 psig (13790 kPa)** for Type 316 stainless-steel body.
 - Float Pressure Limit: **150 psig (1034 kPa)**.
 - Temperature Range: **Minus 4 to 275 deg F (Minus 20 to 135 deg C)**.

- e. Electrical Rating: 10 A at 125/250-V ac.
 - f. Switch Type: **[SPDT] [DPDT]** snap switch.
4. Wetted Parts Construction:
- a. Float and Rod: Type 316 stainless steel.
 - b. Body: **[Brass] [Type 316 stainless steel]**.
 - c. Magnetic Keeper: **[Type 430 stainless steel] [Type 316 stainless steel]**.
 - d. Process Connection: **NPS 1-1/2 (DN 40) NPT**.
 - e. Enclosure:
 - 1) Die-cast aluminum alloy.
 - 2) Threaded cover.
 - 3) NEMA 250, Type 4.
 - 4) Electrical Connection: Terminal block.
 - 5) Conduit Connection: **NPS 3/4 (NPS 20) NPT**.
- B. Electrode-Type Liquid-Level Switches:
- 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Proximity Division, Dwyer Instruments, Inc.;** Model DPL110.
 - b. **<Insert manufacturer's name; product name or designation>**.
 - 2. Description:
 - a. Conductivity technology.
 - b. Dual point level settings.
 - c. No moving parts.
 - d. Adjustable sensitivity.
 - 3. Performance:
 - a. Pressure Limit: **30 psig (207 kPa)**.
 - b. Temperature Limit: **212 deg F (100 deg C)**.
 - c. Power Supply: 120-V ac, 50 or 60 Hz.
 - d. Electrical Rating: 5 A at 240-V ac.
 - e. Switch Type: SPDT snap switch.
 - 4. Probes:
 - a. Electrodes: **0.125-inch (6-mm) diameter**.
 - b. Material: Type 316 stainless steel.
 - c. Length: To suit application up to **72 inches (1800 mm)**.
 - d. Process Connection: **NPS 1 (DN 25) NPT**.
 - e. Enclosure:
 - 1) Polypropylene.
 - 2) NEMA 250, Type 6.

3) Electrical Connection: Cable and standard octal socket.

C. RF Admittance-Type Liquid-Level Switches:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Proximity Division, Dwyer Instruments, Inc.;** Series CLS2.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Description:**
 - a. Capacitive technology.
 - b. No moving parts.
 - c. Not affected by sticky, dusty, or clingy materials that coat or build up on probe.
 - d. Immune to external radio frequency (RF) sources.
 - e. Sensitivity: Eight selectable settings.
 - f. Mounting: Horizontal or vertical.
3. **Performance:**
 - a. Pressure Limit: **365 psig** (2517 kPa).
 - b. Ambient Temperature Range: **Minus 40 to 185 deg F** (Minus 40 to 85 deg C).
 - c. Process Temperature Range: **Minus 40 to 250 deg F** (Minus 40 to 121 deg C).
 - d. Universal Power Supply: 12- to 240-V ac and dc.
 - e. Electrical Rating: 8 A at 120- and 240-V ac.
 - f. Switch Type: SPDT snap switch, selectable for normally open or closed operation.
 - g. Response Time: 0.2 seconds.
 - h. Time Delay: Adjustable, zero to 60 seconds.
4. **Probes:**
 - a. Material: Type 316 stainless steel.
 - b. Insulator Material: PVDF.
 - c. Length: To suit application up to **72 inches** (1800 mm).
 - d. Process Connection: **NPS 1** (DN 25) NPT.
 - e. Enclosure:
 - 1) NEMA 250, Type 4X.
 - 2) Electrical Connection: Screw terminals on removable terminal block.
 - 3) Conduit Connection: **NPS 1/2** (DN 15) NPT.

2.3 LEVEL TRANSMITTERS

A. RF Admittance-Type Liquid-Level Sensor and Transmitter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ametek Drexelbrook;** Universal II 508 series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Description:** Complete package with electronic unit, sensing element, connecting cable.
 - a. Continuous level transmitter shall produce an output signal that is proportional to level.
 - b. Measurement shall be free from effects of changes in temperature, density, or acoustic noise in vapor space above level.
 - c. Continuous measurement shall be independent of changes in material density and unaffected by presence of material clinging to sensing element.
 - d. No moving parts and no routine cleaning and recalibration necessary.
 - e. Electronic unit shall be integral to sensing element or mounted remotely up to **100 feet (30 m)** away from sensor.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments (Class I, Groups C and D; Class II, Groups E, F, and G).
3. **Sensor:**
 - a. Material: Teflon-coated **[Type 304] [Type 316]** stainless steel.
 - b. Length: To suit installation.
 - c. Connection: **NPS 3/4 (NPS 20) NPT[or flanged].**
4. **Electronic unit housed in NEMA 250, Type 4X enclosure.**
 - a. **Calibrated Range:** Varies with application. At least **[10] [20] <Insert number>** percent beyond high- and low-level set point and alarm levels.
 - b. **Accuracy:** Within 1 percent of calibrated range.
 - c. Two wire, loop powered.
 - d. **Supply Voltage:** 11.5 to 50-V dc.
 - e. **Maximum Load:** 625 ohms at 24-V dc.
 - f. **Output Signal:** 4 to 20 mA dc.
 - g. **Response Time:** 0.5 to 30 seconds, adjustable.
 - h. **Temperature Range:** **Minus 40 to 165 deg F (Minus 40 to 74 deg C).**
 - i. **Zero and Span Adjustments:** Non-interacting.
 - j. **Visual Indication:** Continuous digital display of level.
 - k. **Field-changeable failsafe condition and phasing in event measurement** requires changes to optimize level reading.
 - l. Free from effects of radio frequency interference.
 - m. Free from harmful effects of static electricity on sensing element with discharges of up to 10 A without damage.
 - n. Adjustable time delay (signal dampening).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement, sway, or a break in attachment when subjected to a <Insert value> force.
- C. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- D. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- E. Mount switches and transmitters not subject to code, state, and federal accessibility requirements within a range of 42 to 72 inches (1.1 to 1.6 m) above the adjacent floor, grade or service catwalk, or platform.
 - 1. Make every effort to mount at 60 inches (1.5 m).
- F. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments.

3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 LEVEL INSTRUMENTS INSTALLATION

- A. Mounting Location: Rough-in instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification on face.

3.6 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.7 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
4. Equipment and procedures used for calibration shall comply with instrument manufacturer's written recommendations.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have an accuracy of at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures in ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Switches: Calibrate switches to make or break contact at setpoints indicated.

E. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.8 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of**

system and equipment Installer] [manufacturer's authorized service representative]. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.9 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate level instrument demonstration video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.17

SECTION 230923.18 - LEAK-DETECTION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following types of leak-detection switches:
 - 1. Point-type, leak-detection switches.
 - 2. Cable-type, leak-detection switches.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.18**.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating control signal, default control signal with loss of power, and electrical power requirements.
 - 2. Product description with complete technical data and product specification sheets.
 - 3. Installation operation and maintenance instructions including factors affecting performance.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: To include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 LEAK-DETECTION SWITCHES

- A. Point-Type, Leak-Detection Switches:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. W. E. Anderson Division, Dwyer Instruments, Inc; Series WD2.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Features: Audible and visual alarm with relay output for remote indication.
3. Alarm activated based on change in resistance.
4. Performance:
 - a. Service: Water.
 - b. Temperature Limits: **32 to 122 deg F** (zero to 50 deg C).
 - c. Switch Type: SPDT relay.
 - d. Electric Connection: Cable attached.
5. Construction: Acrylic, ABS plastic.
6. Field Power: 24-V ac or dc.

- B. Cable-Type, Leak-Detection Switches:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. W. E. Anderson Division, Dwyer Instruments, Inc; Series WD.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Control Module Features:
 - a. Power and alarm LEDs.
 - b. Alarm test switch.
 - c. Continuous tape integrity self check.
3. Performance:
 - a. Service: Water, or other conductive liquid.
 - b. Switch Type: DPDT.
 - c. Electric Connection: Screw terminals.

- d. Conduit Connection: 0.5 inch (13 mm).
4. Construction:
 - a. Control Module Enclosure: Extruded aluminum.
 - b. Tape: Hydrophobic with connector on each end.
 - c. Tape Length: [60 inches ((1500 mm))] [10 feet (3 m)] [15 feet (4.5 m)] [25 feet (7.5 m)]. Field extendable.
 5. Field Power: 24-V ac or 24- to 30-V dc.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 LEAK-DETECTION INSTRUMENT APPLICATION

- A. **<Insert application>: [Leak-detection switches (point type)] [Leak-detection switches (cable type)].**

3.3 INSTALLATION, GENERAL

- A. Properly support instruments, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- B. Fastening Hardware:
 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force, or by oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- C. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required

for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

3.4 CONNECTIONS

- A. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power connections.

3.5 INSTALLATION

- A. Mount switches not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.7 CHECKOUT PROCEDURES

- A. Check installed products before continuity tests and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation for applicable considerations that impact performance.

3.8 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 - 3. Equipment and procedures used for calibration shall meet instrument manufacturer's written recommendations.
 - 4. Provide diagnostic and test equipment for calibration and adjustment.

5. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
6. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
7. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

C. Switches: Calibrate switches to make or break contact at set points indicated.

3.9 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of systems and equipment installer] [manufacturer's authorized service representative]**. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, lubrication, cleaning, and adjusting as required for proper **<Insert equipment>** operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.10 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.18

SECTION 230923.19 - MOISTURE INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes moisture switches, sensors, and transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.19**.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Product description with complete technical data, performance curves, and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: To include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 MOISTURE SWITCHES

- A. Humidistat for Duct Applications:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. **TAC Brand, Schneider Electric United States;** Model HC-201.
b. **<Insert manufacturer's name; product name or designation>.**

2. Description:

- a. Two-position control.
b. Field-adjustable set point.
c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

3. Performance:

- a. Relative Humidity Range: 15 to 95 percent.
b. Relative Humidity Differential: 5 percent.
c. Ambient Temperature: **40 to 135 deg F** (4 to 57 deg C).
d. Voltage: 120-V ac.
e. Current: 7.2 FLA.
f. Switch Type: SPDT snap switch.

4. Construction:

- a. Enclosure: Metal, NEMA 250, Type 1.
b. Electrical Connections: Screw terminals.

- B. Humidistat for Space Applications:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. **TAC Brand, Schneider Electric United States;** Model HC-101.
b. **<Insert manufacturer's name; product name or designation>.**

2. Description:

- a. Two-position control.
 - b. Field-adjustable set point.
 - c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Performance:
- a. Relative Humidity Range: 10 to 90 percent.
 - b. Relative Humidity Differential: 5 percent.
 - c. Ambient Temperature: 40 to 135 deg F (4 to 57 deg C).
 - d. Voltage: 24-V ac.
 - e. Pilot Duty: 60 VA.
 - f. Switch Type: SPDT snap switch.
4. Construction:
- a. Enclosure: Plastic, NEMA 250, Type 1.
 - b. Electrical Connections: Cable, 6 inches (150 mm) long.

2.2 MOISTURE SENSORS AND TRANSMITTERS

A. Sensors and Transmitters with Digital Display:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Vaisala Inc.;** Model HMT100 Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Accuracy including non-linearity, hysteresis, and repeatability: Within 2 percent from zero to 90 percent relative humidity and within 2.5 percent from 90 to 100 percent relative humidity when operating between 60 to 77 deg F (16 to 25 deg C).
 - b. Relative Humidity Range: Zero to 100 percent.
 - c. Factory calibrated and NIST traceable with certificate included.
3. Construction:
 - a. Provide housing with integral sensor for room applications.
 - b. Provide housing with remote sensor probe for ducted applications.
 - 1) Duct Sensor Body: 300 series stainless steel or chrome-plated aluminum, at least 2 inches (50 mm) long for duct-mounted applications.
 - 2) Provide sensor with cable for field installation in conduit.
 - 3) For duct-mounted applications, thread the sensor assembly for connection to a threaded mounting flange.

- c. Provide general-purpose humidity sensor unless application requires special requirements. Provide sensor with sintered stainless-steel filter for duct applications.
 - d. Housing shall be ABS/PC plastic or powder-coated aluminum.
 - e. Housing Classification: NEMA 250, Type 4 or 4X.
 - f. Provide housing with wall-mounting plate.
4. Output Signal: 2-wire, 4- to 20-mA output signal with a drive capacity of at least 500 ohms at 24-V dc.
 5. Provide unit with a digital display of relative humidity in percent.

B. Sensor and Transmitter without Display:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Vaisala Inc.;** HMW 60 Series (for space applications) and HMD 60 Series (for duct and equipment applications).
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Accuracy including non-linearity, hysteresis, and repeatability: Within 2 percent from zero to 90 percent relative humidity and within 3 percent from 90 to 95 percent relative humidity when operating at **68 deg F (20 deg C)**.
 - b. Relative Humidity Range:
 - 1) Duct: Zero to 100 percent.
 - 2) Space: Zero to 95 percent relative.
 - c. Factory calibrated and NIST traceable with certificate included.
3. Construction for Space Applications:
 - a. Housing with integral sensor.
 - b. Housing shall be ABS plastic or powder-coated aluminum.
 - c. Enclosure: NEMA 250, Type 4.
 - d. Provide housing with a wall-mounting plate.
4. Construction for Duct and Equipment Applications:
 - a. Housing with integral sensor.
 - b. Duct Sensor Body: 300 series stainless steel.
 - c. Provide sensor with sintered stainless-steel filter for duct applications.
 - d. Housing shall be cast aluminum.
 - e. Enclosure: NEMA 250, Type 4.
5. Output Signal: Two-wire, 4- to 20-mA output signal with drive capacity of at least 500 ohms at 24-V dc.

C. Sensor and Transmitter without Display:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **MAMAC Systems, Inc.;** Models HU-224 (for space applications) and HU-225 (for duct applications).
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Relative Humidity Range: Zero to 100 percent.
 - b. Accuracy: Within **[2] [or] [3]** percent.
 - c. Operating Temperatures: **Minus 30 to 130 deg F** (Minus 1 to 54 deg C).
 - d. Hysteresis: Within 1 percent.
3. Construction:
 - a. Duct-type sensor for duct-mounted applications. Integral-type sensor for room or space applications.
 - b. Sensor Body: 300 series stainless steel, **6 inches (150 mm)** long for duct-mounted applications.
 - c. For outdoor **[and duct]** applications, install circuitry in a NEMA 250, Type 4 or 4X enclosure.
4. Output Signal:
 - a. Two-wire, 4- to 20-mA output signal with a drive capacity of at least 600 ohms at 24-V dc.
 - b. Non-interacting zero and span adjustments.

D. Combination Humidity and Temperature Sensor and Transmitter with Display:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Vaisala Inc.;** Model HMT330 Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Description:
 - a. Factory package consisting of humidity and temperature sensor, digital display, keypad user interface, installation hardware, interconnecting sensor cabling, installation instructions, and operating manual.
 - b. Each transmitter shall be individually calibrated and provided with NIST traceable calibration certifications.
 - c. Provide a service cable for connecting to a notebook computer and Microsoft Windows compatible software.

3. Display:
 - a. Alphanumeric display of the following on the face of the enclosure:
 - 1) Percent relative humidity.
 - 2) Absolute humidity.
 - 3) Mixing ratio.
 - 4) Dry-bulb temperature.
 - 5) Wet-bulb temperature.
 - 6) Dew point temperature.
 - 7) Enthalpy.
 - b. Visual display of measurement trends, and minimum and maximum values over a one-year period.
4. Electronics Enclosure:
 - a. Integral to sensors for wall- (room-)mounted applications and remote from temperature and humidity sensors for duct and equipment applications.
 - b. NEMA 250, Type 4 or 4X.
 - c. Labeled terminal strip for field wiring connections.
 - d. **1/2-inch** ((16-mm))trade size threaded conduit connection.
5. Programming:
 - a. Transmitter parameters shall be field programmable through keypad on the face of the enclosure.
 - b. Programmed parameters shall be stored in nonvolatile EEPROM.
6. Output Signals:
 - a. Three Analog Outputs: 4 to 20 mA or zero to 10-V dc for each output. [**Option to use a serial communication interface.**]
7. Temperature Sensor:
 - a. Temperature range matched to application, but not less than **minus 40 to 140 deg F** (minus 40 to 60 deg C).
 - b. Within **0.5 deg F** (0.3 deg C) accuracy over the temperature range of **50 to 100 deg F** (10 to 38 deg C) and within **1 deg F** (0.6 deg C) over the remainder of the range.
 - c. Provide duct installation kit for duct applications.
8. Humidity Sensor:
 - a. Relative Humidity Measurement Range: Zero to 100 percent.
 - b. Response time in still air within 40 seconds.
 - c. Accuracy including non-linearity, hysteresis, and repeatability:
 - 1) For Temperature Between **59 and 77 Deg F** (15 to 25 Deg C) and Relative Humidity between Zero and 90 Percent: Within 1 percent.

- 2) For Temperature between **59 and 77 Deg F** (15 to 25 Deg C) and Relative Humidity between 90 and 100 Percent: Within 1.7 percent.
 - 3) For Temperature between **Minus 4 and 104 Deg F** (Minus 20 to 40 Deg C): Within 1 percent plus 0.008 times relative humidity reading.
 - 4) For Temperature between **Minus 40 and 356 Deg F** (Minus 40 to 180 Deg C): Within 1.5 percent plus 0.015 times the relative humidity reading.
 - d. Sintered, stainless-steel filter, protecting sensor.
 - e. Provide duct installation kit for duct applications.
9. Power Supply:
- a. Field Power: 120-V ac, 60 Hz unless otherwise required by the application.
 - b. Internal Power: As required by transmitter.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 MOISTURE INSTRUMENT APPLICATIONS

- A. **<Insert application>: [Sensor and transmitter with digital display] [Sensor and transmitter without display] [Combination humidity and temperature sensor and transmitter with display].**

3.3 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support instruments, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- C. Fastening Hardware:

1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- D. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- E. Corrosive Environments:
1. Use products that are suitable for environment to which they are subjected.
 2. If possible, avoid or limit use of materials in corrosive environments.
 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 MOISTURE INSTRUMENTS INSTALLATION

- A. Mounting Location: Rough-in instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.
- B. Mounting Height:
 1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
 2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code, state, and Federal accessibility

requirements within a range of 42 to 72 inches ((1.1 to 1.6 m))above the adjacent floor, grade, or service catwalk or platform.

- a. Make every effort to mount at 60 inches (1.5 m).

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification[**on face of ceiling directly below instruments concealed above ceilings**].

3.7 CHECKOUT PROCEDURES

- A. Check installed products before continuity tests and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.8 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
 4. Equipment and procedures used for calibration shall meet instrument manufacturer's written instructions.
 5. Provide diagnostic and test equipment for calibration and adjustment.
 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
 9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of

specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistance source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.9 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of systems and equipment Installer] [manufacturer's authorized service representative]**. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, lubrication, cleaning, and adjusting as required for proper **<Insert equipment>** operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.10 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without

paying royalties.

END OF SECTION 230923.19

SECTION 230923.21 - MOTION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. PIR motion sensors.
 - 2. Ultrasonic motion sensors.
 - 3. Dual-technology motion sensors.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.21**.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Include product description with complete technical data, performance curves, and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Product installation location shown in relationship to visual range and obstructions.
 2. Wall- and ceiling-mounted instruments located in finished space showing relationship to other installed devices.
- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For motion instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 INDOOR MOTION SENSORS

- A. **Manufacturers:** Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
- B. **Basis-of-Design Product:** Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
1. [Bryant Electric; a Hubbell Incorporated company.](#)
 2. [Cooper Industries, Inc.](#)
 3. [Hubbell Building Automation, Inc.; a Hubbell Incorporated company.](#)
 4. [Leviton Manufacturing Co., Inc.](#)
 5. [Lightolier Controls; a Philips group brand.](#)
 6. [Lithonia Lighting; Acuity Brands Lighting, Inc.](#)
 7. [Lutron Electronics Co., Inc.](#)
 8. [NSi Industries, LLC; TORK Products.](#)
 9. [RAB Lighting.](#)
 10. [Sensor Switch, Inc.; an Acuity Brands company.](#)
 11. [Square D; a brand of Schneider Electric.](#)
 12. [WattStopper.](#)
 13. <Insert manufacturer's name>.
- C. Description: Wall- or ceiling-mounted, solid-state units with a separate relay unit.

1. Operation: Unless otherwise indicated, turn on when covered area is occupied and off when unoccupied; with a time delay for turning off, adjustable over a minimum range of 1 to 15 minutes.
 2. Sensor Output: Contacts rated to operate the connected relay, complying with UL 773A. Sensor shall be powered from the relay unit.
 3. Relay Unit: Dry contacts rated for 20-A load at 120- and 277-V ac. Power supply to sensor shall be 24-V dc, 150 mA, Class 2 power source as defined by NFPA 70.
 4. Mounting:
 - a. Sensor: Suitable for mounting in any position on a standard outlet box.
 - b. Relay: Externally mounted through a 1/2-inch (13-mm) knock out in a standard electrical enclosure.
 - c. Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
 5. Indicator: Digital display, to show when motion is being detected during testing and normal operation of the sensor.
 6. Bypass Switch: Override the on function in case of sensor failure.
- D. PIR Type: Ceiling mounting; detect occupancy by sensing a combination of heat and movement in coverage area.
1. Detector Sensitivity: Detect occurrences of 6-inch- (150-mm-) minimum movement of any portion of a human body that presents a target of not less than 36 sq. in. (232 sq. cm).
 2. Detection Coverage (Room): Detect occupancy anywhere in a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 3. Detection Coverage (Corridor): Detect occupancy within 90 feet (27.4 m) when mounted on a 10-foot- (3-m-) high ceiling.
- E. Ultrasonic Type: Ceiling mounting; detect occupancy by sensing a change in pattern of reflected ultrasonic energy in coverage area.
1. Detector Sensitivity: Detect a person of average size and weight moving not less than 12 inches (305 mm) in either a horizontal or a vertical manner at an approximate speed of 12 inches/s (305 mm/s).
 2. Detection Coverage (Small Room): Detect occupancy anywhere within a circular area of 600 sq. ft. (56 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 4. Detection Coverage (Large Room): Detect occupancy anywhere within a circular area of 2000 sq. ft. (186 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 5. Detection Coverage (Corridor): Detect occupancy anywhere within 90 feet (27.4 m) when mounted on a 10-foot- (3-m-) high ceiling in a corridor not wider than 14 feet (4.3 m).

- F. Dual-Technology Type: Ceiling mounting; detect occupancy by using a combination of PIR and ultrasonic detection methods in coverage area. A particular technology or combination of technologies that controls on-off functions shall be field selectable by operating controls on unit.
1. Sensitivity Adjustment: Separate for each sensing technology.
 2. Detector Sensitivity: Detect occurrences of **6-inch-** (150-mm-) minimum movement of any portion of a human body that presents a target of not less than **36 sq. in.** (232 sq. cm), and detect a person of average size and weight moving not less than **12 inches** (305 mm) in either a horizontal or a vertical manner at an approximate speed of **12 inches/s** (305 mm/s).
 3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of **1000 sq. ft.** (93 sq. m) when mounted on a **96-inch-** (2440-mm-) high ceiling. Apply occupancy detectors where indicated.

2.2 SWITCHBOX-MOUNTED MOTION SENSORS

- A. **Manufacturers:** Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
- B. **Basis-of-Design Product:** Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
1. [Bryant Electric; a Hubbell Incorporated company.](#)
 2. [Cooper Industries, Inc.](#)
 3. [Hubbell Building Automation, Inc.; a Hubbell Incorporated company.](#)
 4. [Leviton Manufacturing Co., Inc.](#)
 5. [Lightolier Controls; a Philips Group brand.](#)
 6. [Lithonia Lighting; Acuity Brands Lighting, Inc.](#)
 7. [Lutron Electronics Co., Inc.](#)
 8. [NSi Industries, LLC; TORK Products.](#)
 9. [RAB Lighting.](#)
 10. [Sensor Switch, Inc.; an Acuity Brands company.](#)
 11. [Square D; a brand of Schneider Electric.](#)
 12. [WattStopper.](#)
 13. **<Insert manufacturer's name>.**
- C. **General Requirements for Sensors:** Automatic-wall-switch occupancy sensor, suitable for mounting in a single gang switchbox.
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Operating Ambient Conditions: Dry interior conditions, **32 to 120 deg F** (zero to 49 deg C).
 3. Switch Rating: Not less than 800-VA fluorescent at 120 V, 1200-VA fluorescent at 277 V, and 800-W incandescent.

D. Wall-Switch Sensor Tag WS1:

1. Standard Range: 180-degree field of view, field adjustable from 180 to 40 degrees; with a minimum coverage area of [900 sq. ft. (84 sq. m)] [2100 sq. ft (196 sq. m)].
2. Sensing Technology: [PIR] [Dual technology - PIR and ultrasonic].
3. Switch Type: [SP.] [SP, dual circuit.] [SP, manual "on," automatic "off."] [SP, field selectable automatic "on," or manual "on" automatic "off."]
4. Voltage: [Match the circuit voltage] [120 V] [277 V] [Dual voltage, 120 and 277 V]; [passive-infrared] [dual-technology] type.
5. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc (108 to 1600 lux). The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.
6. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
7. Concealed "off" time-delay selector at 30 seconds, and 5, 10, and 20 minutes.
8. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and helps eliminate false "off" switching.

E. Wall-Switch Sensor Tag WS2:

1. Standard Range: 210-degree field of view, with a minimum coverage area of 900 sq. ft. (84 sq. m).
2. Sensing Technology: PIR.
3. Switch Type: [SP.] [SP, dual circuit.] [SP, manual "on," automatic "off."] [SP, field selectable automatic "on," or manual "on" automatic "off."]
4. Voltage: [Match the circuit voltage] [120 V] [277 V] [Dual voltage, 120 and 277 V]; [passive-infrared] [dual-technology] type.
5. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc (108 to 1600 lux). The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.
6. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
7. Concealed "off" time-delay selector at 30 seconds, and 5, 10, and 20 minutes.
8. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and helps eliminate false "off" switching.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SENSOR INSTALLATION

- A. Coordinate layout and installation of ceiling-mounted devices with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, smoke detectors, fire-suppression systems, and partition assemblies.
- B. Coordinate layout and installation of wall-mounted devices with other wall-mounted devices. Align centerline with adjacent devices. Align centerline with devices above.
- C. Install and aim sensors in locations to achieve not less than 90 percent coverage of areas indicated. Do not exceed coverage limits specified in manufacturer's written instructions.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to evaluate lighting control devices and perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Operational Test: After installing time switches and sensors, and after electrical circuitry has been energized, start units to confirm proper unit operation.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning

controls and equipment.

- D. Motion instruments will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting sensors to suit actual occupied conditions. Provide up to [two] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.
 - 1. Verify operation at outer limits of detector range. Set time delay to suit Owner's operations.

3.7 DEMONSTRATION

- A. Coordinate demonstration of products specified in this Section with demonstration requirements for direct-digital control systems specified in Section 230923 "Direct-Digital Control System for HVAC."
- B. [Engage a factory-authorized service representative to train] [Train] Owner's maintenance personnel to adjust, operate, and maintain lighting control devices.

END OF SECTION 230923.21

SECTION 230923.22 - POSITION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes position limit switches for use in direct-digital control systems for HVAC.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.22**.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include operating characteristics, electrical characteristics, and furnished accessories indicating default control signal with loss of power and electrical power requirements.
 - 2. Include product description with complete technical data and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring.

PART 2 - PRODUCTS

2.1 POSITION LIMIT SWITCHES

A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. **Omron;** Model D4A.
2. **<Insert manufacturer's name; product name or designation>.**

B. Description: Select type of actuating head (plunger, roller lever, or rod) to suit application.

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Performance:

1. Life expectancy: Not less than 30 million mechanical operations and 750,000 electrical operations.
2. Operating Frequency: 300 mechanical operations per minute and 30 electrical operations per minute.
3. Voltage: 125-, 250-, 480-, and 600-V ac or 8-, 12-, 14-, 24-, 30-, 48-, 125-, and 250-V dc, as required by application.
4. Current Rating: As required by application.
5. Temperature Rise: 50 deg C.
6. Ambient Temperature: **14 to 175 deg F** (Minus 10 to 79 deg C).
7. Ambient Relative Humidity: 35 to 95 percent.

D. Construction:

1. NEMA 250, Type 4X enclosure.
2. Switch Type: SPDT or DPDT, as required by application.
3. Status indicator integral to switch. Field switchable to light when contacts are actuated and operating, or contacts are free and not operating.
4. Electrical Connection: Screw or plug-in terminals.
5. Conduit Connection: **NPS 1/2** ((DN 50)).

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for instruments installed in duct systems to verify actual locations

of connections before installation.

- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support instruments, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement, sway, or a break in attachment when subjected to a <Insert value> force.
- C. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not to overstress threads by using excessive force or oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- D. Install products in locations that are accessible and that permit maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- E. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.

- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 POSITION INSTRUMENTS INSTALLATION

- A. Mounting Location:
 - 1. Rough-in instrument-mounting locations before setting instruments and routing, cable, wiring, and conduit to final location.
 - 2. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
- B. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated, using neoprene gaskets or grommets.

3.5 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact.
- B. Switches: Calibrate switches to make or break contact at set points indicated.

END OF SECTION 230923.22

SECTION 230923.23 - PRESSURE INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Air-pressure sensors.
2. Air-pressure switches.
3. Air-pressure transmitters.
4. Liquid-pressure switches.
5. Liquid-pressure transmitters.

- B. Related Requirements:

1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.23**.

1.3 DEFINITIONS

- A. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a control, asset management, safety, or other system using any control platform.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over

- range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
 4. Installation instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and [**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Product installation location shown in relationship to room, duct, pipe, and equipment.
2. Wall-mounted instruments located in finished space, showing relationship to light switches, fire alarm devices, and other installed devices.
3. Size and location of wall access panels for instruments installed behind walls.
4. Size and location of ceiling access panels for instruments installed in accessible ceilings.

B. Product Certificates: For each product requiring a certificate.

C. Product Test Reports: For each product requiring test performed by [**manufacturer and witnessed by a qualified testing agency**] [**a qualified testing agency**].

D. Source quality-control reports.

E. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Environmental Conditions:

1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instrument alone cannot comply with requirement, install instrument in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[**and cooled**], filtered, and ventilated as required by instrument and application.
2. Instruments and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Instrument-installed location shall dictate following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: **[Type 2] [Type 3] [Type 12] <Insert type>**.
 - b. Outdoors, Unprotected: **[Type 4] [Type 4X] <Insert type>**.
 - c. Indoors, Heated with Filtered Ventilation: **[Type 1] [Type 2] <Insert type>**.
 - d. Indoors, Heated with Nonfiltered Ventilation: **[Type 2] [Type 12] <Insert type>**.
 - e. Indoors, Heated and Air-Conditioned: **[Type 1] <Insert type>**.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: **[Type 12] [Type 4] [Type 4X] <Insert type>**.
 - 2) Air-Moving Equipment Rooms: **[Type 1] [Type 2] [Type 12] <Insert type>**.
 - g. Localized Areas Exposed to Washdown: **[Type 4] [Type 4X] <Insert type>**.
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: **[Type 2] [Type 3] [Type 12] <Insert type>**.
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: **[Type 4] [Type 4X] <Insert type>**.
 - j. Hazardous Locations: Explosion-proof rating for condition.
 - k. **<Insert location and enclosure requirements>**.

2.2 AIR-PRESSURE SENSORS

A. Duct Insertion Static Pressure Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Model A 301 Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Insertion length shall be at **[4 inches (100 mm)] [6 inches (150 mm)] [8 inches (200 mm)] [12 inches (300 mm)]**.
 3. Sensor with four radial holes of **0.04-inch (1-mm)** diameter.
 4. **[Brass] [or] [stainless-steel]** construction.
 5. Sensor with threaded end support, sealing washers and nuts.
 6. Connection: **NPS 1/4 (DN 6)** compression fitting.
 7. Suitable for flat oval, rectangular, and round duct configurations.
- B. Duct Insertion Static Pressure Sensor:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **MAMAC Systems, Inc.;** Model A-520.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Sensor probe with two opposing orifices designed to reduce error-associated air velocity.
 3. Sensor insertion length shall be **[4 inches (100 mm)] [or] [8 inches (200 mm)]**.
 4. Construct sensor of **[6061-T6 aluminum alloy] [or] [Type 304 stainless steel]**.
 5. Connection: Threaded, **NPS 1/8 (DN 6)** swivel fitting for connection to copper tubing or **NPS 1/4 (DN 10)** barbed fitting for connection to polyethylene tubing.
 6. Sensor probe attached to a mounting flange with neoprene gasket and two holes for fasteners.
 7. Mounting flange shall suitable for flat oval, rectangular, and round duct configurations.
 8. Pressure Rating: **10 psig (69 kPa)**.
- C. Duct Traverse Static Pressure Sensor:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Air Monitor Corporation;** STAT probe.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Sensor shall traverse the duct cross section and have at least one pickup point every **6 inches ((150mm))** along length of sensor.
 3. Construct sensor of 18-gage Type T6063-T5 extruded and anodized aluminum.
 4. Sensor supported with threaded rod, sealing washer, and nut at one end and a mounting plate with gasket at other end.

5. Mounting plate with threaded, **NPS 3/8 (DN 12)** compression fitting for connection to tubing.
6. Accuracy within 1 percent of actual operating static pressure.
7. Dual offset static sensor design shall provide accurate sensing of duct static pressure in the presence of turbulent and rotational airflows with a maximum 30 degree yaw and pitch.
8. Suitable for velocities of **100 to 10000 fpm (0.51 to 51 m/s)** and temperatures of up to **200 deg F (93 deg C)**.
9. Sensor air resistance shall be less than 0.1 times the velocity pressure at probe-operating velocity.
10. Suitable for flat oval, rectangular, and round duct configurations.

D. Outdoor Static Pressure Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Model A306.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Provides average outdoor pressure signal.
3. Sensor with no moving parts.
4. Kit includes sensor, vinyl tubing mounting hardware.

E. Outdoor Static Pressure Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Model A420.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Provides average outdoor pressure signal.
3. Sensor with no moving parts.
4. NEMA 250, Type 4X enclosure.
5. Pressure Connection: Brass barbed fitting for **NPS 1/4 ((DN 10))** tubing.
6. Conduit fitting around pressure fitting for sensor support and protection to pressure connection.

F. Outdoor Static Pressure Sensor:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Air Monitor Corporation;** SOAP.
 - b. **<Insert manufacturer's name; product name or designation>.**

2. Sensor with no moving parts.
 3. Operation not affected and impaired by rain and snow.
 4. Sensing plates constructed of 0.1406-inch (3.6-mm) Type 316 stainless steel.
 5. Accuracy within:
 - a. 1 percent of the actual outdoor atmospheric pressure when subjected to varying horizontal radial wind velocities up to 40 mph.
 - b. 2 percent of the actual outdoor atmospheric pressure while subjected to varying radial wind velocities up to 40 mph with approach angles up to 30 degrees to horizontal.
 - c. 3 percent of the actual outdoor atmospheric pressure while subjected to varying radial wind velocities up to 40 mph with approach angles up to 60 degrees to horizontal.
 - d. Threaded, NPS 2 (DN 50) connection.
- G. Space Static Pressure Sensor for Wall Mounting:
1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Dwyer Instruments, Inc.; Model A420.
 - b. <Insert manufacturer's name; product name or designation>.
 2. 100-micron filter mounted in stainless-steel wall plate senses static pressure.
 3. Wall plate provided with gasket and screws, and sized to fit standard single-gang electrical box.
 4. Back of sensor plate fitted with brass barbed fitting for tubing connection.
- H. Space Static Pressure Sensor for Wall Mounting:
1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. MAMAC Systems, Inc.; Model A523.
 - b. <Insert manufacturer's name; product name or designation>.
 2. White ABS plastic wall plate with integral sensing port to sense static pressure.
 3. Wall plate provided with matching colored screws and sized to fit standard single-gang electrical box.
 4. Back of sensor plate fitted with brass union fitting for tubing connection.
 5. Pressure rating: 10 psig (69kPa).
- I. Space Static Pressure Sensor for Wall Mounting:
1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

- a. Air Monitor Corporation; Model SAP/B.
 - b. <Insert manufacturer's name; product name or designation>.
2. **[Aluminum] [Stainless-steel]** wall plate with perforated center arranged to sense space static pressure. Exposed surfaces are provided with brush finish.
 3. Wall plate provided with screws and sized to fit standard single-gang electrical box.
 4. Back of sensor plate fitted with multiple sensing ports, pressure impulse suppression chamber, airflow shielding, and **0.125-inch (3-mm)** fitting for tubing connection.
 5. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of **1000 fpm (5.1 m/s)** from a 360-degree radial source.
- J. Space Static Pressure Sensor for Recessed Ceiling Mounting:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. Air Monitor Corporation; Model SAP/R.
 - b. <Insert manufacturer's name; product name or designation>.
 2. **[Aluminum] [Stainless-steel]** round plate with perforated center arranged to sense space static pressure. Exposed surfaces provided with brush finish.
 3. Sensor intended for flush mount on face of ceiling with pressure chamber recessed in ceiling plenum.
 4. Back of sensor plate fitted with multiple sensing ports, pressure impulse suppression chamber, airflow shielding, and **0.125-inch (3-mm)** fitting for concealed tubing connection.
 5. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of **1000 fpm (5.1 m/s)** from a 360-degree radial source.
- K. Space Static Pressure Sensor for Exposed or Suspended Mounting:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. Air Monitor Corporation; **[Model SAP/S for surface mounted] [Model SAP/P for suspended mount]**.
 - b. <Insert manufacturer's name; product name or designation>.
 2. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of **1000 fpm (5.1 m/s)** from a 360-degree radial source.
 3. **[Aluminum] [Stainless steel]** with perforations arranged to sense space static pressure. Exposed surfaces provided with brush finish.
 4. Sensor fitted with multiple sensing ports, pressure impulse suppression chamber,

- and airflow shielding.
- 5. Surface-mounted sensor provided with solid mounting plate intended for mount to ceiling with pressure chamber exposed to view.
- 6. Surface-mounted sensor with **0.125-inch (3-mm)** fitting for exposed tubing connection.
- 7. Suspended sensor intended for pendent mount with pressure chamber exposed to view.
- 8. Suspended sensor with **NPS 1/2 (DN 15)** fitting for exposed pipe or tubing connection.

2.3 AIR-PRESSURE SWITCHES

A. Air-Pressure Differential Switch:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series 1900.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Diaphragm operated to actuate an SPDT snap switch.
 - a. Fan safety shutdown applications: Switch with manual reset.
3. Electrical Connections: Three-screw configuration, including one screw for common operation and two screws for field-selectable normally open or closed operation.
4. Enclosure Conduit Connection: Knock out or threaded connection.
5. User Interface: Screw-type set-point adjustment located inside removable enclosure cover.
6. High and Low Process Connections: Threaded, **NPS 1/8 (DN 6)**.
7. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
8. Operating Data:
 - a. Electrical Rating: 15 A at 120- to 480-V ac.
 - b. Pressure Limits:
 - 1) Continuous: **45 inches wg (11.2 kPa)**.
 - 2) Surge: **10 psig (68.9 kPa)**.
 - c. Temperature Limits: **Minus 30 to 180 deg F (Minus 34 to 82 deg C)**.
 - d. Operating Range: Approximately 2 times set point.
 - e. Repeatability: Within 3 percent.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency,

and marked for intended location and application.

B. Air-Pressure Differential Switch with Set-Point Indicator:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series 1630.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Diaphragm operated to actuate an SPDT snap switch.
3. Electrical Connections: Three-screw configuration, including one screw for common operation and two screws for field-selectable normally open or closed operation.
4. Enclosure Conduit Connection: Knock out or threaded connection.
5. User Interface: Screw-type set-point adjustment with enclosed set-point indicator and scale.
6. High and Low Process Connections: Threaded, **NPS 1/8 (DN 6)**.
7. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
8. Operating Data:
 - a. Electrical Rating: 15 A at 120- to 480-V ac.
 - b. Pressure Limits:
 - 1) Continuous: **10 psig (69 kPa)**.
 - 2) Surge: **25 psig (172 kPa)**.
 - c. Temperature Limits: **Minus 30 to 110 deg F (Minus 34 to 43 deg C)**.
 - d. Operating Range: Approximately 2 times set point.
 - e. Repeatability: Within 1 percent.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Air-Pressure Differential Switch with Dual Scale Adjustable Set Point:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series ADPS.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Diaphragm operated to actuate an SPDT snap switch.
3. Electrical Connections: Push-on screw terminals.
4. Enclosure Conduit Connection: Knock out or threaded connection.

5. User Interface: Dual scale set-point adjustment knob located inside removable enclosure cover.
 6. High and Low Process Connections: Slip-on tubing connections.
 7. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 13.
 8. Operating Data:
 - a. Electrical Rating: 1.5 A at 250-V ac.
 - b. Pressure Limits: 40 inches wg (10 kPa)
 - c. Temperature Limits: Minus 4 to 185 deg F (Minus 20 to 85 deg C).
 - d. Operating Range: Approximately 2 times set point.
- D. Air-Pressure Differential Indicating Switch:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Photohelic Series 3000.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Combination gage with low- and high-limit switches.
 3. Nominal 4-inch- (100-mm-) diameter analog indication with white dial face, graduated black markings, pointer to indicate measured value, and a separate adjustable pointer for each switch set point.
 4. Switch zero and set-point **[tamperproof]** adjustment screws or knobs on the dial face.
 5. Each switch used as a safety limit shall have a manual reset button local to switch.
 6. Switch Type: Each set point shall have two Form C relays, DPDT.
 7. Electrical Connections: Screw terminals.
 8. Enclosure Conduit Connection: NPS 3/4 (DN 20) threaded connection.
 9. High and Low Process Connections: Threaded, NPS 1/8 (DN 6).
 10. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
 11. Operating Data:
 - a. Electrical Rating: 10 A at 120- to 240-V ac.
 - b. Pressure Limits: 25 psig (172 kPa).
 - c. Temperature Limits: 20 to 120 deg F (Minus 7 to 49 deg C).
 - d. Operating Range: Approximately twice normal operating range unless otherwise required for application.
 - e. Accuracy:

- 1) 4 percent for ranges through 0.5 in. wg (125 Pa).
 - 2) 2 percent for ranges 1 in. wg (250 Pa) and greater.
- f. Repeatability: Within 1 percent of full scale.
 - g. Switch Deadband: One pointer width and within 1 percent of full scale for each switch set point.
 - h. Power Supply: [24] [or] [120]-V ac, 50/60 Hz.
 - i. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.4 AIR-PRESSURE TRANSMITTERS

A. Air-Pressure Differential Transmitter:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Setra Systems, Inc.; Model 267.
 - b. <Insert manufacturer's name; product name or designation>.
2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy: Within [1] [0.5] [0.4] [0.25] percent of the full-scale range.
 - c. Hysteresis: Within 0.10 percent of full scale.
 - d. Repeatability: Within 0.05 percent of full scale.
 - e. Stability: Within 1 percent of span per year.
 - f. Overpressure: 10 psig (69 kPa).
 - g. Temperature Limits: Zero to 150 deg F (Minus 18 to 66 deg C).
 - h. Compensate Temperature Limits: 40 to 150 deg F (4 to 66 deg C).
 - i. Thermal Effects: 0.033 percent of full scale per degree F.
 - j. Shock and vibration shall not harm the transmitter.
3. Output Signals:
 - a. Analog Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 800-ohm load.
 - b. Analog Voltage Signal:
 - 1) Three wire, zero to [5] [10] V.
 - 2) Minimum Load Resistance: 1000 ohms.
4. Display: Four-digit digital display with minimum 0.4-inch- (10-mm-) high numeric characters.
5. Operator Interface: Zero and span adjustments located behind cover.
6. Construction:

- a. Plastic casing with removable plastic cover.
- b. Threaded, **NPS 1/4 (DN 10)** swivel fittings for connection to copper tubing or **NPS 3/16 (DN 7)** barbed fittings for connection to polyethylene tubing. Fittings on bottom of instrument case.
- c. Screw terminal block for wire connections.
- d. Vertical plane mounting.
- e. NEMA 250, Type 4.
- f. Provide mounting bracket suitable for installation.

B. Air Pressure Differential Transmitter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Ashcroft Inc.;** Model XLDP.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy: Within **[0.25] [0.5]** percent of the span at reference temperature of **70 deg F (21 deg C)**.
 - c. Hysteresis: Within 0.02 percent of the span.
 - d. Repeatability: Within 0.05 percent of the calibrated span.
 - e. Stability: Within 0.25 percent of span per year.
 - f. Overpressure: **15 psig (103 kPa)**.
 - g. Temperature Limits: **Minus 20 to 160 deg F (Minus 29 to 71 deg C)**.
 - h. Compensate Temperature Limits: **35 to 135 deg F (2 to 57 deg C)**.
 - i. Thermal Effects: 0.015 percent of full scale per degree F.
 - j. Warm-up Time: Within 5 seconds.
 - k. Response Time: **[5 ms] [250 ms] [One second]**.
 - l. Shock and vibration shall not harm the transmitter.
3. Output Signals:
 - a. Analog Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Analog Voltage Signal:
 - 1) Three wire, zero to **[5] [6] V**.
 - 2) Minimum Load Resistance: 1000 ohms.
4. Operator Interface:
 - a. Zero and span adjustments within 10 percent of full span.
 - b. Potentiometer adjustments located on face of transmitter.

5. Construction:

- a. Type 300 stainless-steel enclosure.
- b. Swivel fittings for connection to copper tubing or barbed fittings for connection to polyethylene tubing. Fittings on front of instrument enclosure.
- c. Screw terminal block for wire connections.
- d. Vertical plane mounting.
- e. NEMA 250, Type 2.
- f. Mounting Bracket: Appropriate for installation.
- g. Reverse wiring protected.
- h. Calibrate to NIST-traceable standards and provide each transmitter with a certificate of calibration.

C. Air-Pressure Differential Transmitters for Hazardous Environments:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. **Ashcroft Inc.;** Model iXLDP.
- b. **<Insert manufacturer's name; product name or designation>.**

2. FM Approved for hazardous environments. Intrinsically safe for Classes I, II, and III; Divisions 1 and 2; Groups A through H.

3. Performance:

- a. Range: Approximately 2 times set point.
- b. Accuracy: Within **[0.25] [0.5]** percent of the span at reference temperature of 70 degrees F.
- c. Hysteresis: Within 0.02 percent of the span.
- d. Repeatability: Within 0.05 percent of the calibrated span.
- e. Stability: Within 0.25 percent of span per year.
- f. Overpressure: **20 psig (138 kPa).**
- g. Temperature Limits: **Minus 20 to 185 deg F (Minus 29 to 85 deg C).**
- h. Compensate Temperature Limits: **Zero to 160 deg F (Minus 18 to 71 deg C).**
- i. Thermal Effects: 0.01 percent of full scale per degree F.
- j. Warm-up Time: Within 5 seconds.
- k. Response Time: **[8 ms] [250 ms].**
- l. Shock and vibration shall not harm the transmitter.

4. Output Signals:

a. Analog Current Signal:

- 1) Two-wire, 4- to 20-mA dc current source.
- 2) Signal capable of operating into 1000-ohm load.

b. Analog Voltage Signal:

- 1) Three wire, zero to **[5] [6]** V.

- 2) Minimum Load Resistance: 1000 ohms.
 5. Operator Interface:
 - a. Zero and span adjustments within 10 percent of full span.
 - b. Potentiometer adjustments located on face of transmitter.
 6. Construction:
 - a. Type 300 stainless-steel enclosure.
 - b. Swivel fittings for connection to tubing. Fittings on bottom of instrument enclosure.
 - c. Two **1/2-inch (16-mm)** trade size conduit connections isolated from electronics.
 - d. Screw terminal block for wire connections.
 - e. Vertical plane mounting.
 - f. NEMA 250, Type 4X.
 - g. Mounting Bracket: Appropriate for installation.
 7. Reverse wiring protected.
 8. Calibrate to NIST-traceable standards and provide each transmitter with a certificate of calibration.
- D. Air-Pressure Differential Indicating Transmitter:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series DM-2000.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy Including Hysteresis and Repeatability: Within 1 percent of full scale at **77 deg F (25 deg C)**.
 - c. Stability: Within 1 percent of full scale per year.
 - d. Overpressure: **10 psig (69 kPa)**.
 - e. Temperature Limits: **20 to 120 deg F (Minus 7 to 49 deg C)**.
 - f. Thermal Effects: 0.055 percent of full scale per degree F.
 3. Display: Four-digit digital display with minimum **0.4-inch- ((10-mm-))** high numeric characters.
 4. Operator Interface:
 - a. Zero and span adjustments.
 - b. Selectable engineering units.
 5. Analog Output Current Signal:

- a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 1200-ohm load.
 6. Construction:
 - a. Plastic casing with clear plastic cover.
 - b. Integral fittings for plastic tubing connections on side of instrument case for high- and low-pressure connections.
 - c. Terminal block for wire connections.
 - d. Vertical plane mounting.
 - e. NEMA 250, Type 1.
 - f. Nominal 4-inch ((100-mm)) diameter face.
 - g. Mounting Bracket: Appropriate for installation.
- E. Air-Pressure Differential Indicating Transmitter:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series 616W.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy including hysteresis and repeatability: Within 0.25 percent of full scale.
 - c. Stability: Within 1 percent of full scale per year.
 - d. Overpressure: Varies with range. At least 1.5 times range.
 - e. Temperature Limits: **Zero to 140 deg F** (Minus 18 to 60 deg C).
 - f. Compensate Temperature Limits: **20 to 120 deg F** (Minus 7 to 49 deg C).
 - g. Thermal Effects: 0.02 percent of full scale per degree F.
 3. Display: Digital with minimum **0.4-inch-** (10-mm-) high numeric characters.
 4. Operator Interface: Zero and span adjustments.
 5. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 1200-ohm load.
 6. Construction:
 - a. Plastic casing with removable clear plastic cover.
 - b. Integral barbed fittings for rubber or plastic tubing connections on bottom of instrument case for high- and low-pressure connections.
 - c. Screw terminal block for wire connections.
 - d. Vertical plane mounting.
 - e. NEMA 250, Type 4X.
 - f. Mounting Bracket: Appropriate for installation.

F. Air-Pressure Differential Indicating Transmitter with Field-Selectable Features:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series MS.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Field-Selectable Features:
 - a. Field configurable for pressure and velocity applications through user interface.
 - b. Field selectable from one of three pressure ranges both in SI (metric) and inch-pound (IP) units of measure.
 - c. Select range based on application. Range shall be approximately 2 times set point.
3. Performance:
 - a. Accuracy Including Hysteresis and Repeatability:
 - 1) Within 2 percent for **0.10 in. wg (25 Pa)**, **1.0 in. wg (250 Pa)** and all bi-directional ranges.
 - 2) Within 1 percent for other ranges.
 - b. Stability: Within 1 percent of full scale per year.
 - c. Response Time: Adjustable 0.5- to 15-second time constant with 95 percent response within 1.5 to 45 seconds.
 - d. Overpressure: **1 psig (6.9 kPa)** maximum operating; **10 psig (69 kPa)** burst pressure.
 - e. Temperature Limits: **Zero to 150 deg F (Minus 18 to 66 deg C)**.
4. Display: Four-digit digital display with minimum **0.4-inch- (10-mm-)** high numeric characters.
5. Operator Interface:
 - a. Selectable pressure ranges, where indicated.
 - b. Zero and span adjustments.
 - c. Selectable air velocity mode with square root function.
 - d. Adjustable signal dampening
6. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 1200-ohm load.
7. Analog Output Voltage Signal:
 - a. Three wire, zero to 10 V.
 - b. Minimum Load Resistance: 1000 ohms.

8. Construction:
- a. Plastic casing with removable clear plastic cover.
 - b. NPS 3/16 (DN 7) nominal ID plastic tubing connections on side of instrument case for high- and low-pressure connections.
 - c. NPS 1/2 (DN 15) NPS threaded connection for conduit.
 - d. Terminal block for wire connections.
 - e. Vertical plane mounting.
 - f. NEMA 250, Type 4X.
 - g. Nominal 4-inch- (100-mm-) diameter face.
 - h. Mounting Bracket: Appropriate for installation.
- G. Air-Pressure Differential Transmitter with 0.10 Percent Accuracy and Auto Zero Feature:
1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Air Monitor Corporation; Veltron II.
 - b. <Insert manufacturer's name; product name or designation>.
 2. Description:
 - a. 4- to 20-mA dc output signal.
 - b. NEMA 250, Type 1 enclosure.
 - c. Construct the assembly so that shock, vibration, and pressure surges of up to 1 psig (6.9 kPa) will neither harm nor affect the accuracy of the transmitter.
 - d. Transmitter with automatic zeroing circuit capable of automatically readjusting the transmitter to zero at predetermined time intervals. The automatic zeroing circuit shall re-zero the transmitter to within 0.1 percent of true zero.
 - e. Performance:
 - 1) Range: Approximately 2 times set point.
 - 2) Calibrated Span: Field adjustable, minus 40 percent of the range.
 - 3) Accuracy: Within 0.10 percent of natural span.
 - 4) Repeatability: Within 0.15 percent of calibrated span.
 - 5) Linearity: Within 0.2 percent of calibrated span.
 - 6) Hysteresis and deadband (combined): Less than 0.2 percent of calibrated span.
 - f. Integral digital display for continuous indication of pressure differential.
- H. Air-Pressure Differential Transmitter with 0.25 Percent Accuracy and Auto Zero Feature:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Air Monitor Corporation**; DPT 2500 Plus.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Description:
 - a. 4- to 20-mA dc output signal.
 - b. NEMA 250, Type 1 enclosure.
 - c. Construct assembly so shock, vibration, and pressure surges of up to 1 psig (6.9 kPa) will neither harm nor affect the accuracy of the transmitter.
 - d. Transmitter with automatic zeroing circuit capable of automatically readjusting the transmitter to zero at predetermined time intervals. The automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
 - e. Performance:
 - 1) Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
 - 2) Calibrated Span: Field adjustable, minus 40 percent of the range.
 - 3) Accuracy: Within 0.25 percent of natural span.
 - 4) Repeatability: Within 0.15 percent of calibrated span.
 - 5) Linearity: Within 0.2 percent of calibrated span.
 - 6) Hysteresis and deadband (combined): Less than 0.2 percent of calibrated span.
 - f. Integral digital display for continuous indication of pressure differential.
- I. Air-Pressure Differential Indicating Transmitter, Switch, and Controller:
 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.**; Series DH3 Digihelic.
 - b. **<Insert manufacturer's name; product name or designation>**.
 2. Description:
 - a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
 - b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
 - c. Select instrument range based on application. Range shall be approximately 2 times set point.
 3. Performance:

- a. Accuracy Including Hysteresis and Repeatability:
 - 1) Within 1 percent for ranges less than 5 in. wg (1250 Pa).
 - 2) Within 0.5 percent at 77 deg F (25 deg C) for other ranges.
 - b. Stability: Within 1 percent per year.
 - c. Response Time: 250 ms.
 - d. Overpressure: 5 psig (34 kPa) for instrument ranges less than 50 in wg (12.5 kPa) and 9 psig (62 kPa) for 100 in. wg (25 kPa) range.
 - e. Temperature Limits: 32 to 140 deg F (Zero to 60 deg C).
 - f. Thermal Effects: 0.020 percent per degree F.
 - g. Warm-up Period: One hour.
4. Controller Programming through Menu Keys to Access Five Menus:
- a. Security level.
 - b. Pressure, velocity, or flow application.
 - c. Engineering units.
 - d. K-factor for use with flow application.
 - e. Set-point control only; set-point and alarm operation; and alarm operation as high, low, or high/low with manual or automatic reset and delay.
 - f. View high and low readings.
 - g. Digital dampening for smoothing erratic applications.
 - h. Scaling of analog output to fit range and field calibration.
5. Display:
- a. Digital, four-digit display with backlight, with 0.4-inch- (10-mm-) high alphanumeric characters.
 - b. Four indicators; two for set point and two for alarm status.
6. Operator Interface:
- a. Set-point adjustment through keypad on face of instrument.
 - b. Zero and span adjustments accessible through menu.
 - c. Programming through keypad.
7. Analog Output Signal:
- a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 900-ohm load.
8. Digital Output Signal:
- a. Two SPDT relays.
 - b. Each rated for one amp at 30-V ac or dc.
9. Construction:
- a. Die cast-aluminum casing and bezel.
 - b. Threaded, NPS 1/8 (DN 6) connections on side and back.

- c. Vertical plane mounting.
- d. NEMA 250, Type 1.
- e. Nominal **4-inch-** (100-mm-) diameter face.
- f. Mounting Bracket: Appropriate for installation.

2.5 LIQUID-PRESSURE SWITCHES

A. Liquid Gage Pressure Switch, Diaphragm Operated, Low Pressure:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. [Mercoïd Controls, Division of Dwyer Instruments, Inc.](#); Series AP.
- b. **<Insert manufacturer's name; product name or designation>.**

2. Description:

- a. Diaphragm operated to actuate an SPDT snap switch.
- b. Electrical Connections: Screw terminal.
- c. Enclosure Conduit Connection: Knock out or threaded connection.
- d. User Interface: External screw with visual set-point adjustment.
- e. Process Connection: Threaded, **NPS 1/4 (DN 10)**.
- f. Enclosure:
 - 1) Dry Indoor Installations: NEMA 250, Type 1.
 - 2) Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - 3) Hazardous Environments: Explosion proof.

3. Operating Data:

- a. Electrical Rating: 15 A at 120-V ac.
- b. Pressure Limits:
 - 1) Range **1 to 30 psig** (7 to 207 kPa): **60 psig** (414 kPa).
 - 2) Range **10 to 125 psig** (69 to 862 kPa): **160 psig** (1103 kPa).
- c. Temperature Limits: **Minus 30 to 150 deg F** (Minus 35 to 66 deg C).
- d. Operating Range: [**1 to 30 psig** (7 to 207 kPa)] [**10 to 250 psig** (69 to 862 kPa)].
- e. Deadband: Fixed.

4. Pressure Chamber Material: **[Steel] [or] [Stainless steel]**.

5. Diaphragm Material: **[Nylon] [or] [PTFE]**.

B. Liquid Gage Pressure Switch-Diaphragm Operated:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. [Mercoild Controls, Division of Dwyer Instruments, Inc.](#); Series SA 1000.
 - b. <Insert manufacturer's name; product name or designation>.
2. Diaphragm operated to actuate a [SPDT] [or] [DPDT] snap switch.
 3. Electrical Connections: Screw terminal.
 4. Enclosure Conduit Connection: Knock out or threaded connection.
 5. User Interface: Internal hex nut set-point adjustment with enclosed set-point indicator and scale.
 - a. Process Connection: Threaded, [NPS 1/4 (DN 6)] [or] [NPS 1/2 (DN 15)].
 6. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1, 12.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4X[**with drain**].
 - c. Hazardous Environments: Explosion proof.
 7. Operating Data:
 - a. Electrical Rating: 15 A at 120-, 240-, and 480-V ac.
 - b. Pressure Limits: 1200 psig (8274 kPa).
 - c. Ambient Temperature Limits: Minus 30 to 180 deg F (Minus 35 to 82 deg C).
 - d. Process Temperature Limits: Minus 4 to 167 deg F (Minus 20 to 75 deg C).
 - e. Adjustable Operating Range: [10 to 150 psig (69 to 1034 kPa)] [20 to 250 psig (138 to 1724 kPa)] [30 to 500 psig (207 to 3447 kPa)].
 - f. Deadband: Adjustable.
 8. Pressure Chamber Material: [Aluminum] [or] [brass] [or] [stainless steel].
 9. Diaphragm Material: [Buna-N] [or] [fluorocarbon].
- C. Liquid Gage Pressure Switch-Bourdon Tube Operated:
1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. [Dwyer Instruments, Inc.](#); Series DA, DS.
 - b. <Insert manufacturer's name; product name or designation>.
 2. Description:
 - a. Bourdon tube operated to actuate a [SPDT] [DPDT] snap switch.
 - b. Provide switches used in safety limiting applications with [auto] [manual] reset.
 - c. Wetted Materials: [Brass] [or] [Type 403 stainless steel] [or] [Type 316 stainless steel].
 - d. Electrical Connections: Screw terminal.
 - e. Enclosure Conduit Connection: Knock out or threaded connection.
 - f. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.

- g. Process Connection: Threaded, **NPS 1/4 (DN 10)**.
- h. Enclosure:
 - 1) Dry Indoor Installations: NEMA 250, Type 1.
 - 2) Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - 3) Hazardous Environments: Explosion proof.
- i. Operating Data:
 - 1) Electrical Rating: **[5] [10]** A at 120-V ac.
 - 2) Pressure Limits: Equal to maximum pressure in full-scale range, but not less than system design pressure rating.
 - 3) Temperature Limits: **180 deg F (82 deg C)**.
 - 4) Operating Range: Approximately 2 times set point, but not less than system design pressure rating.
 - 5) Deadband: **[Adjustable] [Fixed] [Adjustable or fixed as required by application]**.
- j. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. Liquid-Pressure Differential Switch with Set-Point Indicator:

- 1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series DP.
 - b. **<Insert manufacturer's name; product name or designation>**.
- 2. Description:
 - a. **[Brass] [or] [Type 316 stainless-steel]** double opposing bellows operate to actuate a SPDT snap switch.
 - b. Electrical Connections: Screw terminal.
 - c. Enclosure Conduit Connection: Knock out or threaded connection.
 - d. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
 - e. High and Low Process Connections: Threaded, **NPS 1/8 (DN 3)**.
 - f. Enclosure:
 - 1) Dry Indoor Installations: NEMA 250, Type 1.
 - 2) Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - 3) Hazardous Environments: Explosion proof.
 - g. Operating Data:
 - 1) Electrical Rating: 15 A at 120- to 240-V ac.
 - 2) Pressure Limits: At least 5 times full-scale range, but not less than system design pressure rating.

- 3) Temperature Limits: **Minus 10 to 180 deg F** (Minus 23 to 82 deg C).
- 4) Operating Range: Approximately 2 times set point.
- 5) Deadband: **[Adjustable] [Fixed] [Adjustable or fixed as required by application]**.

E. Liquid-Pressure Differential Switch:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. **Ashcroft Inc.;** LPA, S Series.
- b. **<Insert manufacturer's name; product name or designation>.**

2. Description:

- a. Type 316 stainless-steel double opposing bellows operate to actuate an SPDT snap switch.
- b. Wetted materials: Type 316 stainless steel.
- c. Seal: **[Buna-N] [or] [Viton]**.
- d. Electrical Connections: Screw terminal.
- e. Enclosure Conduit Connection: Knock out or threaded connection.
- f. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
- g. High and Low Process Connections: Threaded, **NPS 1/4 (DN 10)**.
- h. Enclosure: NEMA 250, Type 4 or 4X.
- i. Operating Data:
 - 1) Electrical Rating: 10 A at 120- to 240-V ac.
 - 2) Pressure Limits: **Zero to 500 psig** ((Zero to 3447 kPa).)
 - 3) Ambient Temperature Limits: **Minus 20 to 150 deg F** (Minus 29 to 66 deg C).
 - 4) Process Temperature Limits: **20 to 300 deg F** (Minus 7 to 149 deg C).
 - 5) Operating Range: 2 times set point, unless otherwise required by application.
 - 6) Deadband: **[Adjustable] [Fixed] [Adjustable or fixed as required by application]**.
- j. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.6 LIQUID-PRESSURE TRANSMITTERS

A. Liquid Gage Pressure Transmitter with Adjustable Span[**for Hazardous Environments**]:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. [Rosemount Inc., Emerson Electric Co.](#); Model 3051CG.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Hazardous Classification: FM Approved for hazardous environments.
- a. Intrinsically safe for Classes I, II, and III; Divisions 1 and 2; Groups A through H.
 - b. Explosion proof for Class I; Division 1; Groups B, C, and D.
 - c. Dust ignition proof for Class II, Division 1, Groups E, F, and G.
 - d. Dust ignition proof for Class III, Division 1.
3. Performance:
- a. Range: **Minus 300 to 300 psig** (Minus 2068 to 2068 kPa).
 - b. Span: Field adjustable.
 - c. Minimum Span: **3 psig** (21 kPa).
 - d. Reference Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: **3626 psig** (25 000 kPa).
 - g. Process Temperature Limits: **Minus 40 to 250 deg F** (Minus 40 to 121 deg C).
 - h. Ambient Temperature Limits: **Minus 40 to 185 deg F** (Minus 40 to 85 deg C).
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
4. Analog Output Current Signal:
- a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable from zero to 30 seconds.
5. Operator Interface: Zero and span adjustments located behind cover.
6. Display: Digital, five-digit, two-line display with **0.4-inch-** (10-mm-) high alphanumeric characters.
7. Construction:
- a. Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. Threaded, **NPS 1/2** (DN 15) process connection on bottom of instrument.
 - e. Drain/vent valve on process connection.
 - f. Two **1/2-inch** (16-mm) trade size conduit connections on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting Bracket: Appropriate for installation.

B. Liquid-Pressure Differential Transmitter with Adjustable Span[for Hazardous Environments]:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Rosemount Inc., Emerson Electric Co.;** Model 3051CD.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Hazardous Classification: FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III; Divisions 1 and 2; Groups A through H.
 - b. Explosion proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust ignition proof for Class II, Division 1, Groups E, F, and G.
 - d. Dust ignition proof for Class III, Division 1.
3. Performance:
 - a. Range: **Minus 300 to 300 psig** (Minus 2068 to 2068 kPa).
 - b. Span: Field adjustable.
 - c. Minimum Span: **3 psig** (21 kPa).
 - d. Reference Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: **3626 psig** (25 000 kPa).
 - g. Process Temperature Limits: **Minus 40 to 250 deg F** (Minus 40 to 121 deg C).
 - h. Ambient Temperature Limits: **Minus 40 to 185 deg F** (Minus 40 to 85 deg C).
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
4. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable from zero to 30 seconds.
5. Operator Interface: Zero and span adjustments located behind cover.
6. Display: Digital, five-digit, two-line display with **0.4-inch-** (10-mm-) high alphanumeric characters.
7. Construction:
 - a. Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. Threaded, **NPS 1/2** (DN 15) process connection on bottom of instrument.
 - e. Drain/vent valve on process connection.
 - f. Two **1/2-inch** (16-mm) trade size conduit connections on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.

i. Mounting Bracket: Appropriate for installation.

C. Liquid-Pressure Differential Transmitter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Dwyer Instruments, Inc.;** Series 645.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Span: Adjustable plus or minus one milliamp, noninteractive.
 - c. Accuracy: Within 0.25 percent of full scale.
 - d. Pressure: Maximum operating pressure 2.5 times range.
 - e. Temperature Limits: **Zero to 175 deg F (Minus 18 to 79 deg C).**
 - f. Compensate Temperature Limits: **30 to 150 deg F (Minus 1 to 66 deg C).**
 - g. Thermal Effects: 0.02 percent of full scale per degree F.
 - h. Response Time: 30 to 50 ms.
 - i. Shock and vibration shall not harm the transmitter.
3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
4. Operator Interface:
 - a. Zero and span adjustments located behind cover.
 - b. Bleed screws on side of body, two screws on low-pressure side, and one screw on high-pressure side, for air in line and pressure cavity.
5. Construction:
 - a. Aluminum and stainless-steel enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH or 300 Series stainless steel.
 - c. Threaded, **NPS 1/4 (DN 10)** process connections on side of instrument enclosure.
 - d. Knock out for **1/2-inch (16-mm)** nominal conduit connection on side of instrument enclosure.
 - e. Screw terminal block for wire connections.
 - f. NEMA 250, Type 4X.
 - g. Mounting Bracket: Appropriate for installation.
6. Three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Manifold shall have threaded, **NPS 1/4 (DN 10)** process connections.

D. Liquid-Pressure Differential Transmitter:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Setra Systems, Inc.;** Model 230.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. **Performance:**
 - a. Range: Approximately 2 times the set point.
 - b. Span: Adjustable plus or minus one milliamp, noninteractive.
 - c. Accuracy: Within 0.25 percent of full scale.
 - d. Hysteresis: Within 0.1 percent of full scale.
 - e. Repeatability: Within 0.05 percent of full scale.
 - f. Maximum Working Pressure: **250 psig (1724 kPa).**
 - g. Temperature Limits: **Zero to 175 deg F (Minus 18 to 79 deg C).**
 - h. Compensate Temperature Limits: **30 to 150 deg F (Minus 1 to 66 deg C).**
 - i. Thermal Effects: 0.02 percent of full scale per degree F.
 - j. Response Time: 30 to 50 ms.
 - k. Shock and vibration shall not harm the transmitter.
3. **Analog Output Current Signal:**
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
4. **Analog Output Voltage Signal:**
 - a. Three wire, zero to **[5] [10]** V.
 - b. Minimum Load Resistance: 1000 ohms.
5. **Operator Interface:**
 - a. Zero and span adjustments located behind cover.
 - b. Bleed screws on side of body, two screws on low-pressure side, and one screw on high-pressure side, for air in line and pressure cavity.
6. **Construction:**
 - a. Aluminum and stainless-steel enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH or 300 Series stainless steel.
 - c. Threaded, **NPS 1/4 (DN 10)** process connections on side of instrument enclosure.
 - d. Knock out for **1/2-inch (15-mm)** nominal conduit connection on side of instrument enclosure.
 - e. Screw terminal block for wire connections.
 - f. NEMA 250, Type 4.
 - g. Mounting Bracket: Appropriate for installation.

7. Provide transmitter with three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Provide manifold with NPS 1/4 (DN 10) NPT process connections.

E. Liquid-Pressure Differential Transmitter with Field-Selectable Range:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Dwyer Instruments, Inc.; Series WWDP.
 - b. <Insert manufacturer's name; product name or designation>.
2. Performance:
 - a. Field-Selectable Range:
 - 1) 5, 10, 25, 50 psig (34, 69, 172, 345 kPa).
 - 2) 10, 20, 50, 100 psig (69, 138, 345, 689 kPa).
 - 3) 25, 50, 125, 250 psig (172, 345, 862, 1724 kPa).
 - b. Field-selectable unidirectional or bidirectional range.
 - c. Accuracy: Within 1 percent of the full-scale range, except lowest selectable range within 2 percent.
 - d. Stability: Within 0.5 percent of span per year.
 - e. Pressure: Maximum operating pressure equal to highest pressure in range.
 - f. Overpressure: Proof pressure 2.2 times full scale; burst pressure 40 times full scale.
 - g. Temperature Limits: Minus 44 to 185 deg F (Minus 42 to 85 deg C).
 - h. Compensate Temperature Limits: 32 to 130 deg F (Zero to 54 deg C).
 - i. Thermal Effects: 2 percent of full scale per 100 deg F (56 deg C).
 - j. Response Time: Field selectable from 1 to 5 seconds.
 - k. Shock and vibration shall not harm the transmitter.
3. Configurable Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
4. Configurable Analog Output Voltage Signals:
 - a. Three wire, zero to 5 V, zero to 10 V, and 1 to 5 V.
 - b. Minimum Load Resistance: 1000 ohms.
5. Display: Four-digit LCD with minimum 0.4-inch- (10-mm-) high numeric characters.
6. Operator Interface:
 - a. Digital zero button located behind cover.
 - b. Range selector located behind cover.

7. Construction:

- a. Cast-aluminum enclosure with removable cover.
- b. Wetted parts of transmitter constructed of 17-4 PH stainless steel.
- c. Threaded, **NPS 1/8 (DN 6)** process connections on bottom of instrument enclosure.
- d. **1/2-inch (16-mm)** trade size connection for conduit on bottom of instrument enclosure.
- e. Screw terminal block for wire connections.
- f. Vertical plane mounting.
- g. NEMA 250, Type 4.
- h. Mounting Bracket: Appropriate for installation.

F. Liquid-Pressure Differential Transmitter with Field-Selectable Ranges:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **MAMAC Systems, Inc.;** PR-283.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Performance:
 - a. Field-Selectable Ranges:
 - 1) **5, 10, 20 psig** (34, 69, 138 kPa).
 - 2) **25, 50, 100 psig** (172, 345, 689 kPa).
 - 3) **75, 150, 300 psig** (517, 1034, 2068 kPa).
 - b. Accuracy: Within 1 percent of the full-scale range.
 - c. Static Pressure: 2 times full-scale range.
 - d. Overpressure: Proof pressure 3 times full-scale range, burst pressure 5 times full scale.
 - e. Compensate Temperature Limits: **Zero to 180 deg F** (Minus 18 to 82 deg C).
 - f. Thermal Effects: 0.025 percent of full scale per degree F.
 - g. Shock and vibration shall not harm the transmitter.
3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
4. Analog Output Voltage Signals:
 - a. Three wire, field selectable from zero to 5 V or zero to 10 V.
 - b. Minimum Load Resistance: 1000 ohms.
5. Operator Interface:
 - a. Zero button located behind cover.

- b. Range selector located behind cover.
6. Construction:
- a. 0.0478-inch- (1.214-mm-) thick, corrosion-resistant steel enclosure with baked-enamel finish.
 - b. Removable front cover.
 - c. Wetted parts of transmitter constructed of 17-4 PH stainless steel.
 - d. Threaded, NPS 1/8 (DN 6) process connections on bottom of instrument enclosure.
 - e. 1/2 inch (16 mm) trade size conduit on side of instrument enclosure.
 - f. Screw terminal block for wire connections.
 - g. Vertical plane mounting.
 - h. NEMA 250, Type 4.
 - i. Mounting Bracket: Appropriate for installation.
7. Provide transmitter with three-valve manifold.
- a. Construct manifold of Type 316 stainless steel.
 - b. Manifold with threaded, NPS 1/4 ((DN 10)) process connections.

2.7 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect assembled pressure instruments, as indicated by instrument requirements. Affix standards organization's certification and label.
- B. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PRESSURE INSTRUMENT APPLICATIONS

A. Duct-Mounted Static Pressure Sensors:

1. **<Insert system> System, <Insert unique application>: [Duct insertion static pressure sensor] [Duct traverse static pressure sensor].**

B. Space Static Pressure Sensors:

1. **<Insert system> System, <Insert unique application>: [Space static pressure sensor for wall mounting] [Space static pressure sensor for recessed ceiling mounting] [Space static pressure sensor for exposed or suspended mounting].**

C. Air-Pressure Differential Switches:

1. **<Insert system> System, <Insert unique application>: [Air-pressure differential switch] [Air-pressure differential switch with set-point indicator] [Air-pressure differential switch with dual scale adjustable set point] [Air-pressure-differential indicating].**

D. Air-Pressure Differential Transmitters:

1. **Duct, <Insert system> System, <Insert unique application>: [Air-pressure differential transmitter] [Air-pressure differential transmitter for hazardous environments] [Air-pressure differential indicating transmitter] [Air-pressure differential transmitter with 0.10 percent accuracy and auto zero feature] [Air-pressure differential transmitter with 0.25 percent accuracy and auto zero feature] [Air-pressure differential indicating transmitter, switch, and controller].**
2. **Space, <Insert system> System, <Insert unique application>: [Air-pressure differential transmitter] [Air-pressure differential transmitter for hazardous environments] [Air-pressure differential indicating transmitter] [Air-pressure differential transmitter with 0.10 percent accuracy and auto zero feature] [Air-pressure differential transmitter with 0.25 percent accuracy and auto zero feature] [Air-pressure differential indicating transmitter, switch, and controller].**

E. Liquid Gage Pressure Switches:

1. **<Insert system> System, <Insert unique application>: [Liquid gage pressure switch, diaphragm operated, low pressure] [Liquid gage pressure switch, diaphragm operated] [Liquid gage pressure switch, bourdon-tube operated].**

F. Liquid-Pressure Differential Switches:

1. **<Insert system> System, <Insert unique application>: [Liquid-pressure differential switch with set-point indicator] [Liquid-pressure differential switch].**

G. Liquid-Pressure Differential Transmitters:

1. **<Insert system> System, <Insert unique application>: [Liquid-pressure differential transmitter with adjustable span] [Liquid-pressure differential transmitter] [Liquid-pressure differential transmitter with field-selectable range].**

3.3 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement, sway, or a break in attachment when subjected to a **<Insert value>** force.
- C. Provide ceiling, floor, roof, wall openings, and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- D. Fastening Hardware:
1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 2. Tighten bolts and nuts firmly and uniformly. Do not to overstress threads by using excessive force or oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- E. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- F. Corrosive Environments:
1. Use products that are suitable for environment to which they are subjected.
 2. If possible, avoid or limit use of materials in corrosive environments.
 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.

- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 PRESSURE INSTRUMENT INSTALLATION

A. Mounting Location:

1. Rough-in: Outline instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.
2. Install switches and transmitters for air and liquid pressure associated with individual air-handling units and associated connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
3. Install liquid and steam pressure switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
4. Install air-pressure switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
6. Install instruments (except pressure gages) in steam, liquid, and liquid-sealed piped services below their process connection point. Slope tubing down to instrument with a slope of [2] [3] <Insert number> percent.
7. Install instruments in dry gas and noncondensable vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of [2] [3] <Insert number> percent.

- B. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

C. Duct Pressure Sensors:

1. Install sensors using manufacturer's recommended upstream and downstream distances.
2. Unless indicated on Drawings, locate sensors approximately [50] [67] [75] percent of distance of longest hydraulic run. Location of sensors shall be submitted and approved before installation.
3. Install mounting hardware and gaskets to make sensor installation airtight.

4. Route tubing from the sensor to transmitter.
5. Use compression fittings at terminations.
6. Install sensor in accordance with manufacturer's instructions.
7. Support sensor to withstand maximum air velocity, turbulence, and vibration encountered to prevent instrument failure.

D. Outdoor Pressure Sensors:

1. Install roof-mounted sensor in least-noticeable location and as far away from exterior walls as possible.
2. Locate wall-mounted sensor in an inconspicuous location.
3. Submit sensor location for approval before installation.
4. Verify signal from sensor is stable and consistent to all connected transmitters. Modify installation to achieve proper signal.
5. Route outdoor signal pipe full size of sensor connection to transmitters. Install branch connection of size required to match to transmitter.
6. Install sensor signal pipe with dirt leg and drain valve below roof penetration.
7. Insulate signal pipe with flexible elastomeric insulation as required to prevent condensation.
8. Connect roof-mounted signal pipe exposed to outdoors to building grounding system.

E. Air-Pressure Differential Switches:

1. Install air-pressure sensor in system for each switch connection. Install sensor in an accessible location for inspection and replacement.
2. A single sensor may be used to share a common signal to multiple pressure instruments.
3. Install access door in duct and equipment to access sensors that cannot be inspected and replaced from outside.
4. Route **NPS 3/8 (DN 12)** tubing from sensor to switch connection.
5. Do not mount switches on rotating equipment.
6. Install switches in a location free from vibration, heat, moisture, or adverse effects, which could damage the switch and hinder accurate operation.
7. Install switches in an easily accessible location serviceable from floor.
8. Install switches adjacent to system control panel if within **[50 feet (15 m)] <Insert distance>**; otherwise, locate switch in vicinity of system connection.

F. Liquid-Pressure Differential Switches:

1. Where process connections are located in mechanical equipment room, install switch in convenient and accessible location near system control panel.
2. Where process connections are installed outside mechanical rooms, route processing tubing to mechanical room housing system control panel and locate switch near system control panel.
3. Where multiple switches serving same system are installed in same room, install switches by system to provide service personnel a single and convenient location for inspection and service.
4. System process tubing connection shall be full size of switch connection, but not less than **[NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] [NPS 1 (DN 25)]**. Install[

5. **stainless-steel**] bushing if required to mate switch to system connection.
6. Connect process tubing from point of system connection and extend to switch.
7. Install isolation valves in process tubing as close to system connection as practical.
8. Install dirt leg and drain valve at each switch connection.
9. Do not mount switches on rotating equipment.
10. Install switches in a location free from vibration, heat, moisture, or adverse effects, which could damage the switch and hinder accurate operation.
11. Install switches in an easily accessible location serviceable from floor.

G. Liquid-Pressure Transmitters:

1. Where process connections are installed in mechanical equipment room, install transmitter in convenient and accessible location near system control panel.
2. Where process connections are installed outside mechanical rooms, route processing tubing to mechanical room housing system control panel and locate transmitter near system control panel.
3. Where multiple transmitters serving same system are installed in same room, install transmitters by system to provide service personnel a single and convenient location for inspection and service.
4. System process tubing connection shall be full size of switch connection, but not less than [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] [NPS 1 (DN 25)]. Install [**stainless-steel**] bushing if required to mate switch to system connection.
5. Connect process tubing from point of system connection and extend to transmitter.
6. Install isolation valves in process tubing as close to system connection as practical.
7. Install dirt leg and drain valve at each transmitter connection.
8. Do not mount transmitters on equipment.
9. Install in a location free from vibration, heat, moisture, or adverse effects, which could damage and hinder accurate operation.

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.7 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.

- C. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.8 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
4. Equipment and procedures used for calibration shall comply with instrument manufacturer's recommendations.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of project design values.

3.9 ADJUSTING

- A. Occupancy Adjustments: When requested within [**12**] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.10 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include [**three**] [**six**] [**nine**] [**12**] months' full maintenance by [**skilled employees of systems and equipment Installer**] [**manufacturer's authorized service representative**]. Include [**monthly**] [**quarterly**] [**semiannual**] [**annual**] preventive maintenance, repair, or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.11 DEMONSTRATION

- A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate pressure instrument demonstration video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.23

SECTION 230923.24 - SPEED INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes speed switches for direct-digital controls for HVAC.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.24**.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Product description with complete technical data and product specification sheets.
 - 3. Installation operation and maintenance instructions, including factors affecting performance.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and [**mounting**] details.
 - 2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
 - 4. Include number-coded identification system for unique identification of wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: To include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 ROTATIONAL SPEED SWITCHES

- A. Rotational Speed Switch (Non-Contact Type):

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. Proximity Controls, Division of Dwyer Instruments, Inc.; Series NSS.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. **Description:**
 - a. Speed switch, sensor, and electronics housed in enclosure.
 - b. Shaft-end-mounted disc, or split collar wrap generates an alternating magnetic field sensed by the switch.
 - c. Dust, dirt, and grease proof.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments Class I, Group D; Class II, Groups E, F, and G; and Class III.
3. **Performance:**
 - a. Field-Adjustable Range: **[10 to 100] [100 to 5000]** rpm.
 - b. Temperature Limits: **Minus 40 to 140 deg F** (Minus 40 to 60 deg C).
 - c. Electrical Rating: 5 A at 115-V ac.
 - d. Switch Type: SPDT.
 - e. Gap Distance: Approximately **0.375 inch** ((9) mm).
4. **Operator Interface:** Potentiometer.
5. **Enclosure Construction:**
 - a. **[PVC] [Cast aluminum]**.
 - b. Removable cover.
 - c. NEMA 250, Type 4X.
 - d. Electrical Connection: Wiring, **12 inches** (300 mm) long, furnished with switch.
 - e. Conduit Connection: **1-inch** (27-mm) trade size.
6. **Disc, Guard, and Mounting Bracket Construction:**
 - a. Magnetic Disc: Nylon or PVC.
 - b. Disc Guard: Stainless steel.

- c. Mounting Bracket: Aluminum with stainless-steel shaft.
- B. Rotational Speed Switch (Contact Type):
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Proximity Controls, Division of Dwyer Instruments, Inc.;** Series DSS.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Description:
 - a. Speed switch, sensor, and electronics housed in one enclosure.
 - b. Photoelectric technology.
 - c. Suitable for mounting in any orientation.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments Class I, Groups C and D; and Class II, Groups F and G.
 3. Performance:
 - a. Three Field-Adjustable Ranges: 0.1 to 10, 1 to 100, and 10 to 1000 rpm.
 - b. De-Energize Set Point: 15 to 20 percent lower than energize speed range.
 - c. Repeatability: Within 2 percent of maximum speed in range.
 - d. Rotation: Clockwise or counterclockwise.
 - e. Temperature Limits: **Minus 40 to 140 deg F** (Minus 40 to 60 deg C).
 - f. Electrical Rating: 3 A at 120- or 240-V ac.
 - g. Switch Type: SPDT.
 4. Operator Interface: Adjustment screw.
 5. Enclosure Construction:
 - a. Aluminum.
 - b. Screw cover.
 - c. NEMA 250, Type 4X.
 - d. Electrical Connection: Screw terminals.
 - e. Conduit Connection: Two, **3/4-inch** (21-mm) trade size.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.

- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Speed-Switch Applications:

- 1. **<Insert application>**: Speed switch, [**contact**] [**non-contact**] type.

- B. Install products level, plumb, parallel, and perpendicular with building construction.

- C. Properly support speed-switch wiring and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.

- D. Fastening Hardware:

- 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.

- E. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

- F. Corrosive Environments:

- 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.

- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."

- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 SPEED-SWITCH INSTALLATIONS

- A. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
- B. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.6 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 3. Equipment and procedures used for calibration shall meet instrument manufacturer's written instructions.
 4. Provide diagnostic and test equipment for calibration and adjustment.
 5. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 6. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 7. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
 8. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement requirements indicated.
- B. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

C. Switches: Calibrate switches to make or break contact at set points indicated.

3.7 ADJUSTING

- A. Occupancy Adjustments: When requested within [**12**] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

END OF SECTION 230923.24

SECTION 230923.27 - TEMPERATURE INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Air temperature sensors.
2. Combination air temperature sensors and switches.
3. Air temperature switches.
4. Air temperature RTD transmitters.
5. Liquid and steam temperature sensors.
6. High-end, commercial-grade, liquid, and steam temperature sensors.
7. Industrial-grade liquid and steam temperature sensors.
8. Liquid temperature switches.
9. High-end, commercial-grade, liquid, and steam temperature transmitters.
10. Industrial-grade liquid and steam temperature transmitters.

- B. Related Requirements:

1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.27**.

1.3 DEFINITIONS

- A. HART (Highway Addressable Remote Transducer) Protocol: The global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bidirectional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from a technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.
- B. RTD: Resistance temperature detector.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 3. Product description with complete technical data, performance curves, and product specification sheets.
 4. Installation operation and maintenance instructions, including factors affecting performance.
- B. Shop Drawings:
1. Include plans, elevations, sections, and [**mounting**] details.
 2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power, signal, and control wiring.
 4. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.
- C. Samples: For each exposed product installed in finished space.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Product installation location shown in relationship to room, duct, pipe, and equipment.
 2. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices, and other installed devices.
 3. Sizes and locations of wall access panels for instruments installed behind walls.
 4. Sizes and locations of ceiling access panels for instruments installed in inaccessible ceilings.
- B. Product Certificates: For each product requiring a certificate.
- C. Product Test Reports: For each product, for tests performed by [**manufacturer and witnessed by a qualified testing agency**] [**a qualified testing agency**].
- D. Field quality-control reports.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Provide **[one] [two] <Insert quantity>** matching product(s) in Project inventory for each unique size and type of the following:
 - 1. **<Insert product>**.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Environmental Conditions:
 - 1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instrument alone cannot meet requirement, install instrument in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[**and cooled**], filtered, and ventilated as required by instrument and application.
 - 2. Instruments and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Instrument's installed location shall dictate following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: **[Type 2] [Type 3] [Type 12] <Insert type>**.
 - b. Outdoors, Unprotected: **[Type 4] [Type 4X]**.
 - c. Indoors, Heated with Filtered Ventilation: **[Type 1] [Type 2] <Insert type>**.
 - d. Indoors, Heated with Non-Filtered Ventilation: **[Type 2] [Type 12] <Insert type>**.
 - e. Indoors, Heated and Air Conditioned: **[Type 1] <Insert type>**.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: **[Type 12] [Type 4] [Type 4X] <Insert type>**.
 - 2) Air-Moving Equipment Rooms: **[Type 1] [Type 2] [Type 12] <Insert type>**.
 - g. Localized Areas Exposed to Washdown: **[Type 4] [Type 4X] <Insert type>**.
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: **[Type 2] [Type 3] [Type 12] <Insert type>**.

- i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: **[Type 4] [Type 4X] <Insert type>**.
- j. Hazardous Locations: Explosion-proof rating for condition.
- k. **<Insert location and enclosure requirements>**.

2.2 AIR TEMPERATURE SENSORS

A. Platinum RTDs: Common Requirements:

1. 100 or 1000 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
3. Performance Characteristics:
 - a. Range: **Minus 50 to 275 deg F** (Minus 46 to 135 deg C).
 - b. Interchangeable Accuracy: At **32 deg F** (zero deg C) within **0.5 deg F** (0.3 deg C).
 - c. Repeatability: Within **0.5 deg F** (0.3 deg C).
 - d. Self-Heating: Negligible.
4. Transmitter Requirements:
 - a. Transmitter required for each 100-ohm RTD.
 - b. Transmitter optional for 1000-ohm RTD, contingent on compliance with end-to-end control accuracy.

B. Platinum RTD, Single-Point Air Temperature Duct Sensors:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** S400 Series PD or PF.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. **[100] [or] [1000]** ohms.
3. Temperature Range: **Minus 50 to 275 deg F** ((Minus 45 to 135 deg C).)
4. Probe: Single-point sensor with a stainless-steel sheath.
5. Length: As required by application to achieve tip at midpoint of air tunnel, up to **18 inches** ((450 mm) long).
6. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
7. Gasket for attachment to duct or equipment to seal penetration airtight.
8. Conduit Connection: **1/2-inch** ((16-mm) trade size.)

C. Platinum RTD, Air Temperature Averaging Sensors:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. Minco; S400 Series PD or PF.
 - b. <Insert manufacturer's name; product name or designation>.
2. [100] [or] [1000] ohms.
 3. Temperature Range: Minus 50 to 275 deg F ((Minus 45 to 135 deg C).)
 4. Multiple sensors to provide average temperature across entire length of sensor.
 5. Rigid probe of aluminum, brass, copper, or stainless-steel sheath.
 6. Flexible probe of aluminum, brass, copper, or stainless-steel sheath and formable to a 4-inch (100-mm) radius.
 7. Length: As required by application to cover entire cross section of air tunnel.
 8. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 9. Gasket for attachment to duct or equipment to seal penetration airtight.
 10. Conduit Connection: 1/2-inch ((16-mm) trade size.)
- D. Platinum RTD Outdoor Air Temperature Sensors:
1. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Minco; S400 Series PD or PF.
 - b. <Insert manufacturer's name; product name or designation>.
 2. [100] [or] [1000] ohms.
 3. Temperature Range: Minus 50 to 275 deg F ((Minus 45 to 135 deg C).)
 4. Probe: Single-point sensor with a stainless-steel sheath.
 5. Solar Shield: Stainless steel.
 6. Enclosure: NEMA 250, Type 4 or 4X junction box or combination conduit and outlet box with removable cover and gasket.
 7. Conduit Connection: 1/2-inch (16-mm) trade size.
- E. Platinum RTD Space Air Temperature Sensors:
1. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Minco; S400 Series PD or PF.
 - b. <Insert manufacturer's name; product name or designation>.
 2. [100] [or] [1000] ohms.
 3. Temperature Range: Minus 50 to 212 deg F ((Minus 45 to 100 deg C).)
 4. Sensor assembly shall include a temperature sensing element mounted under a [bright white, non-yellowing, plastic] [flush, brushed-aluminum] cover.
 5. Provide a mounting plate that is compatible with the surface shape that it is mounted to and electrical box used.
 6. Concealed wiring connection.
- F. Thermal Resistors (Thermistors): Common Requirements:

1. 10,000 ohms at 25 deg C and a temperature coefficient of 23.5 ohms/ohm/deg C.
 2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
 3. Performance Characteristics:
 - a. Range: **Minus 50 to 275 deg F** (Minus 46 to 135 deg C).
 - b. Interchangeable Accuracy: At **77 deg F** (25 deg C) within **0.5 deg F** (0.3 deg C).
 - c. Repeatability: Within **0.5 deg F** (0.3 deg C).
 - d. Drift: Within **0.5 deg F** (0.3 deg C) over 10 years.
 - e. Self-Heating: Negligible.
 4. Transmitter optional, contingent on compliance with end-to-end control accuracy.
- G. Thermistor, Single-Point Duct Air Temperature Sensors:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** TS400 Series TB.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Temperature Range: **Minus 50 to 275 deg F** ((Minus 45 to 135 deg C).)
 3. Probe: Single-point sensor with a stainless-steel sheath.
 4. Length: As required by application to achieve tip at midpoint of air tunnel, up to **18 inches** ((450 mm) long).
 5. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 6. Gasket for attachment to duct or equipment to seal penetration airtight.
 7. Conduit Connection: **1/2- inch** (16-mm) trade size.
- H. Thermistor Averaging Air Temperature Sensors:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** TS400 Series TB.
 - b. **<Insert manufacturer's name; product name or designation>.**
 2. Temperature Range: **Minus 50 to 275 deg F** ((Minus 45 to 135 deg C).)
 3. Multiple sensors to provide average temperature across entire length of sensor.
 4. Rigid probe of aluminum, brass, copper, or stainless-steel sheath.
 5. Flexible probe of aluminum, brass, copper, or stainless-steel sheath and formable to a **4-inch** (100-mm) radius.
 6. Length: As required by application to cover entire cross section of air tunnel.
 7. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 8. Gasket for attachment to duct or equipment to seal penetration airtight.
 9. Conduit Connection: **1/2-inch** (16-mm) trade size.

I. Thermistor Outdoor Air Temperature Sensors:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** TS400 Series TB.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Temperature Range: **Minus 50 to 275 deg F** ((Minus 45 to 135 deg C).)
3. Probe: Single-point sensor with a stainless-steel sheath.
4. Solar Shield: Stainless steel.
5. Enclosure: NEMA 250, Type 4 or 4X junction box or combination conduit and outlet box with removable cover and gasket.
6. Conduit Connection: **1/2-inch** (16-mm) trade size.

J. Thermistor Space Air Temperature Sensors:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** TS400 Series TB.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Temperature Range: **Minus 50 to 212 deg F** ((Minus 45 to 100 deg C).)
3. Sensor assembly shall include a temperature sensing element mounted under a **[bright white, non-yellowing, plastic] [flush, brushed-aluminum]** cover.
4. Provide a mounting plate that is compatible with the surface shape that it is mounted to and electrical box used.
5. Concealed wiring connection.

K. Space Air Temperature Sensors for Use with DDC Controllers Controlling Terminal Units:

1. **[100-] [or] [1000-]ohm platinum RTD[or thermistor].**
2. Thermistor:
 - a. Pre-aged, burned in, and coated with glass; inserted in a metal sleeve; and entire unit encased in epoxy.
 - b. Thermistor drift shall be less than plus or minus **0.5 deg F** (0.3 deg C) over 10 years.
3. Temperature Transmitter Requirements:
 - a. Mating transmitter required with each 100-ohm RTD.
 - b. Mating transmitters optional for 1000-ohm RTD and thermistor, contingent on compliance with end-to-end control accuracy.
4. Provide digital display of sensed temperature.
5. Provide sensor with local control.

- a. Local override to turn HVAC on.
- b. Local adjustment of temperature set point.
- c. Both features shall be capable of manual override through control system operator.

2.3 COMBINATION AIR TEMPERATURE SENSOR AND SWITCH

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
1. **Minco;** Model AS103759 PF38EXXB2L.
 2. **<Insert manufacturer's name; product name or designation>.**
- B. Source Limitations: Obtain temperature-measuring sensors and transmitters and airflow from single manufacturer.
- C. Combination temperature sensor and switch in same instrument.
- D. Air Temperature Switch:
1. Factory preset set point of **38 deg F (3 deg C)**. Field-adjustable set point from **30 to 44 deg F (minus 1 to 7 deg C)**.
 2. Responsive to coldest **12-inch ((300-mm))** section of sensor length.
 3. DPST latching relay rated at 25 A and 120-V ac, with powered controller, coil, and manual rest at panel. Wire one leg to fan start circuit and other leg to signal a remote alarm.
- E. Air Temperature Sensor:
1. Temperature-averaging type over sensor length. Length to be determined by installing trade to provide uniform coverage over air tunnel. Consult manufacturer for recommendations.
 2. Platinum RTD with a value of 1000 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
 3. Accuracy: Within **0.9 deg F (0.5 deg C)**.
 4. Output Signal: 4 to 20 mA for connection to remote monitoring.
 5. Encase RTDs in a flexible nominal **0.375-inch- (9-mm-)** diameter sheath constructed of brass.
 6. Lead wires shall be 18-gage AWG copper.
 7. Enclosure: NEMA 250, Type 4.

2.4 AIR TEMPERATURE SWITCHES

- A. Thermostat and Switch for Low Temperature Control in Duct Applications:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

- a. [Honeywell International Inc., Building Solutions](#); L482A.
 - b. [Siemens](#); 134-1504.
 - c. **<Insert manufacturer's name; product name or designation>**.
2. Description:
- a. Two-position control.
 - b. Field-adjustable set point.
 - c. Manual reset.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Performance:
- a. Operating Temperature Range: **15 to 55 deg F** (Minus 9 to 13 deg C).
 - b. Temperature Differential: **5 deg F** (2.8 deg C), non-adjustable and additive.
 - c. Enclosure Ambient Temperature: **Minus 20 to 140 deg F** (Minus 11 to 60 deg C).
 - d. Sensing Element Maximum Temperature: **250 deg F** (121 deg C).
 - e. Voltage: 120-V ac.
 - f. Current: 16 FLA.
 - g. Switch Type: Two SPDT snap switches operate on coldest **12-inch** (300-mm) section along element length.
4. Construction:
- a. Vapor-Filled Sensing Element: Nominal **20 feet** (6 m) long.
 - b. Dual Temperature Scale: Fahrenheit and Celsius visible on face.
 - c. Set-Point Adjustment: Screw.
 - d. Enclosure: Painted metal, NEMA 250, Type 1.
 - e. Electrical Connections: Screw terminals.
 - f. Conduit Connection: **1/2-inch** (16-mm) trade size.
- B. Thermostat and Switch for High Temperature Control in Duct Applications:
1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [TAC Brand, Schneider Electric United States](#); Model TA-3433.
 - b. **<Insert manufacturer's name; product name or designation>**.
 2. Source Limitations: Obtain temperature-measuring sensors and transmitters and airflow from single manufacturer.
 3. Description:
 - a. Two-position control.
 - b. Field-adjustable set point.
 - c. Manual reset.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency,

and marked for intended location and application.

4. Performance:

- a. Temperature Range: 100 to 160 deg F (38 to 71 deg C).
- b. Temperature Differential: 5 deg F (2.8 deg C).
- c. Ambient Temperature: Zero to 260 deg F (Minus 18 to 127 deg C).
- d. Voltage: 120-V ac.
- e. Current: 16 FLA.
- f. Switch Type: SPDT snap switch.

5. Construction:

- a. Sensing Element: Helical bimetal.
- b. Enclosure: Metal, NEMA 250, Type 1.
- c. Electrical Connections: Screw terminals.
- d. Conduit Connection: 1/2-inch (16-mm) trade size.

2.5 AIR TEMPERATURE RTD TRANSMITTERS

A. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

1. **Minco**; TT Series.
2. **<Insert manufacturer's name; product name or designation>**.

B. Source Limitations: Obtain temperature-measuring sensors and transmitters and airflow from single manufacturer.

C. House electronics in NEMA 250 enclosure.

1. Duct: [Type 1] [Type 2] [Type 3].
2. Outdoor: [Type 4] [or] [Type 4X].
3. Space: Type 1.

D. Conduit Connection: 1/2-inch ((16-mm) trade size.)

E. Functional Characteristics:

1. Input:
 - a. 100-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, two-wire sensors.
 - b. 1000-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, two-wire sensors.
2. Span (Adjustable):
 - a. Space: 40 to 90 deg F (4 to 32 deg C).

- b. Supply Air Cooling and Heating: 40 to 120 deg F (4 to 49 deg C).
 - c. Supply Air Cooling Only: 40 to 90 deg F (4 to 32 deg C).
 - d. Supply Air Heating Only: 40 to 120 deg F (4 to 49 deg C).
 - e. Exhaust Air: 50 to 100 deg F (10 to 38 deg C).
 - f. Return Air: 50 to 100 deg F (10 to 38 deg C).
 - g. Mixed Air: Minus 40 to 140 deg F (Minus 40 to 60 deg C).
 - h. Outdoor: Minus 40 to 140 deg F (Minus 40 to 60 deg C).
3. Output: 4- to 20-mA dc, linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24-V dc.
 4. Zero and span field adjustments, plus or minus 5 percent of span. Minimum span of 50 deg F (28 deg C).
 5. Match sensor with temperature transmitter and factory calibrate together.

F. Performance Characteristics:

1. Calibration Accuracy: Within 0.1 percent of the span.
2. Stability: Within 0.2 percent of the span for at least 6 months.
3. Combined Accuracy: Within 0.5 percent.

2.6 LIQUID AND STEAM TEMPERATURE SENSORS, COMMERCIAL GRADE

A. RTD:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **MAMAC Systems, Inc.;** 703D Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Description:
 - a. Platinum with a value of **[100] [or] [1000]** ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
 - b. Encase RTD in a stainless-steel sheath with a **0.25-inch** (6-mm) OD.
 - c. Sensor Length: **4, 6, or 8 inches** ((100, 150, or 200 mm)) as required by application.
 - d. Process Connection: Threaded, **NPS 1/2** ((DN 15).)
 - e. Two-stranded copper lead wires.
 - f. Powder-coated steel enclosure, NEMA 250, Type 4.
 - g. Conduit Connection: **1/2-inch** ((16-mm) trade size.)
 - h. Performance Characteristics:
 - 1) Range: **Minus 40 to 210 deg F** (Minus 40 to 99 deg C).
 - 2) Interchangeable Accuracy: Within **0.54 deg F** (0.3 deg C) at **32 deg F** (zero deg C).

B. Thermowells:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **MAMAC Systems, Inc.;** A500 Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Stem: **[Straight] [or] [stepped]** shank formed from solid bar stock.
3. Material: **[Brass] [or] [stainless steel]**.
4. Process Connection: Threaded, **NPS 3/4 (DN 20)**.
5. Sensor Connection: Threaded, **NPS 1/2 (DN 15)**.
6. Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
7. Furnish thermowells installed in insulated pipes and equipment with an extended neck.
8. Length: **4, 6, or 8 inches ((100, 150, or 200 mm))** as required by application.
9. Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.

2.7 LIQUID AND STEAM TEMPERATURE SENSORS, HIGH-END COMMERCIAL GRADE

A. RTD:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** RTD Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Resistance temperature sensors shall comply with IEC 60751, Class B requirements.
3. Platinum with a value of 100 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
4. Encase RTD in a Type 316 stainless-steel sheath with a **0.25-inch (8-mm)** OD.
5. Provide **[two] [three] [four]**-wire, PTFE-insulated, nickel-coated, 22-gage, stranded copper leads.
6. Provide spring-loaded RTDs for thermowell installations.
7. Performance Characteristics:
 - a. Range: **Minus 328 to 932 deg F (Minus 200 to 500 deg C)**.
 - b. Interchangeable Accuracy: Within **0.54 deg F (0.3 deg C)** at **32 deg F (zero deg C)**.
 - c. Stability: Within 0.05 percent maximum ice-point resistance shift after 1000 hours at **752 deg F (400 deg C)**.
 - d. Hysteresis: Within 0.04 percent of range.
 - e. Response Time: 62.8 percent of change in 4 seconds with water flowing across sensor at **3 fps (0.9 m/s)**.

B. Thermowells:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** TW Series.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Stem: **[Straight] [or] [stepped] [or] [tapered]** shank formed from solid bar stock.
3. Material: **[Type 304] [or] [Type 316]** stainless steel.
4. Process Connection: Threaded, **NPS 3/4 (DN 20)**
5. Sensor Connection: Threaded, **NPS 1/2 (DN 15)**
6. Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
7. Furnish thermowells installed in insulated pipes and equipment with an extended neck that extends beyond the face of the insulation covering.
8. Length: As required by application and pipe size.
9. Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.

C. Connection Heads:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Minco;** CH 359 Connection Head.
 - b. **<Insert manufacturer's name; product name or designation>.**
2. Housing: Low-copper cast-aluminum alloy, complying with NEMA 250, Type 4.
3. Terminals: Six or eight as required by sensor.
4. Conduit Connection: **1/2-inch (16-mm)** trade size.
5. Sensor Connection: **NPS 1/2 (DN 15).**

- D. Assembly: Sensor manufacturer shall furnish sensor, thermowell, and sensor connection head to provide a matched assembly.

2.8 LIQUID AND STEAM TEMPERATURE SENSORS, INDUSTRIAL GRADE

A. RTD:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. **Rosemount Inc., Emerson Electric Co.;** Series 78S.
 - b. **<Insert manufacturer's name; product name or designation>.**

2. Resistance temperature sensors shall comply with IEC 60751, Class A requirements.
3. Platinum with a value of 100 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
4. Encase RTD in a Type 316 stainless-steel sheath with a 0.25-inch (8-mm) OD.
5. Provide [two] [three] [four]-wire, PTFE-insulated, nickel-coated, 22-gage, stranded copper leads.
6. Provide spring-loaded RTDs for thermowell installations.
7. Performance Characteristics:
 - a. Range: Minus 328 to 932 deg F (Minus 200 to 500 deg C).
 - b. Interchangeable Accuracy: Within 0.27 deg F (0.15 deg C) at 32 deg F (zero deg C).
 - c. Stability: Within 0.05 percent maximum ice-point resistance shift after 1000 hours at 752 deg F (400 deg C).
 - d. Hysteresis: Within 0.04 percent of range.
 - e. Response Time: 62.8 percent of change in 4 seconds with water flowing across sensor at 3 fps ((0.9 m/s)).
 - f. Self-Heating: 18-mW minimum power dissipation required to cause a 1.8 deg F (1 deg C) temperature measurement error in water flowing at 3 fps ((0.9 m/s)).

B. Thermowells:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. Rosemount Inc., Emerson Electric Co.; Series 91.
 - b. <Insert manufacturer's name; product name or designation>.
2. Stem: [Straight] [or] [stepped] [or] [tapered] shank formed from solid bar stock.
3. Material: [Type 304] [or] [Type 316] stainless steel.
4. Process Connection: Threaded, NPS 3/4 (DN 20), or flange-face, [NPS 1 (DN 25)] [NPS 1-1/2 (DN 38)] [NPS 2 (DN 50)], [Class 150] [Class 300] ASME B16.5.
5. Sensor Connection: Threaded, NPS 1/2 (DN 15).
6. Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
7. Furnish thermowells installed in insulated pipes and equipment with an extended neck that extends beyond the face of the insulation covering.
8. Length: As required by application and pipe size.
9. Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.

C. Connection Heads:

1. **Products:** Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

- a. [Rosemount Inc., Emerson Electric Co.](#); Connection Head.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Housing: Low-copper cast-aluminum alloy, complying with NEMA 250, Type 4.
 3. Terminals: Six or eight as required by sensor, nickel-plated brass.
 4. Conduit Connection: **1/2-inch** (16-mm) trade size.
 5. Sensor Connection: Threaded, **NPS 1/2** (DN 15).
- D. Assembly: Sensor manufacturer shall furnish sensor, thermowell, and sensor connection head to provide a matched assembly.

2.9 LIQUID TEMPERATURE SWITCHES

A. Thermostat and Switch for Temperature Control in Pipe Applications:

1. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [Honeywell International Inc., Building Solutions](#); L6006C.
 - b. **<Insert manufacturer's name; product name or designation>**.
2. Description:
 - a. Two-position control.
 - b. Field-adjustable set point.
 - c. Manual reset.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Performance:
 - a. Operating Temperature Range: **65 to 200 deg F** (18 to 3 deg C).
 - b. Temperature Differential Deadband: **5 to 30 deg F** (3 to 17 deg C), adjustable.
 - c. Enclosure Ambient Temperature: **150 deg F** (66 deg C).
 - d. Sensing Element Pressure Rating: **200 psig** (1379 kPa).
 - e. Voltage: 120-V ac.
 - f. Current: 8 FLA.
 - g. Switch Type: SPDT snap switch.
4. Construction:
 - a. Vapor-Filled Immersion Element: Copper, nominal **3 inches** (75 mm) long.
 - b. Temperature Scale: Fahrenheit, visible on face.
 - c. Set-Point Adjustment: Screw.
 - d. Enclosure: Painted metal, NEMA 250, Type 1.
 - e. Electrical Connections: Screw terminals.
 - f. Conduit Connection: **3/4-inch** ((21-mm) trade size).

2.10 LIQUID AND STEAM TEMPERATURE TRANSMITTERS, COMMERCIAL GRADE

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
1. **Minco;** TT Series.
 2. **<Insert manufacturer's name; product name or designation>.**
- B. House electronics in NEMA 250, **[Type 4] [or] [Type 4X]** enclosure.
- C. Enclosure Connection: **1/2-inch (16-mm)** trade size.
- D. Functional Characteristics:
1. Input: 100-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, **[two-] [or] [three-]**wire sensors.
 2. Default Span (Adjustable):
 - a. Chilled Water: **Zero to 100 deg F** (Minus 18 to 38 deg C).
 - b. Condenser Water: **Zero to 120 deg F** (Minus 18 to 49 deg C).
 - c. Heating Hot Water: **32 to 212 deg F** ((Zero to 100 deg C)).
 - d. Heat Recovery: **Zero to 120 deg F** (Minus 18 to 49 deg C).
 - e. **<Insert system and span>.**
 3. Output: 4- to 20-mA dc, linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24-V dc.
 4. Zero and span field adjustments, plus or minus 5 percent of span. Minimum span of **50 deg F (28 deg C)**.
 5. Match sensor with temperature transmitter and factory calibrate together. Each matched sensor and transmitter set shall include factory calibration data traceable to NIST.
- E. Performance Characteristics:
1. Calibration Accuracy: Within 0.1 percent of the span.
 2. Stability: Within 0.2 percent of the span for at least 6 months.
 3. Combined Accuracy: Within 0.5 percent.

2.11 LIQUID AND STEAM TEMPERATURE TRANSMITTERS, INDUSTRIAL GRADE

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
1. **Rosemount Inc., Emerson Electric Co.;** Model 644.
 2. **<Insert manufacturer's name; product name or designation>.**
- B. Hazard Classification: FM Approved for hazardous environments.

1. Intrinsically safe for Classes I, II, and III; Division 1; Groups A through G.
2. Explosion proof for Class I; Division 1; Groups B, C, and D.
3. Dust-ignition proof for Classes II and III; Division 1; Groups E, F, and G.

C. Performance:

1. Digital Accuracy: Within 0.27 deg F (0.15 deg C) with a 180 deg F (82 deg C) span.
2. Digital to Analog Accuracy: Within 0.03 percent of span.
3. Total Accuracy: Within 0.32 deg F (0.18 deg C) with a 180 deg F (82 deg C) span.
4. Stability: Within 0.15 percent of output reading for 24 months.
5. Ambient Temperature Limits: Minus 4 to 185 deg F (Minus 20 to 85 deg C).
6. Humidity Limits: Zero to 99 percent.

D. Electronics Enclosure:

1. Materials: Aluminum alloy or stainless steel.
2. NEMA 250, Type 4X enclosure.
3. Conduit Connections: 1/2-inch (16-mm) trade size.
4. Mounting kit to suit application.

E. Functional Characteristics:

1. Input: 100-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C.
2. Range: Minus 328 to 1562 deg F (Minus 200 to 850 deg C).
3. Field-Adjustable Span: 18 deg F (10 deg C) minimum.
4. Default Spans:
 - a. Chilled Water: Zero to 100 deg F (Minus 18 to 38 deg C).
 - b. Condenser Water: Zero to 120 deg F ((Minus 18 to 49 deg C)).
 - c. Heating Hot Water: 32 to 212 deg F (Zero to 100 deg C).
 - d. Heat Recovery: Zero to 120 deg F (Minus 18 to 49 deg C).
 - e. <Insert system and span>.
5. Output Signal:
 - a. 4- to 20-mA dc, linear with temperature.
 - b. Digital signal based on HART protocol carried with current signal.
 - c. RFI insensitive.
 - d. Minimum drive load of 600 ohms at 24-V dc.
6. Self-Calibration: The analog-to-digital measurement circuitry automatically self-calibrates for each temperature update by comparing the dynamic measurement to extremely stable and accurate internal reference elements.
7. Digital display of engineering units.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 TEMPERATURE INSTRUMENT APPLICATIONS

- A. Air Temperature Sensors:
 - 1. Duct, <Insert application>: [Thermistor] [100-ohm platinum RTD] [1000-ohm platinum RTD].
 - 2. Outdoor, <Insert application>: [Thermistor] [100-ohm platinum RTD] [1000-ohm platinum RTD].
 - 3. Space, <Insert application>: [Thermistor] [100-ohm platinum RTD] [1000-ohm platinum RTD].
- B. Air Temperature Transmitters:
 - 1. Duct, <Insert application>: [Not required] [Air temperature RTD transmitter].
 - 2. Outdoor, <Insert application>: [Not required] [Air temperature RTD transmitter].
 - 3. Space, <Insert application>: [Not required] [Air temperature RTD transmitter].
- C. Liquid and Steam Temperature Sensors:
 - 1. <Insert system> System, <Insert unique application>: [Liquid and steam temperature sensor, commercial grade] [Liquid and steam temperature sensor, high-end commercial grade] [Liquid and steam temperature sensor, industrial grade].
- D. Liquid and Temperature Transmitters:
 - 1. <Insert system> System, <Insert unique application>: [Liquid and steam temperature transmitter, commercial grade] [Liquid and steam temperature transmitter, industrial grade].

3.3 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support instruments, tubing, piping, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a <Insert value> force.
- C. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- D. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- E. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 TEMPERATURE INSTRUMENT INSTALLATIONS

A. Mounting Location:

1. Roughing In:

- a. Outline instrument mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
 - b. Provide independent inspection to confirm that proposed mounting locations comply with requirements indicated and approved submittals.
 - 1) Indicate dimensioned locations with mounting height for all surface-mounted products on Shop Drawings.
 - 2) Do not begin installation without submittal approval of mounting location.
 - c. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.
2. Install switches and transmitters for air and liquid temperature associated with individual air-handling units and associated connected ductwork and piping near air-handling units co-located in air-handling unit system control panel to provide service personnel a single and convenient location for inspection and service.
 3. Install liquid and steam temperature switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 4. Install air temperature switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 5. Mount switches and transmitters on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.

B. Special Mounting Requirements:

1. Protect products installed outdoors from solar radiation, building and wind effect with stand-offs and shields constructed of **[Type 316 stainless] <Insert material>**.
2. Temperature instruments having performance impacted by temperature of mounting substrate shall be isolated with an insulating barrier located between instrument and substrate to eliminate effect. Where instruments requiring insulation are located in finished space, conceal insulating barrier in a cover matching the instrument cover.

C. Mounting Height:

1. Mount temperature instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
 2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code or state and Federal accessibility requirements within a range of **42 to 72 inches** ((1.1 to 1.6 m)) above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at **60 inches** (1500 mm).
- D. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.
- E. Space Temperature Sensor Installation:
1. Conceal assembly in an electrical box of sufficient size to house sensor and transmitter, if provided.
 2. Install electrical box with a faceplate to match sensor cover if sensor cover does not completely cover electrical box.
 3. In finished areas, recess electrical box within wall.
 4. In unfinished areas, electrical box may be surface mounted if electrical light switches are surface mounted. Use a cast-aluminum electric box for surface-mounted installations.
 5. Align electrical box with other electrical devices such as visual alarms and light switches located in the vicinity to provide a neat and well-thought-out arrangement. Where possible, align in both horizontal and vertical axis.
- F. Outdoor Air Temperature Sensor Installation:
1. Mount sensor in a discrete location facing north.
 2. Protect installed sensor from solar radiation and other influences that could impact performance.
 3. If required to have a transmitter, mount transmitter remote from sensor in an accessible and serviceable location indoors.
- G. Single-Point Duct Temperature Sensor Installation:
1. Install single-point-type, duct-mounted, supply- and return-air temperature sensors. Install sensors in ducts with sensitive portion of the element installed in center of duct cross section and located to sense near average temperature. Do not exceed **24 inches** (610 mm) in sensor length.
 2. Install return-air sensor in location that senses return-air temperature without influence from outdoor or mixed air.
 3. Rigidly support sensor to duct and seal penetration airtight.
 4. If required to have transmitter, mount transmitter remote from sensor at accessible and serviceable location.
- H. Averaging Duct Temperature Sensor Installation:

1. Install averaging-type air temperature sensor for temperature sensors located within air-handling units, similar equipment, and large ducts with air tunnel cross-sectional area of **20 sq. ft. (1.86 sq. m)** and larger.
 2. Install sensor length to maintain coverage over entire cross-sectional area. Install multiple sensors where required to maintain the minimum coverage.
 3. Fasten and support sensor with manufacturer-furnished clips to keep sensor taut throughout entire length.
 4. If required to have transmitter, mount transmitter in an accessible and serviceable location.
- I. Low-Limit Air Temperature Switch Installation:
1. Install multiple low-limit switches to maintain coverage over entire cross-sectional area of air tunnel.
 2. Fasten and support sensing element with manufacturer-furnished clips to keep element taut throughout entire length.
 3. Mount switches outside of airstream at a location and mounting height to provide easy access for switch set-point adjustment and manual reset.
 4. Install on entering side of cooling coil unless otherwise indicated on Drawings.
- J. Liquid Temperature Sensor Installation:
1. Assembly shall include sensor, thermowell[**and connection head**].
 2. For pipe **NPS 4 (DN 100)** and larger, install sensor and thermowell length to extend into pipe between 50 to 75 percent of pipe cross section.
 3. For pipe smaller than **NPS 4 (DN 100)**:
 - a. Install reducers to increase pipe size to **NPS 4 ((DN 100))**at point of thermowell installation.
 - b. For pipe sizes **NPS 2-1/2 and NPS 3 (DN 65 and DN 80)**, thermowell and sensor may be installed at pipe elbow or tee to achieve manufacturer-recommended immersion depth in lieu of increasing pipe size.
 - c. Minimum insertion depth shall be **2-1/2 inches (65 mm)**.
 4. Install matching thermowell.
 5. Fill thermowell with heat-transfer fluid before inserting sensor.
 6. Tip of spring-loaded sensors shall contact inside of thermowell.
 7. For insulated piping, install thermowells with extension neck to extend beyond face of insulation.
 8. Install thermowell in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement. If top dead center location is not possible due to field constraints, install thermowell at location along top half of pipe.
 9. For applications with transmitters, mount transmitter remote from sensor in an accessible and serviceable location from floor[**service platform or catwalk**].

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.7 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.8 CHECK-OUT PROCEDURES

- A. Check installed products before continuity tests, leak tests, and calibration.
- B. Check temperature instruments for proper location and accessibility.
- C. Verify sensing element type and proper material.
- D. Verify location and length.
- E. Verify that wiring is correct and secure.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 - 3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
 - 4. Equipment and procedures used for calibration shall meet instrument manufacturer's written instructions.
 - 5. Provide diagnostic and test equipment for calibration and adjustment.
 - 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked

- by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
 9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistance source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.10 FIELD QUALITY CONTROL

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.

C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. Perform according to manufacturer's written instruction.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Prepare test and inspection reports.

3.11 ADJUSTING

- A. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.12 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include [three] [six] [nine] [12] months' full maintenance by **skilled employees of systems and equipment Installer** [manufacturer's authorized service representative]. Include [monthly] [quarterly] [semiannual] [annual] preventive maintenance, repair or replacement of worn or defective components, cleaning and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.13 DEMONSTRATION

- A. **Engage a factory-authorized service representative to train** [Train] Owner's maintenance personnel to adjust, operate, and maintain temperature instruments.
- B. Provide a complete set of instructional videos covering each product specified and installed and showing the following:
 - 1. Software programming.
 - 2. Calibration and test procedures.
 - 3. Operation and maintenance requirements and procedures.
 - 4. Troubleshooting procedures.
- C. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- D. Record videos on DVD disks.
- E. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.27

SECTION 230923.33 - VIBRATION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes vibration switches and combination switch and transmitters connected to direct digital control systems for HVAC.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.33**.

1.3 DEFINITIONS

- A. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating default control signal with loss of power, calibration data specific to each unique application, and electrical power requirements.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation operation and maintenance instructions including factors affecting performance.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and[**mounting**] details.

2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include number-coded identification system for unique identification of wiring and cable.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: To include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 MECHANICAL VIBRATION SWITCHES

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 1. **Metrix Instrument Co.;** Model 5550.
 2. **<Insert manufacturer's name; product name or designation>.**
- B. Description: Inertia-sensitive armature mechanism trips on high vibration and operates snap action switch.
- C. Performance:
 1. Frequency Range: Zero to 3600 rpm.
 2. Vibration Range: Zero to **[2] [5] [10]** g.
 3. Temperature Limits: **Minus 40 to 158 deg F** (Minus 40 to 70 deg C).
 4. Electrical Rating: 15 A at 125- or 480-V ac.
 5. Switch Type: **[SPDT] [DPDT]** snap switch.
 6. Start Delay: 20 to 30 seconds, by applying reset voltage at start signal to prevent switch from tripping.
- D. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments Class I, Groups B, C, and D; Class II, Groups E, F, and G.
- E. Operator Interface:
 1. Vibration Set-Point Adjustment: Zero to 100 percent of range.
 2. Push-button reset on switch face and reset coil for remote reset.
- F. Enclosure Construction:
 1. Cast aluminum.
 2. NEMA 250, **[Type 4] [or] [Type 4X]**.
 3. Electrical Connection: Screw terminals.

4. Conduit Connection: **3/4-inch** (21-mm) trade size.

2.2 ELECTRONIC VIBRATION SWITCHES

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. **Metrix Instrument Co.;** Model 5477.
2. **<Insert manufacturer's name; product name or designation>.**

- B. Description:

1. Accelerometer-based velocity response.
2. Single set point.

- C. Performance:

1. Frequency Range: 3 to 500 Hz.
2. Vibration Range: Zero to **1.0 inch** (25.4 mm) per second.
3. Temperature Limits: **Minus 4 to 167 deg F** (Minus 20 to 75 deg C).
4. Electrical Rating: 5-A inductive, 60-A surge for one cycle; normally open-triac leakage is 10 mA.
5. Trip Logic: Field-selectable, normally open-/normally closed-triac, non-latching, automatic reset.
6. Start Trip Timer: 30 seconds.
7. Monitor Trip Delay: 3 seconds.

- D. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments Class I, Groups C and D; Class II, Groups E, F, and G.

- E. Operator Interface:

1. Vibration Set-Point Adjustment: Externally adjustable with tamperproof gradual dial.
2. Trip Indicator: Flashing red LED.
3. Digital Display: 2.5-digit numerical display of vibration level.

- F. Enclosure Construction:

1. Cast aluminum.
2. Screw-on cover.
3. NEMA 250, Type 4.
4. Electrical Connection: Two wires, **24 inches** (600 mm) long.
5. Conduit Connection: **1/2-inch** (16-mm) trade size, sealed entry.
6. Flange mounting adapter, as applicable.

2.3 COMBINATION VIBRATION SWITCH AND TRANSMITTERS

A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. **Metrix Instrument Co.;** PRO6000 Series.
2. **<Insert manufacturer's name; product name or designation>.**

B. Description:

1. Input sensitivity.
2. Full-scale vibration range.
3. Mode: Peak or rms.
4. Trip delay.
5. Start delay.
6. Relay State: Latching or non-latching.
7. Relay: Non-energized, normally open or energized, normally closed.

C. Accelerometer integral to unit with capability of multiple remote sensor inputs.

1. Instrument furnished with programming and setup software.

D. Performance:

1. Frequency Range for Integral Accelerometer: 2 to 1000 Hz.
2. Ambient Temperature Limits: **Minus 40 to 185 deg F** (Minus 40 to 85 deg C).
3. Humidity: 100 percent condensing.

E. Analog Output Current Signal:

1. Two-wire, 4- to 20-mA dc current source.
2. Signal capable of operating into 1000-ohm load.

F. Digital Output Signal: **[Single] [Dual]** relay(s).

G. Operator Interface:

1. USB or keypad configurable.
2. Digital Display: Two lines of display.

H. Enclosure Construction:

1. Cast aluminum.
2. Screw-on cover.
3. NEMA 250, Type 4X.
4. Electrical Connection: Screw terminals.
5. Conduit Connection: **3/4-inch (21-mm)** trade size.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 VIBRATION INSTRUMENT APPLICATIONS

- A. **<Insert application>: [Mechanical switch] [Electronic switch] [Combination switch and transmitter].**

3.3 INSTALLATION

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
- C. Properly support instrument wiring and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.
- D. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- E. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- F. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments.
 - 3. When conduit is in contact with a corrosive environment, use Type 316

stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.

4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification.

3.6 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
 4. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
 5. Provide diagnostic and test equipment for calibration and adjustment.
 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.

8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Switches: Calibrate switches to make or break contact at set points indicated.

3.7 ADJUSTING

- A. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

END OF SECTION 230923.33

SECTION 230923.43 - WEATHER STATIONS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes weather stations connected to direct-digital controls for HVAC.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section **230923.43**.

1.3 DEFINITIONS

- A. I/O: Input/output.
- B. RS-232: A TIA standard for asynchronous serial data communications between terminal devices.
- C. RS-485: A TIA standard for multipoint communications using two twisted pairs.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating control signal over range, electrical power requirements, and limitations of ambient operating environment including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation operation and maintenance instructions including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and **[mounting]** details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.5 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For weather stations to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 WEATHER STATION

- A. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**

1. **WeatherHawk;** Series 500.
2. **<Insert manufacturer's name; product name or designation>.**

B. Description:

1. Weather station shall measure and record wind speed and direction, air temperature and relative humidity, barometric pressure, solar radiation, and rain.
2. Design weather station for applications with minimal visual impact, high reliability, and a long interval between routine servicing.
3. Weather station shall use solid-state sensors with no moving parts.
4. Weather station shall not be impaired by heavy snowfall or freezing conditions that produce rime ice. Provide a thermostatically controlled heater element in the sensor head that keeps the wind sensor elements and the precipitation sensor surface free of snow and ice to **minus 62 deg F** (minus 52 deg C).
5. Weather station shall directly connect to host device, or wirelessly connect to a host device through a fully integrated, industrial-grade, 916-MHz spread spectrum radio-frequency communications technology. Where required by application, replace 916-MHz radio-frequency components with 922-MHz and 2.4-GHz radio-frequency components to comply with local, regional, and national radio-frequency licensing requirements.

6. RS-232 serial data I/O shall be located on the bottom of the weather station and used as a second serial communications port, for programming and testing the system, or for direct data downloads using a personal computer or personal digital assistant.
7. Weather station shall be provided with a mounting system supplied by weather station manufacturer that is suitable for the installation.

C. Sensor Technology:

1. Wind speed and direction shall use acoustic techniques. Sensor shall consist of three equally spaced ultrasonic transducers in a horizontal plane. Values of any two array paths shall enable computation of both wind speed and direction, and a signal processing technique shall enable the measurement to be calculated using the two array paths of the best quality.
2. Rain shall be measured using a stainless-steel piezometric impact surface that counts the raindrops and measures their acoustic signature, integrating that information to provide a near-real-time value for rainfall amount and rate.
3. Barometric pressure, relative humidity, air temperature, and solar radiation measurements shall be made by scientific grade sensors.
4. Air-temperature and relative-humidity sensors shall be combined in an integrated, user-replaceable unit that requires no calibration.
 - a. Relative humidity sensor shall be a thin-polymer, capacitive sensor.
 - b. Air-temperature sensor shall be a capacitive ceramic sensor.
5. Barometric pressure shall be measured with a capacitive silicon, temperature-corrected, strain gage.
6. Solar radiation shall be measured by a silicon pyranometer with a cut filter limiting the spectral exposure to the 300- to 1100-nm wavelength.

D. Performance:

1. Air Temperature:
 - a. Range: **Minus 60 to 140 deg F** (Minus 51 to 60 deg C).
 - b. Accuracy: Within **0.9 deg F** (0.5 deg C).
 - c. Resolution: **0.1 deg F** (0.06 deg C).
2. Relative Humidity:
 - a. Range: Zero to 100 percent.
 - b. Accuracy: Within 3 percent over the range of zero to 90 percent and within 5 percent between 90 to 100 percent.
 - c. Resolution: 0.1 percent.
3. Barometric Pressure:
 - a. Range: **17.72- to 32.48-in. Hg** (450 to 825 mm).
 - b. Accuracy: **0.015-in. Hg** (0.38 mm) between **32 to 86 deg F** (0 to 30 deg C).
 - c. Resolution: **0.03-in. Hg** (0.76 mm) between **minus 60 to 140 deg F** (minus 51

to 60 deg C).

4. Solar Radiation:

- a. Spectral Range: 300 to 1100 nm.
- b. Reproducibility: Within 2 percent.
- c. Output: 0.2 mV per watts per square meters.
- d. Range: Zero to 1000 W per square meters.
- e. Temperature Range: **Minus 40 to 130 deg F** (Minus 40 to 54 deg C).

5. Rain:

- a. Collecting Area: **9.3 sq. in.** (6000 sq. mm).
- b. Range: **Zero to 7.87 inches** (Zero to 200 mm) per hour.
- c. Accuracy: Within 5 percent.
- d. Resolution: **0.001 inch** (0.025 mm).

6. Wind Direction:

- a. Azimuth: Zero to 360 degrees.
- b. Response Time: 250 ms.
- c. Accuracy: Within 2 degrees.
- d. Resolution: 1 degree.

7. Wind Speed:

- a. Range: **Zero to 134 mph** (Zero to 216 km/h).
- b. Response Time: 0.25 second.
- c. Accuracy: Greater of **0.67 mph** (1.1 km/h) or 2 percent.
- d. Resolution: **0.22 mph** (0.35 km/h).

8. Data Storage: 60 days of hourly data.

E. Output Signals:

1. RS-232 or RS-485 serial interface directly from weather station to host.
2. In applications that cannot accept a serial signal, provide a serial-to-analog converter.
3. Serial-to-Analog Converter:
 - a. **Products:** Subject to compliance with requirements, **[provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:**
 - 1) **Nokeval Oy;** 7470 Series.
 - 2) **<Insert manufacturer's name; product name or designation>.**
 - b. Serial converter designed to add analog outputs for measuring instruments that have only serial output.
 - c. Configure to give analog outputs from all measuring sensors and calculated

- parameters.
 - d. Each converter shall have four analog outputs with a 4- to 20-mA signal.
 - e. Provide multiple converters for applications requiring more points.
 - f. Converter requires a 24-V dc power supply.
- F. Communication Interface:
- 1. Weatherproof serial cables shall be used to connect the RS-232 I/O on the weather station. Cables shall use nickel-plated brass DB-9 connectors for corrosion resistance and include a Sanoprene jacket suitable for both high-ultraviolet and direct-burial environments.
 - 2. An RF4xx spread spectrum radio-frequency transceiver shall be provided with every wireless weather station.
- G. Unit shall be provided with a 120-V ac, 60-Hz power supply, a serial cable, and an antenna.
- H. Software:
- 1. Data Transfer Protocols, Software, and Data Interface Hardware: Weather stations that communicate using a proprietary protocol shall be provided with a software development kit to enable a qualified software developer in development of software drivers for third-party devices or software.
 - 2. Manufacturer shall submit description and pricing information of software application offerings for weather station management, data acquisition and logging, report generation, and data display for review and consideration.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support weather station, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to forces that are consistent with building code structural design requirements.

C. Fastening Hardware:

1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.

D. Corrosive Environments:

1. Use products that are suitable for environment to which they are subjected.
2. If possible, avoid or limit use of materials in corrosive environments.
3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
4. Where components are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification.

3.5 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:

1. Calibrate each weather station installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment used for calibrating. Submit procedures before calibration and adjustment.
3. For each analog signal, make a three-point test of calibration for both linearity and accuracy.
4. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed weather stations shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed weather station with a signal accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each weather station according to instrument instruction manual supplied by manufacturer.
8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistance source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Prepare test and inspection reports.

3.7 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.

3.8 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[three] [six] [nine] [12]** months' full maintenance by **[skilled employees of systems and equipment Installer] [manufacturer's authorized service representative]**. Include **[monthly] [quarterly] [semiannual] [annual]** preventive maintenance, repair, or replacement of worn or defective components, lubrication, cleaning, and adjusting as required for proper **<Insert equipment>** operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain weather stations.
- B. Provide a complete set of instructional videos covering each product specified and installed and showing the following:
1. Software programming.
 2. Calibration and test procedures.
 3. Operation and maintenance requirements and procedures.
 4. Troubleshooting procedures.
- C. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- D. Record videos on DVD disks.
- E. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.43

SECTION 230993 - SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes control sequences for HVAC systems, subsystems, and equipment.
- B. Related Sections include the following:
 - 1. Section 230900 "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

1.3 DEFINITIONS

- A. DDC: Direct digital control.
- B. VAV: Variable air volume.

1.4 HEATING CONTROL SEQUENCES

- A. Heating-Water Supply Temperature Control:
 - 1. Input Device: [**Thermostat**] [**Thermistor temperature sensor**] [**Resistance temperature sensor**].
 - 2. Output Device: Control valve.
 - 3. Action: Modulate control valve to maintain heating-water supply temperature.
 - 4. Display:
 - a. Heating-water supply temperature.
 - b. Heating-water supply temperature set point.
 - c. Control-valve position.
- B. Heating-Water Supply Temperature Reset:
 - 1. Input Device: [**Electric, outdoor-air-reset controller**] [**Outdoor-air sensor**].
 - 2. Output Device: [**Unitary controller**] [**DDC system software**].
 - 3. Action: Reset heating-water supply temperature in straight-line relationship with

outdoor-air temperature for the following conditions:

- a. [195 deg F (90 deg C)] <Insert highest heating temperature> heating water when outdoor-air temperature is [minus 30 deg F (minus 35 deg C)] <Insert lowest outdoor-air temperature>.
- b. [130 deg F (54 deg C)] <Insert lowest heating temperature> heating water when outdoor-air temperature is 75 deg F (24 deg C).
- c. [150 deg F (65 deg C)] <Insert temperature> minimum, heating-water temperature.

4. Display:

- a. Outdoor-air temperature.
- b. Heating-water supply temperature.
- c. Heating-water supply temperature set point.

C. Control Primary Circulating Pump(s):

1. Input Device: [Thermostat] [DDC system].
2. Output Device: [Starter] [DDC system command to starter] relay.
3. Action: Energize pump(s) at outdoor-air temperatures below [65 deg F (18 deg C)] <Insert temperature>.
4. Display:
 - a. Outdoor-air temperature.
 - b. Operating status of primary circulating pump(s).

1.5 CENTRAL REFRIGERATION EQUIPMENT SEQUENCES

A. Start and Stop Condenser-Water Pump(s):

1. Enable: Allow pump to start when water is in cooling tower:
 - a. Input Device: Water pressure transducer.
 - b. Output Device: Hard wired through motor starter[; DDC system binary output].
 - c. Action: Confirm water in cooling-tower sump.
2. Enable: When outdoor-air temperature conditions are met:
 - a. Input Device: [Space thermostat] [DDC system outdoor-air temperature].
 - b. Output Device: Hard wired through motor starter[; DDC system binary output].
 - c. Action: Confirm outdoor-air temperature is above 50 deg F (10 deg C).
3. Enable: When demand conditions are met:
 - a. Input Device: DDC system software demand.
 - b. Action: Confirm cooling demand from ventilation system(s).

4. Initiate:
 - a. Input Device: **[Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Time clock] [Binary output]**.
 - c. Action: Energize pump(s).

5. Display:
 - a. Low-level cooling-tower sump alarm.
 - b. Outdoor-air temperature.
 - c. Cooling (software) demand indication.
 - d. Time and time schedule.
 - e. Condenser-water pump(s) on-off status.
 - f. Condenser-water pump(s) on-off indication.

- B. Start and Stop Chilled-Water Pump(s):
 1. Input Device: Flow switch in condenser-water circuit.
 2. Output Device: **[Starter] [DDC system command to starter]** relay.
 3. Action: Energize pump(s).
 4. Display:
 - a. Chilled-water flow indication.
 - b. Chilled-water pump(s) on-off status.
 - c. Chilled-water pump(s) on-off indication.

- C. Start and Stop Cooling-Tower Fans(s):
 1. Input Device: Flow switch in condenser-water circuit.
 2. Output Device: **[Starter] [DDC system command to starter]** relay.
 3. Action: Energize fan(s).
 4. Display:
 - a. Condenser-water flow indication.
 - b. Cooling-tower fan(s) on-off indication.

- D. Start and Stop Refrigeration Machine(s):
 1. Input Device: Flow switch in condenser-water circuit. **[Flow switch in chilled-water circuit.]**
 2. Output Device: **[Refrigeration] [DDC system command to refrigeration]** machine terminal strip.
 3. Action: Energize refrigeration machine(s) internal control circuit.
 4. Display:
 - a. Condenser-water flow indication.
 - b. Chilled-water flow indication.
 - c. Refrigeration machine on-off indication.
 - d. Chilled-water supply and return temperature.
 - e. Chilled-water temperature control-point adjustment.

E. Start and Stop Chiller(s):

1. Input Device: Flow switches in condenser-water and chilled-water circuit.
2. Output Device: **[Chiller] [DDC system command to chiller]** terminal strip.
3. Action: Energize chiller internal control circuit.
4. Display:
 - a. Condenser-water flow indication.
 - b. Chilled-water flow indication.
 - c. Chiller(s) on-off status.
 - d. Chiller(s) on-off indication.
 - e. Chilled-water supply and return temperature.
 - f. Chilled-water temperature control-point adjustment.

F. Alternate Chiller(s):

1. Input Device: **[Electric alternator] [DDC system software]**.
2. Output Device: **[Chiller] [DDC system command to chiller]** terminal strip.
3. Action: Operate chiller(s) on lead-lag, alternating each startup.
4. Action: Adding and dropping chiller(s) as follows: **<Insert sequence and parameters.>**
5. Display: Chiller(s) on-off indication.

G. Alarm Chiller(s) Start Failure:

1. Input Device: Chiller **[control panel terminal strip contact] [software signal]**.
2. Output Device: **[Analog control panel] [DDC system alarm]**.
3. Action: Signal alarm.
4. Display: Chiller "failure-to-start" indication.

H. Chilled-Water Level:

1. Input Device: Expansion tank **[level switch] [liquid sensor]**.
2. Output Device: **[Electric relay signal to alarm panel] [DDC system alarm]**.
3. Action: Signal alarm.
4. Display: Expansion tank low-level alarm.

I. Chilled-Water Supply Temperature:

1. Input Device: Temperature **[sensor] [transmitter]** in common chilled-water supply piping.
2. Output Device: **[Integral chiller controls] [DDC system signal to chiller control panel]**.
3. Action: Maintain constant leaving chilled-water temperature[**reset according to highest cooling demand**].
 - a. Display: Chilled-water supply temperature.

J. Condenser-Water Temperature:

1. Input Device: Temperature **[sensor] [transmitter]** in cooling-tower sump.

2. Output Device: [**Bypass control valve**] [**Cooling-tower fan starter relay**] [**DDC system command to cooling-tower fan starter relay**].
 3. Action: Modulate control valve open to cooling tower and closed to bypass and cycle tower fan(s) [**on and off**][**and to low speed and then to high speed**] to maintain [**65 deg F (18 deg C)**] [**70 deg F (21 deg C)**] sump temperature.[**Close valve when unoccupied.**]
 4. Display:
 - a. Condenser-water sump (return) control-point temperature.
 - b. Condenser-water sump (return) temperature.
 - c. Control-valve position.
 - d. Cooling-tower fan(s) on-off indication.
 - e. Condenser-water supply temperature.
- K. Cooling-Tower Sump Heater:
1. Input Device: Sump temperature [**sensor**] [**transmitter**].
 2. Output Device: [**Electric relay**] [**DDC system command to electric relay**] [**and solenoid valve**].
 3. Action: Energize sump heater[; **drain sump on low temperature**].
 4. Display:
 - a. Cooling-tower sump temperature.
 - b. Cooling-tower sump heater on-off indication.
 - c. Cooling-tower dump indication.
- L. Operator Station Display: Indicate the following on operator workstation display terminal:
1. DDC system graphic.
 2. DDC system status, on-off.
 3. Low-level cooling-tower sump alarm.
 4. Outdoor-air temperature.
 5. Cooling (software) demand indication.
 6. Time and time schedule.
 7. Condenser-water pump(s) on-off status.
 8. Condenser-water pump(s) on-off indication.
 9. Condenser-water flow indication.
 10. Chilled-water pump(s) on-off status.
 11. Chilled-water pump(s) on-off indication.
 12. Cooling-tower fan(s) on-off indication.
 13. Chilled-water flow indication.
 14. Refrigeration machine on-off indication.
 15. Chilled-water supply temperature.
 16. Chilled-water return temperature.
 17. Chilled-water temperature control-point adjustment.
 18. Chiller(s) on-off status.
 19. Chiller(s) on-off indication.
 20. Chiller "failure-to-start" indication.
 21. Expansion tank low-level alarm.

22. Condenser-water sump (return) control-point temperature.
23. Condenser-water sump (return) temperature.
24. Condenser-water control-valve position.
25. Cooling-tower fan(s) on-off indication.
26. Condenser-water supply temperature.
27. Cooling-tower sump temperature.
28. Cooling-tower sump heater on-off indication.
29. Cooling-tower dump indication.
30. Chilled-water pressure drop through chiller.
31. Entering condenser-water temperature.
32. Leaving condenser-water temperature.
33. Condenser-water pressure drop through chiller.
34. Chiller condenser-water supply and return temperature.
35. Chiller chilled-water supply and return temperature.
36. System capacity in tons.

1.6 AIR-HANDLING-UNIT CONTROL SEQUENCES

A. Start and Stop Supply Fan(s):

1. Enable: Freeze Protection:
 - a. Input Device: Duct-mounted averaging element thermostat, located before supply fan.
 - b. Output Device: Hard wired through motor starter; **[analog alarm panel]** **[DDC system alarm]**.
 - c. Action: Allow start if duct temperature is above **37 deg F (3 deg C)**; signal alarm if fan fails to start as commanded.
2. Enable: High-Temperature Protection:
 - a. Input Device: Duct-mounted thermostat, located in return air.
 - b. Output Device: Hard wired through motor starter; **[analog alarm panel]** **[DDC system alarm]**.
 - c. Action: Allow start if duct temperature is below **300 deg F (150 deg C)**.
3. Enable: Smoke Control:
 - a. Input Device: Duct-mounted smoke detector, located in **[return]** **[supply]** air.
 - b. Output Device: Hard wired through motor starter; **[analog alarm panel]** **[DDC system alarm]**.
 - c. Action: Allow start if duct is free of products of combustion.
4. Initiate: Occupied Time Schedule:
 - a. Input Device: **[Time clock]** **[DDC system time schedule]**.
 - b. Output Device: **[Time clock]** **[Binary output]** to motor starter.
 - c. Action: Energize fan(s).

5. Initiate: Unoccupied Time Schedule:
 - a. Input Device: **[Room thermostat] [DDC system demand]**.
 - b. Output Device: **[Room thermostat] [Binary output]** to motor starter.
 - c. Action: Energize fan(s).
 6. Unoccupied Ventilation:
 - a. Input Device: **[Time clock and room thermostat] [DDC system time schedule and output]**.
 - b. Output Device: **[Room thermostat] [DDC system binary output]** to motor starter.
 - c. Action: Cycle fan(s) during unoccupied periods.
 7. Display: Supply-fan on-off indication.
- B. Supply Fan(s) Variable-Volume Control:
1. Occupied Time Schedule:
 - a. Input Device: **[Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Time clock] [Binary output]**.
 - c. Action: Enable control.
 2. Volume Control:
 - a. Input Device: **[Static-pressure transmitter] [Differential-pressure switch]** sensing supply-duct static pressure referenced to conditioned-space static pressure.
 - b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer]** to modulating damper actuator. Set inlet guide vanes to **[minimum] [closed]** position when fan is stopped.
 - c. Action: Maintain constant supply-duct static pressure.
 3. Volume Control:
 - a. Input Device: **[Static-pressure transmitter] [Differential-pressure switch]** sensing supply-duct static pressure referenced to conditioned-space static pressure.
 - b. Output Device: **[Receiver controller] [DDC system analog output]** to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
 - c. Action: Maintain constant supply-duct static pressure.
 4. High Pressure:
 - a. Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.
 - b. Output Device: **[Receiver controller] [DDC system binary output]** to **[alarm panel] [motor starter]**.

- c. Action: Stop fan and signal alarm when static pressure rises above excessive-static-pressure set point.
- 5. Display:
 - a. Supply-fan-discharge static-pressure indication.
 - b. Supply-fan-discharge static-pressure set point.
 - c. Supply-fan airflow rate.
 - d. Supply-fan [**inlet vane position**] [**speed**].
- C. Start and Stop Return Fan(s):
 - 1. Initiate: Occupied Time Schedule:
 - a. Input Device: [**Time clock**] [**DDC system time schedule**].
 - b. Output Device: [**Time clock**] [**Binary output**] to motor starter.
 - c. Action: Energize fans when supply fans are energized.
 - 2. Initiate: Unoccupied Time Schedule:
 - a. Input Device: [**Room thermostat**] [**DDC system demand**].
 - b. Output Device: [**Room thermostat**] [**Binary output**] to motor starter.
 - c. Action: Energize fans when supply fans are energized.
 - 3. Unoccupied Ventilation:
 - a. Input Device: [**Time clock and room thermostat**] [**DDC system time schedule and output**].
 - b. Output Device: [**Room thermostat**] [**DDC system binary output**] to motor starter.
 - c. Action: Cycle fan(s) during unoccupied periods.
 - 4. Display: Return-fan on-off indication.
- D. Return Fan(s) Variable-Volume Control:
 - 1. Occupied Time Schedule:
 - a. Input Device: [**Time clock**] [**DDC system time schedule**].
 - b. Output Device: [**Time clock**] [**Binary output**].
 - c. Action: Enable control.
 - 2. Volume Control:
 - a. Input Device: [**Static-pressure transmitter**] [**Differential-pressure switch**] sensing building static pressure referenced to outdoor static pressure.
 - b. Output Device: [**Receiver controller**] [**DDC system analog output**] [**DDC system analog output to digital-to-pneumatic transducer**] to modulating damper actuator. Set inlet guide vanes to [**minimum**] [**closed**] position when fan is stopped.
 - c. Action: Maintain constant building static pressure.

3. Volume Control:
 - a. Input Device: [**Static-pressure transmitter**] [**Differential-pressure switch**] sensing building static pressure referenced to outdoor static pressure.
 - b. Output Device: [**Receiver controller**] [**DDC system analog output**] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
 - c. Action: Maintain constant building static pressure.
 4. Display:
 - a. Return-air static-pressure indication.
 - b. Return-air static-pressure set point.
 - c. Return-fan airflow rate.
 - d. Return-fan [**inlet vane position**] [**speed**].
 - e. Building static-pressure indication.
 - f. Building static-pressure set point.
- E. Return Fan(s) Variable-Volume Control:
1. Occupied Time Schedule:
 - a. Input Device: [**Time clock**] [**DDC system time schedule**].
 - b. Output Device: [**Time clock**] [**Binary output**].
 - c. Action: Enable control.
 2. Volume Control:
 - a. Input Device: [**Static-pressure transmitter**] [**Differential-pressure switch**] sensing building static pressure referenced to outdoor static pressure.
 - b. Output Device: [**Receiver controller**] [**DDC system analog output**] [**DDC system analog output to digital-to-pneumatic transducer**] to modulating damper actuator. Set inlet guide vanes to [**minimum**] [**closed**] position when fan is stopped.
 - c. Action: Maintain constant building static pressure.
 3. Volume Control:
 - a. Input Device: [**Static-pressure transmitter**] [**Differential-pressure switch**] sensing building static pressure referenced to outdoor static pressure.
 - b. Output Device: [**Receiver controller**] [**DDC system analog output**] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
 - c. Action: Maintain constant building static pressure.
 4. Display:
 - a. Return-fan-discharge static-pressure indication.
 - b. Return-fan-discharge static-pressure set point.
 - c. Return-fan airflow rate.

d. Return-fan [**inlet vane position**] [**speed**].

F. Preheat Coil:

1. Freeze Protection:

- a. Input Device: Duct-mounted averaging element thermostat, located after preheat coil.
- b. Output Device: Hard wired through motor starter; [**analog alarm panel**] [**DDC system alarm**].
- c. Action: Allow start if duct temperature is above **33 deg F** (1 deg C).

2. Occupied Time Schedule:

- a. Input Device: [**Time clock**] [**DDC system time schedule**].
- b. Output Device: [**Time clock**] [**Binary output**] to motor starter.
- c. Action: Energize coil circulating pump(s).

3. [**Supply**] [**Discharge**]-Air Temperature:

- a. Input Device: [**Time clock and duct-mounted thermostat**] [**DDC system time schedule and electronic temperature sensor**].
- b. Output Device: Modulating control valve.
- c. Action: Maintain air temperature set point of **55 deg F** (13 deg C).

4. Unoccupied Time Schedule:

- a. Input Device: [**Time clock and duct-mounted thermostat mounted in outdoor air**] [**DDC system time schedule and outdoor-air temperature**].
- b. Output Device: [**Time clock**] [**Binary output**] to motor starter.
- c. Action: Energize coil circulating pump(s) when outdoor-air temperature falls below **35 deg F** (2 deg C).

5. Display:

- a. Preheat-coil air-temperature indication.
- b. Preheat-coil air-temperature set point.
- c. Preheat-coil pump operation indication.
- d. Preheat-coil control-valve position.

G. Mixed-Air Control:

1. Occupied Time Schedule:

- a. Input Device: [**Time clock**] [**DDC system time schedule**].
- b. Output Device: [**Pneumatic relay**] [**DDC system output**].
- c. Action: Enable control.

2. Minimum Position:

- a. Input Device: [**Time clock**] [**DDC system time schedule**].

- b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer]** to modulating damper actuator(s).
 - c. Action: Open **[minimum outdoor-air dampers] [outdoor-air dampers to minimum position]**.
 3. Heating Reset:
 - a. Input Device: **[Room thermostat] [DDC system software]**.
 - b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer]** to modulating damper actuator(s).
 - c. Action: **[Close minimum outdoor-air dampers] [Set outdoor-air dampers to minimum position]**.
 4. **[Supply] [Mixed]-Air Temperature:**
 - a. Input Device: **[Duct-mounted thermostat] [Electronic temperature sensor]**.
 - b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer]** to modulating damper actuator(s).
 - c. Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of **55 deg F (13 deg C)**.
 5. Cooling Reset:
 - a. Input Device: Outdoor- and return-air, duct-mounted **[thermostats] [electronic temperature sensors]**.
 - b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer]** to damper actuator(s).
 - c. Action: Set outdoor-air dampers to minimum position when outdoor-air **[temperature exceeds return-air temperature] [enthalpy exceeds return-air enthalpy]**.
 6. Unoccupied Time Schedule:
 - a. Input Device: **[Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer]** to modulating damper actuator(s).
 - c. Action: Position outdoor- and relief-air dampers closed and return-air dampers open.
 7. Display:
 - a. Mixed-air-temperature indication.
 - b. Mixed-air-temperature set point.
 - c. Mixed-air damper position.

H. Humidifier:

1. Occupied Time Schedule:

- a. Input Device: **[Time clock] [DDC system time schedule]** and airflow switch
- b. Output Device: **[Pneumatic relay] [DDC system output]**.
- c. Action: Enable control.

2. Humidity:

- a. Input Device: **[Room humidistat] [Return-air, duct-mounted humidistat] [DDC system]**.
- b. Output Device: **[Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] [enables humidifier] [modulates control valve to maintain humidity] [cycles pump to maintain humidity] [cycles pump and modulates control valve to maintain humidity]** in straight-line relationship for the following conditions:
 - 1) 20 percent when outdoor-air temperature is **[minus 30 deg F (minus 35 deg C)] <Insert temperature>**.
 - 2) 40 percent when outdoor-air temperature is **[75 deg F (24 deg C)] <Insert temperature>**.
- c. Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of **[55 deg F (13 deg C)] <Insert temperature>**.

3. Display:

- a. Relative humidity indication.
- b. Relative humidity set point.
- c. Relative humidity control-valve position.

I. Filters: During occupied periods, when fan is running, differential air-pressure transmitters exist.

1. Occupied Time Schedule:

- a. Input Device: **[Time clock] [DDC system time schedule]**.
- b. Output Device: **[Electric relay] [DDC system output]**.
- c. Action: Enable control.

2. Differential Pressure:

- a. Input Device: **[Differential-pressure switches] [Pressure transmitter]**.
- b. Output Device: **[Analog alarm panel] [DDC system alarm]**.
- c. Action: Signal alarm on low- and high-pressure conditions.

3. Display:

- a. Filter air-pressure-drop indication.
- b. Filter low-air-pressure set point.
- c. Filter high-air-pressure set point.

J. **[Hydronic] [Steam]** Heating Coil:

1. Occupied Time Schedule:

- a. Input Device: **[Time clock] [DDC system time schedule]**.
- b. Output Device: **[Time clock] [Binary output]**.
- c. Action: Enable control.

2. **[Supply] [Discharge]**-Air Temperature:

- a. Input Device: **[Duct-mounted thermostat] [Electronic temperature sensor]**.
- b. Output Device: Normally **[open] [closed]** modulating control valve.
- c. Action: Maintain supply-air temperature set point of **55 deg F (13 deg C)**.

3. Temperature Reset:

- a. Input Device: **[Duct-mounted thermostat] [Electronic temperature sensor]** in return air.
- b. Output Device: **[Direct to receiver controller] [DDC system]** in straight-line relationship for the following conditions:

- 1) **[65 deg F (18 deg C)] <Insert temperature>** when return-air temperature is **[70 deg F (21 deg C)] <Insert temperature>**.
- 2) **[55 deg F (13 deg C)] <Insert temperature>** when return-air temperature is **[75 deg F (24 deg C)] <Insert temperature>**.

- c. Action: Reset supply-air temperature set point of **55 deg F (13 deg C)**.

4. Temperature Reset:

- a. Input Device: **[Load analyzer] [DDC system]** with input from room **[thermostats] [temperature sensors]**.
- b. Output Device: **[Direct to receiver controller] [DDC system]**.
- c. Action: Reset supply-air temperature in response to greatest heating demand.

5. Unoccupied Time Schedule:

- a. Input Device: **[Time clock and room thermostat] [DDC system time schedule and output]**.
- b. Output Device: **[Room thermostat (cycling fan)] [DDC system binary output]**.
- c. Action: **[Enable normal control] [Return valve to normal position]** when fan is cycled on.

6. Display:

- a. Fan-discharge air-temperature indication.
- b. Fan-discharge air-temperature set point.
- c. Heating-coil air-temperature indication.
- d. Heating-coil air-temperature set point.
- e. Heating-coil pump operation indication.
- f. Heating-coil control-valve position.
- g. Hot-deck air-temperature indication.
- h. Hot-deck air-temperature set point.

K. Hydronic Cooling Coil:

1. Occupied Time Schedule:

- a. Input Device: **[Time clock] [DDC system time schedule]**.
- b. Output Device: **[Time clock] [Binary output]**.
- c. Action: Enable control.

2. **[Supply] [Discharge]-Air Temperature:**

- a. Input Device: **[Duct-mounted thermostat] [Electronic temperature sensor]**.
- b. Output Device: Normally **[open] [closed]** modulating control valve.
- c. Action: Maintain supply-air temperature set point of **55 deg F (13 deg C)**.

3. Temperature Reset:

- a. Input Device: **[Duct-mounted thermostat] [Electronic temperature sensor]** in return air.
- b. Output Device: **[Direct to receiver controller] [DDC system]** in straight-line relationship for the following conditions:
 - 1) **[65 deg F (18 deg C)] <Insert temperature>** when return-air temperature is **[70 deg F (21 deg C)] <Insert temperature>**.
 - 2) **[55 deg F (13 deg C)] <Insert temperature>** when return-air temperature is **[75 deg F (24 deg C)] <Insert temperature>**.
- c. Action: Reset supply-air temperature set point of **55 deg F (13 deg C)**.

4. Temperature Reset:

- a. Input Device: **[Load analyzer] [DDC system]** with input from room **[thermostats] [temperature sensors]**.
- b. Output Device: **[Direct to receiver controller] [DDC system]**.
- c. Action: Reset supply-air temperature in response to greatest heating demand.

5. Unoccupied Time Schedule:

- a. Input Device: **[Time clock] [DDC system time schedule]**.
- b. Output Device: **[Time clock] [Binary output]**.
- c. Action: Disable control.

6. Display:
 - a. Fan-discharge air-temperature indication.
 - b. Fan-discharge air-temperature set point.
 - c. Cooling-coil air-temperature indication.
 - d. Cooling-coil air-temperature set point.
 - e. Cooling-coil control-valve position.
 - f. Cold-deck air-temperature indication.
 - g. Cold-deck air-temperature set point.

- L. Multizone Damper Control:
 1. Occupied Time Schedule:
 - a. Input Device: **[Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Time clock] [Binary output]**.
 - c. Action: Enable control.

 2. Room Temperature:
 - a. Input Device: **[Room thermostat] [Electronic temperature sensor]**.
 - b. Output Device: Damper actuator.
 - c. Action: Maintain room temperature.

 3. Display:
 - a. Room temperature indication.
 - b. Room temperature set point.
 - c. Multizone damper position.

- M. Coordination of Air-Handling Unit Sequences: Ensure that preheat, mixed-air, heating-coil, and cooling-coil controls have common inputs and do not overlap in function.

- N. Operator Station Display: Indicate the following on operator workstation display terminal:
 1. DDC system graphic.
 2. DDC system on-off indication.
 3. DDC system occupied/unoccupied mode.
 4. Outdoor-air-temperature indication.
 5. Supply-fan on-off indication.
 6. Supply-fan-discharge static-pressure indication.
 7. Supply-fan-discharge static-pressure set point.
 8. Supply-fan airflow rate.
 9. Supply-fan **[inlet vane position] [speed]**.
 10. Return-fan on-off indication.
 11. Return-air static-pressure indication.
 12. Return-air static-pressure set point.
 13. Return-fan airflow rate.

14. Return-fan [**inlet vane position**] [**speed**].
15. Building static-pressure indication.
16. Building static-pressure set point.
17. Preheat-coil air-temperature indication.
18. Preheat-coil air-temperature set point.
19. Preheat-coil pump operation indication.
20. Preheat-coil control-valve position.
21. Mixed-air-temperature indication.
22. Mixed-air-temperature set point.
23. Mixed-air damper position.
24. Relative humidity indication.
25. Relative humidity set point.
26. Relative humidity control-valve position.
27. Filter air-pressure-drop indication.
28. Filter low-air-pressure set point.
29. Filter high-air-pressure set point.
30. Fan-discharge air-temperature indication.
31. Fan-discharge air-temperature set point.
32. Heating-coil air-temperature indication.
33. Heating-coil air-temperature set point.
34. Heating-coil pump operation indication.
35. Heating-coil control-valve position.
36. Hot-deck air-temperature indication.
37. Hot-deck air-temperature set point.
38. Cooling-coil air-temperature indication.
39. Cooling-coil air-temperature set point.
40. Cooling-coil control-valve position.
41. Cold-deck air-temperature indication.
42. Cold-deck air-temperature set point.
43. Room temperature indication.
44. Room temperature set point.
45. Multizone damper position.

1.7 TERMINAL UNIT OPERATING SEQUENCE

A. Cabinet Unit Heater, [**Hydronic**] [**Steam**]:

1. Room Temperature:
 - a. Input Device: [**Room thermostat**] [**Electronic temperature sensor**].
 - b. Output Device: [**Room thermostat**] [**DDC system binary output**].
 - c. Action: Cycle fan to maintain temperature.
2. Low-Temperature Safety:
 - a. Input Device: Line-voltage, on-off thermostat, pipe mounted.
 - b. Output Device: Hard wired.
 - c. Action: Stop fan when [**return heating-water**] [**condensate**] temperature falls below **35 deg F (2 deg C)**.

3. Display:
 - a. Room temperature indication.
 - b. Room temperature set point.

- B. Cabinet Unit Heater, Electric: Room thermostat cycles fan and sequences stages of heating.

- C. Unit Heater, **[Hydronic]** **[Steam]**:
 1. Room Temperature:
 - a. Input Device: **[Room thermostat]** **[Electronic temperature sensor]**.
 - b. Output Device: **[Room thermostat]** **[DDC system binary output]**.
 - c. Action: Cycle fan to maintain temperature.

 2. Low-Temperature Safety:
 - a. Input Device: Line-voltage, on-off thermostat, pipe mounted.
 - b. Output Device: Hard wired.
 - c. Action: Stop fan when **[return heating-water]** **[condensate]** temperature falls below **35 deg F (2 deg C)**.

 3. Display:
 - a. Room temperature indication.
 - b. Room temperature set point.

- D. Unit Heater, Electric: Room thermostat cycles fan and sequences stages of heating.

- E. Combustion-Air Unit Heaters:
 1. Room Temperature:
 - a. Input Device: **[Room thermostat]** **[Electronic temperature sensor]**.
 - b. Output Device: **[Pneumatic]** **[Electronic]** control-valve operator.
 - c. Action: Modulate valve to maintain temperature.

 2. Display:
 - a. Room temperature indication.
 - b. Room temperature set point.
 - c. Control-valve position.

- F. Radiant Heating Cable, Electric: Room thermostat cycles power.

- G. Radiant Heating Panel, Electric: Room thermostat cycles power.

- H. Radiant Heating Panel, Hydronic:
 1. Room Temperature:

- a. Input Device: **[Room thermostat] [Electronic temperature sensor]**.
 - b. Output Device: **[Pneumatic] [Electronic]** control-valve operator.
 - c. Action: Modulate valve to maintain temperature.
 2. Display:
 - a. Room temperature indication.
 - b. Room temperature set point.
 - c. Control-valve position.
- I. Two-Pipe, Single-Coil, Fan-Coil Unit:
 1. Occupied Time Schedule:
 - a. Input Device: **[Fan switch] [Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Time clock] [Binary output]**.
 - c. Action: Start and stop fan and enable control.
 2. Room Temperature:
 - a. Input Device: **[Room thermostat] [Electronic temperature sensor]** in **[room] [return air]**.
 - b. Output Device: **[Pneumatic] [Electronic]** control-valve operator.
 - c. Action: Modulate valve to maintain temperature.
 3. DDC System Changeover:
 - a. Input Device: **[Thermostat] [Electronic temperature sensor] [in supply-water] [on supply-water piping] [DDC system]**.
 - b. Output Device: **[Hard-wired relay] [DDC system software]**.
 - c. Action: Reverse control-valve action to switch from heating to cooling.
 4. Display:
 - a. DDC system graphic.
 - b. DDC system on-off indication.
 - c. DDC system occupied/unoccupied mode.
 - d. Room temperature indication.
 - e. Room temperature set point.
 - f. Control-valve position.
 - g. Supply-water temperature indication.
- J. Four-Pipe, Hydronic Fan-Coil Unit:
 1. Occupied Time Schedule:
 - a. Input Device: **[Fan switch] [Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Time clock] [Binary output]**.
 - c. Action: Start and stop fan, and enable control.
 2. Room Temperature:

- a. Input Device: **[Room thermostat] [Electronic temperature sensor]**.
 - b. Output Device: **[Pneumatic] [Electronic]** control-valve operators.
 - c. Action: Modulate multiport control valves to maintain temperature.
3. Display:
- a. DDC system graphic.
 - b. DDC system on-off indication.
 - c. DDC system occupied/unoccupied mode.
 - d. Room temperature indication.
 - e. Room temperature set point.
 - f. Control-valve position.
- K. Unit Ventilator: Room thermostat modulates heating-and-cooling control valves; airstream thermostats modulate outdoor- and return-air dampers as follows:
1. Occupied Time Schedule:
 - a. Input Device: **[Fan switch] [Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Time clock] [Binary output]**.
 - c. Action: Start and stop fan, move outdoor- and return-air dampers to **[minimum] [maximum]** outdoor-air position, and enable control.
 2. Room Temperature - Valves:
 - a. Input Device: **[Room thermostat] [Electronic temperature sensor]**.
 - b. Output Device: **[Pneumatic] [Electronic]** control-valve operators.
 - c. Action: Modulate heating-water supply control valve and chilled-water supply control valve in sequence to maintain temperature.
 3. Room Temperature - Dampers:
 - a. Input Device: **[Thermostat] [Electronic temperature sensor]** in mixed air.
 - b. Output Device: **[Pneumatic] [Electronic]** control damper actuators.
 - c. Action: Modulate outdoor- and return-air dampers to maintain temperature.
 4. Supply-Air Temperature Limit:
 - a. Input Device: **[Thermostat] [Electronic temperature sensor]** in discharge air.
 - b. Output Device: **[Pneumatic] [Electronic]** control-valve operators and control damper actuators.
 - c. Action: Override room thermostat to control valves and dampers to prevent discharge air from dropping below a minimum set point.
 5. Warm-up Cycle:
 - a. Input Device: **[Time clock] [DDC system time schedule]**.
 - b. Output Device: **[Hard-wired relay] [DDC system binary output]**.
 - c. Action: Open heating-water supply control valve, close outdoor-air damper, and open return-air damper.

6. Display:
 - a. DDC system graphic.
 - b. DDC system on-off indication.
 - c. DDC system occupied/unoccupied mode.
 - d. Room temperature indication.
 - e. Room temperature set point.
 - f. Control-valve position.
 - g. Damper position.

- L. Heating Coils, [**Hydronic**] [**Steam**]:
 1. Room Temperature:
 - a. Input Device: [**Room thermostat**] [**Electronic temperature sensor**].
 - b. Output Device: [**Pneumatic**] [**Electronic**] [**Electric**] control-valve operators.
 - c. Action: [**Modulate**] [**Cycle**] valve to maintain temperature.

 2. Display:
 - a. Room temperature indication.
 - b. Room temperature set point.
 - c. Control-valve position.

- M. Heating Coils, Electric: Room thermostat [**cycles coils**] [**sequences stages of heating**].

- N. Radiators and Convectors, [**Hydronic**] [**Steam**]:
 1. Occupancy:
 - a. Input Device: Occupancy sensor.
 - b. Output Device: DDC system binary output.
 - c. Action: Report occupancy and enable occupied temperature set point.

 2. Room Temperature:
 - a. Input Device: [**Room thermostat**] [**Electronic temperature sensor**].
 - b. Output Device: [**Pneumatic**] [**Electronic**] [**Electric**] control-valve operators.
 - c. Action: [**Modulate**] [**Cycle**] valve to maintain temperature.
 - 1) Occupied Temperature: **75 deg F** (24 deg C).
 - 2) Unoccupied Temperature: **65 deg F** (18 deg C).

 3. Display:
 - a. Room/area served.
 - b. Room temperature indication.
 - c. Room temperature set point.
 - d. Room temperature set point, occupied.
 - e. Room temperature set point, occupied standby.

- f. Room temperature set point, unoccupied.
 - g. Control-valve position as percent open.
- O. Radiators and Convectors, Electric: Room thermostat [**cycles coils**] [**sequences stages of heating**].
- P. Constant-Volume, Terminal Air Units, [**Hydronic**] [**Steam**]:
- 1. Occupancy:
 - a. Input Device: Occupancy sensor.
 - b. Output Device: DDC system binary output.
 - c. Action: Report occupancy and enable occupied temperature set point.
 - 1) Occupied Temperature: **75 deg F** (24 deg C).
 - 2) Unoccupied Temperature: **65 deg F** (18 deg C).
 - 2. Room Temperature:
 - a. Input Device: [**Room thermostat**] [**Electronic temperature sensor**].
 - b. Output Device: [**Pneumatic**] [**Electronic**] [**Electric**] control-valve operators.
 - c. Action: [**Modulate**] [**Cycle**] valve to maintain temperature.
 - 3. Display:
 - a. Room/area served.
 - b. Room occupied/unoccupied.
 - c. Room temperature indication.
 - d. Room temperature set point.
 - e. Room temperature set point, occupied.
 - f. Room temperature set point, unoccupied.
 - g. Control-valve position as percent open.
- Q. VAV, Terminal Air Units with [**Hydronic**] [**Steam**] Coils:
- 1. Occupancy:
 - a. Input Device: Occupancy sensor.
 - b. Output Device: DDC system binary output.
 - c. Action: Report occupancy and enable occupied temperature set point.
 - 1) Occupied Temperature: **75 deg F** (24 deg C).
 - 2) Unoccupied Temperature: **65 deg F** (18 deg C).
 - 2. Room Temperature:
 - a. Input Device: [**Room thermostat**] [**Electronic temperature sensor**].
 - b. Output Device: [**Pneumatic**] [**Electronic**] damper actuators and control-valve operators.
 - c. Action: Modulate damper and valve to maintain temperature.

- 1) Sequence damper from full open to minimum position, then valve from closed to fully open.
3. Display:
- a. Room/area served.
 - b. Room occupied/unoccupied.
 - c. Room temperature indication.
 - d. Room temperature set point.
 - e. Room temperature set point, occupied.
 - f. Room temperature set point, unoccupied.
 - g. Air-damper position as percent open.
 - h. Control-valve position as percent open.
- R. Dual-Duct, VAV, Terminal Air Units:
1. Occupancy:
 - a. Input Device: Occupancy sensor.
 - b. Output Device: DDC system binary output.
 - c. Action: Report occupancy and enable occupied temperature set point.
 - 1) Occupied Temperature: 75 deg F (24 deg C).
 - 2) Unoccupied Temperature: 65 deg F (18 deg C).
 2. Room Temperature:
 - a. Input Device: **[Room thermostat] [Electronic temperature sensor]**.
 - b. Output Device: **[Pneumatic] [Electronic]** damper actuators.
 - c. Action: Modulate dampers to maintain temperature.
 - 1) Sequence when space temperature is below set point: Close VAV damper to minimum position, open hot-deck dampers and close cold-deck dampers, then open VAV damper.
 - 2) Sequence when space temperature is above set point: Close VAV damper to minimum position, close hot-deck dampers and open cold-deck dampers, then open VAV damper.
 3. Display:
 - a. Room/area served.
 - b. Room occupied/unoccupied.
 - c. Room temperature indication.
 - d. Room temperature set point.
 - e. Room temperature set point, occupied.
 - f. Room temperature set point, unoccupied.
 - g. VAV damper position as percent open.
 - h. Hot-deck damper position as percent open.
 - i. Cold-deck damper position as percent open.

1.8 VENTILATION SEQUENCES

- A. Combustion-Air, Makeup Unit Control, Electric: Start fan when served appliance burner starts; room thermostat sequences stages of heating.
- B. Combustion-Air, Makeup Unit Control, [**Hydronic**] [**Steam**]: Start fan when served appliance burner starts; room thermostat [**cycles**] [**modulates**] control valve.
- C. Gravity Roof Ventilator: [**Occupancy sensor**] [**Room thermostat**] opens dampers.
- D. Exhaust Fan: [**Occupancy sensor**] [**Interlock with light switch**] [**Room thermostat**] cycles fan.
- E. Kitchen Exhaust Fan: Occupancy sensor starts fan and energizes makeup air unit.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230993

SECTION 230993.11 - SEQUENCE OF OPERATIONS FOR HVAC DDC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes control sequences for DDC for HVAC systems, subsystems, and equipment.
- B. Related Requirements:
 - 1. Section 230923 "DDC Systems for HVAC" for control equipment.

1.3 DEFINITIONS

- A. Analog Output: Proportional output signal (zero- to 10-V dc, 4 to 20 mA).
- B. Binary Output: On/off output signal or contact closure.
- C. DDC: Direct digital control.
- D. Digital Output: Data output that must be interpreted digitally.

1.4 ACTION SUBMITTALS

- A. Product Data:
 - 1. An instrumentation list for each controlled system. Label each element of the controlled system in table format. Show, in the table element name, type of device, manufacturer, model number, and control device product data sheet number.
 - 2. A complete description of the operation of the control system, including sequences of operation. Include and reference a schematic diagram of the controlled system.
- B. Shop Drawings:
 - 1. Riser diagrams showing control network layout, communication protocol, and wire types.

2. Schematic diagram of each controlled system. Include all control points labeled with point names shown or listed. Show the location of control elements in the system.
3. Wiring diagram for each controlled system. Show all control elements labels. Where a control element is the same as that shown on the control system schematic, label with the same name. Label all terminals.

1.5 HEATING CONTROL SEQUENCES

A. Control Circulating Pump(s):

1. Input Device:
 - a. Device: [**Air-temperature sensor**] [or] [**air-temperature sensor with air-temperature RTD transmitter**] <Insert device>.
 - b. Location: [**Outdoor-air**] [**Room**] <Insert location>.
 - c. Transference: DDC controller.
2. Output Device:
 - a. Device: Command to electric relay.
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
3. Action:
 - a. Energize pump(s) at outdoor-air temperatures below [**65 deg F (18 deg C)**] <Insert temperature>.
 - b. Energize pump(s) at room temperatures below [**72 deg F (22 deg C)**] <Insert temperature>.
 - c. Enable [**additional circulating pump(s)**] [, **alternate pump(s)**] [, **heating-water supply temperature control**] [and] [, **heating-water supply temperature reset**] control sequences.

B. Additional Circulating Pump(s):

1. Input Device:
 - a. Device: Liquid pressure differential [**switch**] [**transmitter**].
 - b. Location: Between the primary supply and return piping.
 - c. Transference: DDC controller.
2. Output Device:
 - a. Device: Binary output.
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
3. Action:

- a. Energize pump(s) and maintain operation when differential pressure drops below [30] <Insert number> percent of specified pump head.
 - b. Energize pump(s) and maintain operation when differential pressure drops below <Insert pressure differential in psig (kPa)> of specified pump head.
- C. Circulating Pump(s) Failure Alarm:
1. Input Device:
 - a. Device: Liquid pressure differential [switch] [transmitter].
 - b. Location: Between the primary supply and return piping.
 - c. Transference: DDC controller.
 2. Output Device:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
 3. Action:
 - a. Signal alarm condition, no pressure differential between supply and return piping.
- D. Alternate Pump(s):
1. Input:
 - a. Device: DDC controller.
 - b. Location: Software, <Insert software definition>.
 - c. Transference: Software.
 2. Output Device:
 - a. Device: DDC controller.
 - b. Location: Motor controller.
 - c. Transference: Motor-controller relay.
 3. Action: Operate pump(s) on lead-lag, alternating each startup.
 4. Action: Operate pump(s) on lead-lag, alternating on <Insert value> run hours.
- E. Control Circulating Pump(s) Speed:
1. Input Device:
 - a. Device: Liquid pressure differential transmitter.
 - b. Location: Heating supply and return piping.
 - c. Transference: DDC controller.
 2. Output Device:
 - a. Device: Analog command.

- b. Location: Motor controller.
 - c. Transference: Variable-frequency motor controller.
 3. Action:
 - a. Control pump speed to maintain pressure differential of <Insert psig (kPa)>.
- F. Heating-Water Supply Temperature Control:
 1. Input:
 - a. Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.
 - b. Location: Heating-water supply.
 - c. Transference: DDC controller.
 2. Output:
 - a. Device: Control-valve actuator.
 - b. Location: Heating-water supply.
 - c. Transference: Control-valve actuator.
 3. Action:
 - a. Modulate control valve to maintain heating-water supply temperature.
 - b. Reset heating-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
 - 1) **[195 deg F (90 deg C)] <Insert highest heating temperature>** heating water when outdoor-air temperature is **[minus 30 deg F (minus 35 deg C)] <Insert lowest outdoor-air temperature>**.
 - 2) **[130 deg F (54 deg C)] <Insert lowest heating temperature>** heating water when outdoor-air temperature is **75 deg F (24 deg C)**.
- G. Heating-Water Supply Temperature Reset:
 1. Input:
 - a. Device: **[Liquid temperature sensor] [Liquid temperature sensor with liquid temperature transmitter]**.
 - b. Location: Outdoor-air and heating-water supply.
 - c. Transference: DDC controller.
 2. Output:
 - a. Device: DDC controller to boiler controls.
 - b. Location: Local panel.
 - c. Transference: Boiler control panel.
 3. Action:

- a. Reset heating-water supply temperature in response to greatest heating demand to maintain at least one cooling control valve 90 percent open.
- b. Reset heating-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
 - 1) [195 deg F (90 deg C)] <Insert highest heating temperature> heating water when outdoor-air temperature is [minus 30 deg F (minus 35 deg C)] <Insert lowest outdoor-air temperature>.
 - 2) [130 deg F (54 deg C)] <Insert lowest heating temperature> heating water when outdoor-air temperature is [75 deg F (24 deg C)] <Insert highest outdoor-air temperature>.
 - 3) [150 deg F (65 deg C)] <Insert temperature> minimum heating-water temperature.

H. Indicate the following on the operator's workstation display terminal:

1. DDC system graphic.
2. DDC system status, on-off.
3. Outdoor-air temperature.
4. Room temperature.
5. Circulating pump(s) on-off status (enabled or disabled).
6. Circulating pump(s) on-off indication (operating or not operating).
7. Additional circulating pump(s) pressure differential.
8. Additional circulating pump(s) pressure differential set point.
9. Additional circulating pump(s) on-off indication (operating or not operating).
10. Circulating pump(s) alarm pressure differential.
11. Circulating pump(s) alarm pressure differential set point.
12. Alarm (circulating pump(s) failure).
13. Circulating pump(s) speed pressure differential.
14. Circulating pump(s) speed pressure differential set point.
15. Circulating pump(s) speed.
16. Heating-water supply temperature.
17. Heating-water return temperature.
18. Heating-water control-valve position.
19. Heating-water supply temperature set point.
20. Heating-water control-point output valve.

1.6 CENTRAL CHILLED-WATER SYSTEM SEQUENCES

A. Central Chilled-Water System Time Schedule:

1. Occupied Time Schedule:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.

- b. Output:
 - 1) Device: DDC controller.
 - c. Action:
 - 1) Enable startup, initiation, and control.
 - 2) Energize condenser-water pumps on occupied/unoccupied cycle.
 - 3) Energize condenser-water pumps on day/night cycle.
 - 4) After chilled-water system shutdown, operate pump(s) for an additional **[3 minutes]** <Insert time>.
2. Display:
- a. Time and time schedule.
- B. Start and Stop Condenser-Water Pump(s):
- 1. Enable:
 - a. Input:
 - 1) Device: **[Level] [Liquid pressure]** switch.
 - 2) Location: **[Cooling tower sump] [Pump suction]**.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Motor-controller relay.
 - c. Action: Confirm adequate water level **[in cooling-tower sump] [at pump suction]** and energize pump(s).
 - 2. Enable:
 - a. Input:
 - 1) Device: **[Level transmitter] [or] [liquid pressure transmitter]**.
 - 2) Location: **[Cooling tower sump] [Pump suction]**.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Motor-controller relay.
 - c. Action: Confirm adequate water level **[in cooling-tower sump] [at pump suction]** at pressures above <Insert psig (kPa)> and energize pump(s).

3. Enable:
 - a. Input:
 - 1) Device: DDC controller outdoor-air temperature.
 - 2) Location: Outdoors.
 - 3) Transference: Binary output.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Confirm outdoor-air temperature is above [50 deg F (10 deg C)] <Insert temperature> and energize pump(s).
4. Enable:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Software demand.
 - 3) Transference: Binary output.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Confirm cooling demand from ventilation system(s) and energize pump(s).
5. Display:
 - a. Low-level cooling-tower sump alarm.
 - b. Outdoor-air temperature.
 - c. Cooling (software) demand indication.
 - d. Time and time schedule.
 - e. Condenser-water pump(s) on-off status (enabled or disabled).
 - f. Condenser-water pump(s) on-off indication (operating or not operating).

C. Start and Stop Chilled-Water Pump(s):

1. Input:
 - a. Device: [Flow] [Pressure differential] switch.
 - b. Location: Chilled-water piping.
 - c. Transference: [Control voltage relay] [DDC controller].

2. Output:
 - a. Device: **[Hard wired] [Binary output]**.
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
 3. Action: Energize pump(s) when the condenser-water pump(s) and system start.
 4. Display:
 - a. Chilled-water flow indication.
 - b. Chilled-water pump(s) on-off status (enabled or disabled).
 - c. Chilled-water pump(s) on-off indication (operating or not operating).
- D. Start and Stop Cooling-Tower Fan(s):
1. Input:
 - a. Device: **[Flow] [Pressure differential]** switch.
 - b. Location: Condenser-water piping.
 - c. Transference: **[Control relay] [DDC controller]**.
 2. Output:
 - a. Device: **[Hard wired] [Binary output]**.
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
 3. Action: Energize fan(s) when the condenser-water pump(s) and system start.
 4. Display:
 - a. Condenser-water flow indication.
 - b. Cooling-tower fan(s) on-off indication (operating or not operating).
- E. Start and Stop Chillers:
1. Input:
 - a. Device: **[Flow] [or] [pressure differential]** switch.
 - b. Location: Chilled-[**and condenser-**]water piping.
 - c. Transference: **[Chiller controls] [DDC controller]**.
 2. Output:
 - a. Device: **[Hard wired] [Binary output]**.
 - b. Location: Chiller control panel.
 - c. Transference: Chiller controls.
 3. Action: Energize chiller(s) internal control circuit when the condenser-water and chilled-water pump(s), and system start.
 4. Display:

- a. Condenser-water flow indication.
- b. Chilled-water flow indication.
- c. Chiller on-off indication (operating or not operating).
- d. Chilled-water supply and return temperature.
- e. Chilled-water temperature control-point adjustment.

F. Start and Stop Chiller(s):

1. Input:

- a. Device: Flow switches.
- b. Location: Condenser-water and chilled-water circuit.
- c. Transference: [**Chiller terminal strip**] [**DDC system**].

2. Output:

- a. Device: [**Hard wired**] [**Binary output**].
- b. Location: Chiller control panel.
- c. Transference: Chiller controls.

3. Action: Energize chiller internal control circuit when the condenser-water and chilled-water pump(s), and system start.

4. Display:

- a. Condenser-water flow indication.
- b. Chilled-water flow indication.
- c. Chiller(s) on-off status (enabled or disabled).
- d. Chiller(s) on-off indication (operating or not operating).
- e. Chilled-water supply and return temperature.
- f. Chilled-water temperature control-point adjustment.

G. Alternate Chiller(s):

1. Input:

- a. Device: DDC controller.
- b. Location: DDC software, <**Insert software definition**>.
- c. Transference: DDC software.

2. Output Device:

- a. Device: DDC controller command to chiller.
- b. Location: Chiller control panel.
- c. Transference: Chiller controls.

3. Action:

- a. Operate chiller(s) on lead-lag, [**alternating each startup**] [**based on adjustable runtime hour set point**].
- b. Start additional chiller when load exceeds capacity of operating chillers as follows:

- 1) When common chilled-water supply temperature exceeds set point for a **[30-minute]** <Insert time> period.
 - 2) When chiller power draw has reached its operator adjustable high limit for a **[30-minute]** <Insert time> period.
 - 3) When combination of outdoor temperature and time schedule ensure enough run-time before time schedule shutdown.
- c. Stop chiller when load capacity of operating chillers drops to less than **[110]** <Insert number> percent of capacity of next chiller to be shut down for a **[30-minute]** <Insert time> period.
4. Action: <Insert sequence and parameters>.
 5. Display: Chiller(s) on-off indication (operating or not operating).
- H. Alarm Chiller(s) Start Failure:
1. Input:
 - a. Device: **[Software signal]** **[Hardwired]** <Insert devices>.
 - b. Location: Chiller control panel.
 - c. Transference: DDC controller.
 2. Output:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
 3. Action: Signal alarm on signal from chiller control panel.
 4. Display:
 - a. Chiller "failure-to-start" indication.
 - b. <Insert chiller controller alarm points>.
- I. Start and Stop Chiller(s):
1. Input:
 - a. Device: Chiller control panel.
 - b. Location: Chiller.
 - c. Transference: DDC controller.
 2. Output:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
 3. Action: Report chiller electronic control, operating, and alarm functions.
 4. Display:
 - a. <See chiller Sections for listing>.

J. Chilled-Water Level:

1. Input:
 - a. Device: **[Level switch] [Liquid level sensor]**.
 - b. Location: Expansion tank.
 - c. Transference: DDC controller.
2. Input:
 - a. Device: Liquid gage pressure switch.
 - b. Location: Makeup-water piping downstream from pressure-reducing valve.
 - c. Transference: DDC controller.
3. Output:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
4. Action: Signal alarm on **[expansion tank low level] [low pressure]**.
5. Display: **[Expansion tank low-level] [Low-pressure]** alarm.

K. Chilled-Water Supply Temperature:

1. Input:
 - a. Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.
 - b. Location: **[Common]** chilled-water supply piping.
 - c. Transference: DDC controller.
2. Output:
 - a. Device: DDC controller signal.
 - b. Location: Local panel.
 - c. Transference: Chiller control panel.
3. Action: Maintain chilled-water supply temperature.
 - a. Reset chilled-water supply temperature in response to greatest cooling demand to maintain at least one cooling control valve 90 percent open.
 - b. Reset chilled-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
 - 1) **[44 deg F (7 deg C)] <Insert highest chilled-water temperature>** chilled water when outdoor-air temperature is **[80 deg F (26 deg C)] <Insert highest outdoor-air temperature>**.
 - 2) **[54 deg F (12 deg C)] <Insert lowest chilled-water temperature>** chilled water when outdoor-air temperature is **[60 deg F (15 deg C)] <Insert lowest operating outdoor-air temperature>**.

- c. Reset chilled-water supply temperature based on constant return chilled-water temperature of [54 deg F (12 deg C)] <Insert temperature>.
 - d. <Insert reset strategy>.
 4. Display:
 - a. Chilled-water supply temperature.
 - b. Chilled-water supply temperature set point.
- L. Condenser-Water Temperature:
 1. Input:
 - a. Device: [Liquid temperature sensor] [Liquid temperature sensor with liquid temperature transmitter].
 - b. Location: [Cooling-tower sump] [Common condenser-water supply piping].
 - c. Transference: DDC controller.
 2. Output:
 - a. Device: Analog output.
 - b. Location: DDC controller.
 - c. Transference: Control-valve actuator.
 3. Action: Modulate control valve open to cooling tower and closed to bypass to maintain when condenser-water supply temperature is above [85 deg F (29 deg C)] <Insert value> temperature set point. Modulate control valve closed to cooling tower and open to bypass when condenser-water supply temperature is below [55 deg F (13 deg C)] <Insert value> temperature set point.
 4. Output:
 - a. Device: DDC controller control relay.
 - b. Location: DDC controller.
 - c. Transference: Fan starter relay.
 5. Action: Cycle tower fan(s) on and off to maintain [55 deg F (13 deg C)] <Insert value> temperature set point.
 6. Action: Cycle tower fan(s) on and off to maintain condenser-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
 - a. [85 deg F (29 deg C)] <Insert highest condenser-water temperature> condenser water when outdoor-air temperature is [80 deg F (26 deg C)] <Insert highest outdoor-air temperature>.
 - b. [55 deg F (13 deg C)] <Insert lowest condenser-water temperature> condenser water when outdoor-air temperature is [55 deg F (13 deg C)] <Insert lowest operating outdoor-air temperature>.
 7. Output:

- a. Device: DDC controller digital output.
 - b. Location: DDC controller.
 - c. Transference: Fan variable-speed controller.
 8. Action: Cycle tower fan(s) on and modulate fan speed from minimum to maximum to maintain [55 deg F (13 deg C)] <Insert value> temperature set point.
 9. Action: Cycle tower fan(s) on and off to maintain condenser-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
 - a. [85 deg F (29 deg C)] <Insert highest condenser-water temperature> condenser water when outdoor-air temperature is [80 deg F (26 deg C)] <Insert highest outdoor-air temperature>.
 - b. [55 deg F (13 deg C)] <Insert lowest condenser-water temperature> condenser water when outdoor-air temperature is [55 deg F (13 deg C)] <Insert lowest operating outdoor-air temperature>.
 10. Display:
 - a. Control-valve(s) position.
 - b. Cooling-tower fan(s) on-off indication (operating or not operating).
 - c. Cooling-tower fan(s) speed.
 - d. Condenser-water supply temperature.
 - e. Condenser-water supply temperature set point.
 - f. Condenser-water return temperature.
- M. Cooling-Tower Sump Heater:
1. Input:
 - a. Device: [Two-stage] thermostat.
 - b. Location: Cooling tower sump.
 - c. Transference: Heater relay and control-valve actuator.
 2. Output:
 - a. Device: Heater relay and control-valve actuator.
 - b. Location: Electric heater control panel and control-valve actuator in sump drain.
 - c. Transference: Electric heater contactor and control-valve actuator.
 3. Action:
 - a. Energize sump heater if sump temperature falls below [40 deg F (4.5 deg C)] <Insert value> temperature set point.
 - b. Open control valve in sump heater drain piping if sump temperature falls below [35 deg F (1.5 deg C)] <Insert value> temperature set point.
 4. Display:
 - a. Cooling-tower sump temperature.

- b. Cooling-tower sump heater on-off indication (operating or not operating).
- c. Cooling-tower control valve open-close indication.

N. Cooling-Tower Sump Heater:

1. Input:

- a. Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.
- b. Location: Cooling tower sump.
- c. Transference: DDC controller.

2. Output:

- a. Device: Binary output.
- b. Location: Electric heater control panel **[and solenoid valve in sump drain] [and control-valve actuator in sump drain]**.
- c. Transference: Electric heater contactor **[and solenoid valve] [and control-valve actuator]**.

3. Action:

- a. Energize sump heater if sump temperature falls below **<Insert value>** temperature set point.
- b. Open control valve in sump heater drain piping if sump temperature falls below **<Insert value>** temperature set point.

4. Display:

- a. Cooling-tower sump temperature.
- b. Cooling-tower sump heater on-off indication (operating or not operating).
- c. Cooling-tower control valve open-close indication.

O. Control Circulating Pump(s) Speed:

1. Input Device:

- a. Device: **[Liquid pressure differential transmitter] [Liquid flow meter] [Liquid flow sensor]**.
- b. Location: Chilled-water supply and return piping **[and condenser-water supply and return piping]** to chiller.
- c. Transference: DDC controller.

2. Output Device:

- a. Device: DDC controller.
- b. Location: Motor controller.
- c. Transference: Pump variable-speed controller.

3. Action:

- a. Control pump speed to maintain flow through chiller.
- b. Report pressure drop and flow.

P. Circulation through Chiller:

1. Input Device:

- a. Device: [**Liquid pressure differential transmitter**] [**Liquid flow meter**] [**Liquid flow sensor**].
- b. Location: Chilled-water supply and return piping[**and condenser-water supply and return piping**] to chiller.
- c. Transference: DDC controller.

2. Output Device:

- a. Device: DDC controller.

3. Action:

- a. Report pressure drop and flow through chiller.

Q. Indicate the following on the operator's workstation display terminal:

1. DDC system graphic.
2. DDC system status, on-off.
3. Low-level cooling-tower sump alarm.
4. Outdoor temperature.
5. Cooling (software) demand indication.
6. Time and time schedule.
7. Condenser-water pump(s) on-off status (enabled or disabled).
8. Condenser-water pump(s) on-off indication (operating or not operating).
9. Condenser-water flow indication.
10. Chilled-water pump(s) on-off status (enabled or disabled).
11. Chilled-water pump(s) on-off indication (operating or not operating).
12. Cooling-tower fan(s) on-off indication (operating or not operating).
13. Chilled-water flow indication.
14. Refrigeration machine on-off indication (operating or not operating).
15. Chilled-water supply temperature.
16. Chilled-water return temperature.
17. Chilled-water temperature control-point adjustment.
18. Chiller(s) on-off status (enabled or disabled).
19. Chiller(s) on-off indication (operating or not operating).
20. Chiller "failure-to-start" indication.
21. Expansion tank low-level alarm.
22. Condenser-water sump (return) control-point temperature.
23. Condenser-water sump (return) temperature.
24. Condenser-water control-valve position.
25. Cooling-tower fan(s) on-off indication (operating or not operating).
26. Condenser-water supply temperature.
27. Cooling-tower sump temperature.

28. Cooling-tower sump heater on-off indication (operating or not operating).
29. Cooling-tower sump drain indication.
30. Chiller(s) power input (instantaneous).
31. Chilled-water pressure drop through chiller.
32. Chilled-water flow through chiller.
33. Condenser-water pressure drop through chiller.
34. Condenser-water flow through chiller.
35. Chiller condenser-water supply and return temperature.
36. Chiller chilled-water supply and return temperature.
37. System capacity in tons.
38. **<Insert requirement>**.

1.7 AIR-HANDLING-UNIT CONTROL SEQUENCES

A. Air-Handling Unit Time Schedule:

1. Occupied Time Schedule:

a. Input:

- 1) Device: DDC controller.
- 2) Location: Time schedule.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: DDC controller.

c. Action:

- 1) Enable startup, initiation, and control.
- 2) Energize unit on occupied/unoccupied cycle.
- 3) Energize unit on day/night cycle.
- 4) Energize unit on duty cycle.
- 5) Energize return-air fans [**30 seconds**] **<Insert time>** after supply fans are energized.
- 6) Do not enable mixed-air control during morning warm-up period.
 - a) Unoccupied: Position outdoor-air[**and relief-air**] dampers closed and return-air dampers open.
- 7) Do not enable humidifier control during morning warm-up period.
- 8) Enable control of heating coil(s) during morning warm-up period.
- 9) Energize coil circulating pump(s).
- 10) Return heating control valves to normal position when unit is cycled on.
- 11) Do not enable cooling-coil control during morning warm-up period.

B. Start and Stop Supply Fan(s):

1. Enable:
 - a. Input:
 - 1) Device: Low limit temperature switch with [manual] [automatic] reset.
 - 2) Location: Upstream of cooling coil.
 - 3) Transference: Starter relay.
 - b. Output:
 - 1) Device: Hard wired to motor controller[and DDC controller].
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action:
 - 1) Allow start if temperature is above [37 deg F (3 deg C)] <Insert temperature>.
 - 2) Signal alarm if fan fails to start as commanded.
2. Enable:
 - a. Input:
 - 1) Device: Low limit temperature switch with [manual] [automatic] reset.
 - 2) Location: [Supply airstream] <Insert location>.
 - 3) Transference: Starter relay.
 - b. Output:
 - 1) Device: Hard wired to motor controller[and DDC controller].
 - 2) Location: Motor controller.
 - 3) Input Transference: Starter relay.
 - c. Action:
 - 1) Allow start if temperature is below [120 deg F (49 deg C)] <Insert temperature>.
 - 2) Signal alarm if fan fails to start as commanded.
3. Enable:
 - a. Input:
 - 1) Device: Smoke detector with auxiliary contact [manual] [automatic] reset.
 - 2) Location: Duct mounted [before] [and] [after] [supply fan] [air-handling unit].
 - 3) Location: Mounted in air-handling unit.

- 4) Transference: Starter relay.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Output Device: Hard wired through motor controller; DDC controller alarm.
 - d. Action:
 - 1) Allow start if airstream is free of products of combustion.
 - 2) Signal alarm if fan fails to start as commanded.
- C. Supply Fan(s) Variable-Volume Control:
1. Fan Speed Control:
 - a. Input:
 - 1) Device: Air pressure transmitter.
 - 2) Location: Supply-duct static pressure referenced to ambient-space static pressure.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Transference: Variable-frequency motor controller.
 - c. Action:
 - 1) Maintain constant supply-duct static-pressure set point of **<Insert value>**.
 - 2) Set-Point Reset (for Systems with DDC of Individual Zone Terminals): Reset static-pressure set point based on the zone requiring the most pressure; reset set point lower until one zone damper is nearly wide open.
 - 3) Set variable-frequency drive to minimum speed when fan is stopped.
 2. Fan Airflow:
 - a. Input:
 - 1) Device: Airflow **[sensor] [transmitter]**.
 - 2) Location: Supply duct.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: DDC controller.

- c. Action: Report supply-duct airflow.
 - 3. High Pressure:
 - a. Input:
 - 1) Device: Air pressure switch.
 - 2) Location: Supply duct referenced to outside the duct.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output; DDC controller.
 - 2) Transference: Starter relay; operator's workstation.
 - c. Action: When static pressure rises above excessive-static-pressure set point of **<Insert value>**:
 - 1) Stop fan.
 - 2) Signal alarm.
- D. Return Fan(s) Variable-Volume Control:
 - 1. Fan Speed Control:
 - a. Input:
 - 1) Device: Airflow [**sensor**] [**transmitter**].
 - 2) Location: Supply airstream and return airstream.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Variable-frequency drive.
 - 3) Transference: Variable-frequency drive controller.
 - c. Action:
 - 1) Maintain constant airflow offset between supply- and return-air fans.
 - 2) Set variable-frequency drive to minimum speed when fan is stopped.
 - 2. Fan Speed Control:
 - a. Input:
 - 1) Device: Air pressure [**sensor**] [**differential transmitter**].
 - 2) Location: Indoor space static pressure referenced to outdoor static pressure.
 - 3) Transference: DDC controller.

- b. Output:
 - 1) Device: Analog output.
 - 2) Transference: Variable-frequency motor controller.
- c. Action:
 - 1) Maintain constant indoor static-pressure set point of [0.02-inch wg (5 Pa)] <Insert value> positive for outdoors.
 - 2) Set variable-frequency drive to minimum speed when fan is stopped.
- d. Action: Maintain constant indoor static pressure.

E. Preheat Coil:

- 1. Freeze Protection:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] [Thermostat].**
 - 2) Location: After preheat coil.
 - 3) Transference: **[DDC controller] [Starter relay].**
 - b. Output:
 - 1) Device: **[Binary output] [Hard wired].**
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Allow start if duct temperature is above [33 deg F (1 deg C)] <Insert temperature>.
- 2. Low-Temperature Operation:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] <Insert device>.**
 - 2) Location: Outdoor air.
 - 3) Transference: DDC controller.
 - b. Output Device:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action:

- 1) Energize coil circulating pump(s) at outdoor-air temperatures below **[35 deg F (2 deg C)] <Insert temperature>**.
3. **[Supply] [Discharge]-Air Temperature:**
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: **[Supply] [Discharge]** airstream.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Control-valve actuator.
 - c. Action: Maintain air-temperature set point of **[55 deg F (13 deg C)] <Insert temperature>**.
- F. Mixed-Air Control:
1. Minimum Position:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.
 - b. Input:
 - 1) Device: Flow measuring station.
 - 2) Location: Outdoor-air intake.
 - 3) Transference: DDC controller.
 - c. Output:
 - 1) Device: Analog output.
 - 2) Location: Outdoor damper.
 - 3) Transference: Damper actuator(s).
 - d. Action:
 - 1) Open **[minimum outdoor-air dampers] [outdoor-air dampers to minimum position]**.
 - 2) Modulate outdoor-air dampers to maintain minimum airflow at set point of **<Insert value>**.
 2. Heating Reset:

- a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Software.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Outdoor dampers.
 - 3) Transference: Damper actuator(s).
 - c. Action: **[Close minimum outdoor-air dampers] [Set outdoor-air dampers to minimum position].**
3. Carbon Dioxide Reset:
- a. Input:
 - 1) Device: Carbon dioxide transmitter.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Dampers.
 - 3) Transference: Damper actuator(s).
 - c. Action: Reset minimum outdoor-air damper position to maintain carbon dioxide set point of **<Insert value>**.
4. **[Supply] [Mixed]-Air Temperature:**
- a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].**
 - 2) Location: **[Supply-airstream] [Mixed-air plenum] <Insert location>**.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Damper section.
 - 3) Transference: Damper actuator(s).
 - c. Action:

- 1) Modulate outdoor-, return-, and relief-air dampers to maintain air-temperature set point of [55 deg F (13 deg C)] **<Insert temperature>**.
 - 2) Do not enable control during morning warm-up period.
5. Cooling Reset:
- a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] [and moisture sensors and transmitters]**.
 - 2) Location: Outdoor- and return-air ducts.
 - 3) Input Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Outdoor- and return-air ducts.
 - 3) Transference: Damper actuator(s).
 - c. Action: Set outdoor-air dampers to minimum position when outdoor-air **[temperature exceeds return-air temperature] [enthalpy exceeds return-air enthalpy]**.

G. Humidifier:

1. Input:
 - a. Device: Moisture sensor and transmitter.
 - b. Location: **[Return airstream] [Supply airstream] [Space] <Insert location>**.
 - c. Transference: DDC controller.
2. Output:
 - a. Device: Analog output.
 - b. Location: Humidifier.
 - c. Transference: **[Valve actuator] [and] [pump]**.
3. Action:
 - a. **[Modulate humidity control valve] [Cycle humidifier pump] [Cycle humidifier pump and modulate humidity control valve]**.
 - b. Maintain humidity in straight-line relationship for the following conditions:
 - 1) 20 percent when outdoor-air temperature is [minus 30 deg F (minus 35 deg C)] **<Insert temperature>**.
 - 2) 40 percent when outdoor-air temperature is [75 deg F (24 deg C)] **<Insert temperature>**.

H. Evaporative Cooler:

1. Temperature:

a. Input:

- 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
- 2) Location: **[Supply] [Discharge]** airstream.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Evaporative cooler.
- 3) Transference: **[Valve actuator] [and] [pump]**.

c. Action:

- 1) **[Modulate evaporative cooler control valve] [and] [cycle evaporative cooler pump]**.
- 2) Maintain air-temperature set point of **[55 deg F (13 deg C)] <Insert temperature>**.

2. Humidity Limit:

a. Input:

- 1) Device: Moisture sensor and transmitter.
- 2) Location: **[Return airstream] [Supply airstream] [Space] <Insert location>**.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Evaporative cooler.
- 3) Transference: **[Valve actuator] [and] [pump]**.

c. Action:

- 1) Return **[humidity control valve] [humidifier pump] [humidifier pump and humidity control valve]** to their normal position.
- 2) Signal high humidity alarm.

I. Filters:

1. Differential Pressure:

a. Input:

- 1) Device: Pressure differential [**switch**] [**transmitter**].
- 2) Location: Filter bank.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: DDC controller.
- 2) Location: DDC controller.
- 3) Transference: Operator's workstation.

c. Action: Signal alarm on [**low- and**]high-pressure conditions.

J. [**Hydronic**] [**Steam**] Heating Coil:

1. [**Supply**] [**Discharge**]-Air Temperature:

a. Input:

- 1) Device: [**Air-temperature sensor**] [**or**] [**air-temperature sensor with air-temperature RTD transmitter**].
- 2) Location: [**Supply**] [**Discharge**]-air [**duct**] <Insert location>.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Heating-coil control valve.
- 3) Input Transference: Normally [**open**] [**closed**] valve actuator.

c. Action:

- 1) Maintain supply-air-temperature set point of [**55 deg F (13 deg C)**] <Insert temperature> by modulating heating-coil control valve.
- 2) Maintain supply-air-temperature set point in straight-line relationship for the following conditions:
 - a) [**65 deg F (18 deg C)**] <Insert temperature> when return-air temperature is [**70 deg F (21 deg C)**] <Insert temperature>.
 - b) [**55 deg F (13 deg C)**] <Insert temperature> when return-air temperature is [**75 deg F (24 deg C)**] <Insert temperature>.
- 3) Maintain supply-air-temperature set point within limits in response to space temperature reset:
 - a) Minimum [**55 deg F (13 deg C)**] <Insert temperature>.
 - b) Maximum [**131 deg F (55 deg C)**] <Insert temperature>.
- 4) During morning warm-up period, maintain supply-air-temperature set point of [**80 deg F (27 deg C)**] <Insert temperature>.

2. Space Temperature Reset:

- a. Input:
 - 1) Device: Space **[air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: Indoor spaces served by system.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Heating-coil control valve.
 - 3) Input Transference: Normally **[open] [closed]** valve actuator.
 - c. Action:
 - 1) Reset supply-air temperature in response to greatest heating demand.
 - 2) Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.
3. Low-Temperature Operation:
- a. Input Device:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] <Insert device>**.
 - 2) Location: Outdoor air.
 - 3) Transference: DDC controller.
 - b. Output Device:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action:
 - 1) Energize coil circulating pump(s) at outdoor-air temperatures below **[35 deg F (2 deg C)] <Insert temperature>**.

K. Hydronic Cooling Coil:

1. **[Supply] [Discharge]-Air Temperature:**
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [transmitter]**.
 - 2) Location: **[Supply] [Discharge]-air [duct] <Insert location>**.
 - 3) Transference: DDC controller.

- b. Output:
 - 1) Device: Analog output.
 - 2) Location: Cooling-coil valve.
 - 3) Input Transference: Valve actuator.
- c. Action:
 - 1) Maintain supply-air-temperature set point of [55 deg F (13 deg C)] **<Insert temperature>** by modulating cooling-coil control valve.
 - 2) Maintain supply-air-temperature set point within limits in response to space temperature reset:
 - a) Minimum [55 deg F (13 deg C)] **<Insert temperature>**.
 - b) Maximum [68 deg F (20 deg C)] **<Insert temperature>**.
 - 3) Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

2. Temperature Reset:

- a. Input:
 - 1) Device: [Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].
 - 2) Location: Return-air [duct] **<Insert location>**.
 - 3) Transference: DDC controller.
- b. Output:
 - 1) Device: Analog output.
 - 2) Location: Cooling-coil control valve.
 - 3) Transference: Valve actuator.
- c. Action: Reset supply-air temperature in straight-line relationship for the following conditions:
 - 1) [65 deg F (18 deg C)] **<Insert temperature>** when return-air temperature is [70 deg F (21 deg C)] **<Insert temperature>**.
 - 2) [55 deg F (13 deg C)] **<Insert temperature>** when return-air temperature is [75 deg F (24 deg C)] **<Insert temperature>**.
- d. Action:
 - 1) Reset supply-air temperature in response to greatest cooling demand.
 - 2) Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air

temperature.

3. Space Temperature Reset:

a. Input:

- 1) Device: Space [air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].
- 2) Location: Spaces served by system.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Cooling coil.
- 3) Input Transference: Valve actuator.

c. Action:

- 1) Reset supply-air temperature in response to greatest cooling demand.
- 2) Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

4. Space Humidity Reset:

a. Input:

- 1) Device: Humidity sensor and transmitter.
- 2) Location: Return-air [duct] <Insert location>.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Cooling-coil control valve.
- 3) Transference: Valve actuator.

- c. Action: Reset supply-air temperature to [55 deg F (13 deg C)] <Insert temperature> to maintain space relative humidity of [45] <Insert number> percent.

L. Multizone Damper Control:

1. Spaces Temperature:

a. Input Device:

- 1) Device: **[Air-temperature sensors] [or] [air-temperature sensor with air-temperature RTD transmitter].**
 - 2) Location: Spaces served by system.
 - 3) Transference: DDC controller.
- b. Output:
- 1) Device: Analog output.
 - 2) Location: Multizone head.
 - 3) Transference: Damper actuators.
- c. Action: Maintain the following space temperature set points:
- 1) Occupied Cooling Temperature: **[75 deg F (24 deg C)] <Insert temperature>.**
 - 2) Occupied Heating Temperature: **[70 deg F (24 deg C)] <Insert temperature>.**
 - 3) Unoccupied Cooling Temperature: **[85 deg F (24 deg C)] <Insert temperature>.**
 - 4) Unoccupied Heating Temperature: **[65 deg F (18 deg C)] <Insert temperature>.**
- M. Coordination of Air-Handling Unit Sequences: Ensure that preheat, mixed-air, heating-coil, and cooling-coil controls have common inputs and do not overlap in function.
- N. Indicate the following on the operator's workstation display terminal:
1. DDC system graphic.
 2. DDC system on-off indication (operating or not operating).
 3. DDC system occupied/unoccupied mode.
 4. Outdoor-air-temperature indication.
 5. Supply-fan on-off indication (operating or not operating).
 6. Supply duct static-pressure indication.
 7. Supply duct static-pressure set point.
 8. Supply-fan airflow rate.
 9. Supply-fan speed.
 10. Return-fan on-off indication (operating or not operating).
 11. Space static-pressure indication.
 12. Space static-pressure set point.
 13. Return-fan airflow rate.
 14. Return-fan speed.
 15. Preheat-coil air-temperature indication.
 16. Preheat-coil air-temperature set point.
 17. Preheat-coil pump on-off indication (operating or not operating).
 18. Preheat-coil control-valve position.
 19. Mixed-air-temperature indication.
 20. Mixed-air-temperature set point.
 21. Mixed-air damper position.
 22. Relative humidity indication.

23. Relative humidity set point.
24. Relative humidity control-valve position.
25. Filter air-pressure-drop indication.
26. Filter low-air-pressure drop set point.
27. Filter high-air-pressure drop set point.
28. **[Supply] [Discharge]**-air-temperature indication.
29. **[Supply] [Discharge]**-air-temperature set point.
30. Heating-coil leaving-air-temperature indication.
31. Heating-coil leaving-air-temperature set point.
32. Heating-coil pump on-off indication (operating or not operating).
33. Heating-coil control-valve position.
34. Hot-deck air-temperature indication.
35. Hot-deck air-temperature set point.
36. Cooling-coil leaving-air-temperature indication.
37. Cooling-coil leaving-air-temperature set point.
38. Cooling-coil control-valve position.
39. Cold-deck air-temperature indication.
40. Cold-deck air-temperature set point.
41. Space temperature indication.
42. Space temperature set point.
43. Multizone damper position.

1.8 TERMINAL UNIT OPERATING SEQUENCE

A. Cabinet Unit Heater, **[Hydronic] [Steam]**:

1. Space Temperature:
 - a. Input:
 - 1) Device: Line-voltage thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Cycle fan to maintain **[75 deg F (24 deg C)] <Insert value>** space temperature.
2. Space Temperature:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: Occupied space.

- 3) Transference: DDC controller.
 - b. Output Device:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Output Device:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Control-valve actuator.
 - d. Action: [**Cycle fan**] [**Modulate valve**] to maintain [75 deg F (24 deg C)] <Insert value> space temperature.
3. Low-Temperature Safety:
- a. Input Device: Line-voltage, on-off thermostat; mounted.
 - 1) Device: Line-voltage thermostat.
 - 2) Location: [**Return heating-water**] [**Condensate**] pipe.
 - b. Output Device:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Input Transference: Starter relay.
 - c. Action: Stop fan when [**return heating-water**] [**condensate**] temperature falls below [35 deg F (2 deg C)] <Insert temperature>.
- B. Cabinet Unit Heater, Electric:
1. Input:
 - a. Device: Line-voltage thermostat.
 - b. Location: Occupied space.
 2. Output:
 - a. Device: Hard wired.
 - b. Location: Motor-controller and heater relay.
 - c. Transference: Starter relay.
 3. Action: Cycle fan to maintain [75 deg F (24 deg C)] <Insert value> space temperature.
- C. Unit Heater, [**Hydronic**] [**Steam**]:

1. Space Temperature:
 - a. Input:
 - 1) Device: Line-voltage thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Cycle fan to maintain [75 deg F (24 deg C)] <Insert value> space temperature.
2. Space Temperature:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output Device:
 - 1) Device: Binary output.
 - 2) Transference: Starter relay.
 - c. Output Device:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Control-valve actuator.
 - d. Action: **[Cycle fan] [Modulate valve]** to maintain [75 deg F (24 deg C)] <Insert value> space temperature.
3. Low-Temperature Safety:
 - a. Input Device: Line-voltage, on-off thermostat; pipe mounted.
 - 1) Device: Line-voltage thermostat.
 - 2) Location: **[Return heating-water] [Condensate]** pipe.
 - b. Output Device:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Input Transference: Starter relay.

- c. Action: Stop fan when **[return heating-water] [condensate]** temperature falls below **[35 deg F (2 deg C)] <Insert temperature>**.
 - D. Unit Heater, Electric: Space thermostat cycles fan and sequences stages of heating.
 1. Space Temperature:
 - a. Input:
 - 1) Device: Electric multistage thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Unit control panel.
 - 3) Transference: Electric multistage contactors.
 - c. Action: Sequence electric coil stages to maintain **[75 deg F (24 deg C)] <Insert value>** space temperature.
 - E. Combustion-Air Unit Heaters:
 1. Space Temperature:
 - a. Input:
 - 1) Device: Thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Low-voltage wiring.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - c. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - d. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - e. Action: Modulate valve to maintain **[75 deg F (24 deg C)] <Insert value>** space temperature.

F. Radiant Heating Cable, Electric:

1. Space Temperature:

a. Input:

- 1) Device: Electric thermostat.
- 2) Location: Space.

b. Output:

- 1) Device: Line-voltage wiring.
- 2) Location: Junction box.
- 3) Transference: Cable.

- c. Action: Cycle power to maintain [75 deg F (24 deg C)] <Insert value> space temperature set point.

G. Radiant Heating Panel, Electric:

1. Space Temperature:

a. Input:

- 1) Device: Electronic thermostat.
- 2) Location: Space.

b. Output:

- 1) Device: Low-voltage wiring.
- 2) Location: Junction box.
- 3) Transference: Line-voltage relay.

- c. Action: Cycle power to maintain the following space temperature set points:

- 1) Occupied: [75 deg F (24 deg C)] <Insert temperature>.
- 2) Unoccupied: [65 deg F (18 deg C)] <Insert temperature>.

d. Radiant Heating Panel, Hydronic:

2. Space Temperature:

a. Input:

- 1) Device: Electronic thermostat.
- 2) Location: Space.

b. Output:

- 1) Device: Low-voltage wiring.
- 2) Location: Control valve.

- 3) Transference: Valve actuator.
 - c. Action: Cycle valve open and closed to maintain temperature set point.
 - d. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].**
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - e. Output:
 - 1) Device: DDC analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - f. Action: Modulate valve to maintain the following space temperature set points:
 - 1) Occupied: [75 deg F (24 deg C)] **<Insert temperature>.**
 - 2) Unoccupied: [65 deg F (18 deg C)] **<Insert temperature>.**
- H. Two-Pipe, Single-Coil, Fan-Coil Unit:
1. Manual Start:
 - a. Input:
 - 1) Device: Fan switch.
 - 2) Location: Integral to thermostat.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Start and stop fan.
 2. Space Temperature:
 - a. Input:
 - 1) Device: Electronic thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Low-voltage wiring.
 - 2) Location: Control valve.
 - 3) Transference: Valve.

- c. Action: Modulate valve to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] <Insert temperature>.
 - 2) Occupied Heating Temperature: [70 deg F (24 deg C)] <Insert temperature>.
 - 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] <Insert temperature>.
 - 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] <Insert temperature>.
3. Occupied Time Schedule:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Start and stop fan.
4. Space Temperature:
 - a. Input:
 - 1) Device: Air-temperature sensor.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - c. Action: Modulate valve to maintain the following space temperature set points:
 - 1) Occupied: [75 deg F (24 deg C)] <Insert temperature>.
 - 2) Unoccupied: [65 deg F (18 deg C)] <Insert temperature>.
 - d. System Changeover:
 - e. Input:

- 1) Device: Liquid temperature sensor **[or] [liquid temperature sensor with liquid transmitter]**.
 - 2) Location: Supply-water piping.
 - 3) Transference: DDC controller.
 - f. Output:
 - 1) Device: Binary output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - g. Action: Reverse control-valve action to switch from heating to cooling.
- I. Four-Pipe, Hydronic Fan-Coil Unit:
 1. Occupied Time Schedule:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Start and stop fan, and enable control.
 2. Space Temperature:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuators.
 - c. Action: Modulate control valves to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: **[75 deg F (24 deg C)] <Insert temperature>**.

- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] **<Insert temperature>**.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] **<Insert temperature>**.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] **<Insert temperature>**.

J. Unit Ventilator:

1. Occupied Time Schedule:

a. Input:

- 1) Device: DDC controller.
- 2) Location: Time schedule.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Binary output.
- 2) Location: Fan motor controller and damper.
- 3) Transference: Starter relay and damper actuators.

- c. Action: Start and stop fan, move outdoor- and return-air dampers to **[minimum] [maximum]** outdoor-air position, and enable control.

2. Space Temperature - Valves:

a. Input:

- 1) Device: **[Air-temperature sensor] [or] [transmitter]**.
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Control valve.
- 3) Transference: Valve actuator.

- c. Action: Modulate heating-water control valve and chilled-water control valve in sequence to maintain the following space temperature set points:

- 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] **<Insert temperature>**.
- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] **<Insert temperature>**.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] **<Insert temperature>**.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] **<Insert temperature>**.

3. Space Temperature - Dampers:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature RTD transmitter]**.
 - 2) Location: Mixed-air plenum.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Dampers.
 - 3) Transference: Damper actuators.
 - c. Action: Modulate outdoor- and return-air dampers to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: **[75 deg F (24 deg C)] <Insert temperature>**.
 - 2) Occupied Heating Temperature: **[70 deg F (24 deg C)] <Insert temperature>**.
 - 3) Unoccupied Cooling Temperature: **[85 deg F (24 deg C)] <Insert temperature>**.
 - 4) Unoccupied Heating Temperature: **[65 deg F (18 deg C)] <Insert temperature>**.
4. Supply-Air-Temperature Limit:
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: Discharge air.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve and dampers.
 - 3) Transference: Valve and damper actuators.
 - c. Action: Override space temperature set point to control valves and dampers to prevent discharge air from dropping below a minimum set point of **<Insert value>**.
5. Warm-up Cycle:
 - a. Input:
 - 1) Device: DDC controller.

- 2) Location: Time schedule.
- 3) Input Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Control valve and damper.
- 3) Transference: Valve and damper actuators.

- c. Action: Open heating-water control valve, close outdoor-air damper, and open return-air damper.

K. Heating Coils, [**Hydronic**] [**Steam**]:

1. Space Temperature:

a. Input:

- 1) Device: [**Air-temperature sensor**] [or] [**air-temperature sensor with air-temperature RTD transmitter**].
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Control valve.
- 3) Transference: Valve actuator.

- c. Action: Modulate valve to maintain the following space temperature set points:

- 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] <Insert temperature>.
- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] <Insert temperature>.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] <Insert temperature>.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] <Insert temperature>.

L. Heating Coils, Electric:

1. Space Temperature:

a. Input:

- 1) Device: Electric thermostat.
- 2) Location: Space.
- 3) Transference: Low-voltage control.

- b. Output:
 - 1) Device: Pilot relays.
 - 2) Location: Heating-coil electrical cabinet.
 - 3) Transference: Line-voltage relays.
- c. Action: Sequence stages of heating to maintain [75 deg F (24 deg C)] <Insert value> space temperature.

M. Radiators and Convectors, [**Hydronic**] [**Steam**]:

- 1. Occupancy:
 - a. Input:
 - 1) Device: Occupancy sensor.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: DDC controller.
 - c. Action: Report occupancy and enable occupied temperature set point.
- 2. Space Temperature:
 - a. Input:
 - 1) Device: [**Air-temperature sensor**] [**or**] [**air-temperature sensor with air-temperature RTD transmitter**].
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - c. Action: Modulate valve to maintain [75 deg F (24 deg C)] <Insert value> space temperature set point.
 - 1) Occupied Temperature: [75 deg F (24 deg C)] <Insert temperature>.
 - 2) Unoccupied Temperature: [65 deg F (18 deg C)] <Insert temperature>.

N. Radiators and Convectors, Electric:

- 1. Space Temperature:

- a. Input:
 - 1) Device: Electric thermostat.
 - 2) Location: Space.
 - 3) Transference: Low-voltage control.
 - b. Output:
 - 1) Device: Pilot relays.
 - 2) Location: Radiator electrical cabinet.
 - 3) Transference: Line-voltage relays.
 - c. Action: Sequence stages of heating to maintain [75 deg F (24 deg C)] <Insert value> space temperature set point.
- O. Constant-Volume, Terminal Air Units, [Hydronic] [Steam]:
1. Occupancy:
 - a. Input:
 - 1) Device: Occupancy sensor.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: DDC controller.
 - c. Action: Report occupancy and enable occupied temperature set point.
 2. Space Temperature:
 - a. Input:
 - 1) Device: [Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - c. Action: Modulate valve to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] <Insert temperature>.

- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] **<Insert temperature>**.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] **<Insert temperature>**.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] **<Insert temperature>**.

P. Variable-Air-Volume Terminal Air Units with [Hydronic] [Steam] Coils:

1. Occupancy:

a. Input:

- 1) Device: Occupancy sensor.
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Device: DDC controller.

c. Action: Report occupancy and enable occupied temperature set point.

- 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] **<Insert temperature>**.
- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] **<Insert temperature>**.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] **<Insert temperature>**.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] **<Insert temperature>**.

2. Space Temperature:

a. Input:

- 1) Device: [Air-temperature sensor] [or] [transmitter].
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Control damper and valve actuators.
- 3) Input Transference: Control damper and valves.

c. Action: Modulate damper and valve to maintain the following space temperature set points:

- 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] **<Insert temperature>**.
- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] **<Insert temperature>**.

- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] <Insert temperature>.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] <Insert temperature>.
- 5) Modulate damper actuator from full open to minimum position.
- 6) When damper is at minimum position, modulate reheat coil valve from closed to open.
- 7) If occupied space temperature is not maintained with valve open, modulate damper actuator from minimum position to [100] <Insert number> percent open.
- 8) Reverse the sequence for full heating to full cooling.

Q. Dual-Duct, Variable-Air-Volume Terminal Air Units:

1. Occupancy:

a. Input:

- 1) Device: Occupancy sensor.
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: DDC controller.

c. Action: Report occupancy and enable occupied temperature set point.

- 1) Occupied Temperature: [75 deg F (24 deg C)] <Insert temperature>.
- 2) Unoccupied Temperature: [65 deg F (18 deg C)] <Insert temperature>.

2. Space Temperature:

a. Input:

- 1) Device: [Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Damper actuator(s).
- 3) Transference: Dampers.

c. Action: Modulate dampers to maintain the following space temperature set points:

- 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] <Insert temperature>.
- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] <Insert temperature>.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] <Insert temperature>.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] <Insert temperature>.
- 5) When occupied space temperature is below set point, close cold-deck damper to minimum position and open hot-deck damper.
- 6) When occupied space temperature is above set point, close hot-deck damper to minimum position and open cold-deck damper.

R. Sequence Control:

1. Space Temperature:

a. Input:

- 1) Device: [Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Control damper and valve actuators.
- 3) Input Transference: Control dampers and valves.

c. Action: Modulate valves and dampers to maintain the following space temperature set points:

- 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] <Insert temperature>.
- 2) Occupied Heating Temperature: [70 deg F (24 deg C)] <Insert temperature>.
- 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] <Insert temperature>.
- 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] <Insert temperature>.
- 5) Modulate damper actuator from open to minimum position.
- 6) When damper is at minimum position, modulate finned-tube radiation valve from closed to fully open.
- 7) When finned-tube radiation valve is fully open, modulate reheat coil valve from closed to fully open.
- 8) If occupied space temperature is not maintained with both valves open, modulate damper actuator from minimum position to [100] <Insert number> percent open.
- 9) Reverse the sequence for full heating to full cooling.

S. Indicate the following on the operator's workstation display terminal:

1. DDC system graphic.
2. DDC system on-off indication (operating or not operating).
3. DDC system occupied/unoccupied mode.
4. Outdoor-air-temperature indication.
5. Cabinet Unit Heater, Hydronic:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Fan on.
6. Unit Heater, Hydronic:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Fan on.
7. Combustion-Air Unit Heaters:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Control-valve position.
8. Radiant Heating Panel, Hydronic:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Control-valve position.
9. Two-Pipe, Single-Coil, Fan-Coil Unit:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Control-valve position.
 - d. Supply-water temperature indication.
10. Four-Pipe, Hydronic Fan-Coil Unit:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Control-valve position.
11. Unit Ventilator:
 - a. DDC system on-off indication (operating or not operating).
 - b. Space temperature indication.
 - c. Space temperature set point.
 - d. Control-valve position.
 - e. Damper position.

12. Heating Coils, Hydronic:
 - a. Space temperature indication.
 - b. Space temperature set point.
 - c. Control-valve position.

13. Radiators and Convectors, Hydronic:
 - a. Space/area served.
 - b. Space temperature indication.
 - c. Space temperature set point.
 - d. Space temperature set point, occupied.
 - e. Space temperature set point, occupied standby.
 - f. Space temperature set point, unoccupied.
 - g. Control-valve position as percentage open.

14. Constant-Volume, Terminal Air Units, Hydronic:
 - a. Space/area served.
 - b. Space occupied/unoccupied.
 - c. Space temperature indication.
 - d. Space temperature set point, occupied.
 - e. Space temperature set point, unoccupied.
 - f. Control-valve position as percentage open.

15. Variable-Air-Volume Terminal Air Units with Hydronic Coils:
 - a. Space/area served.
 - b. Space occupied/unoccupied.
 - c. Space temperature indication.
 - d. Space temperature set point.
 - e. Space cooling and heating temperature set point, occupied.
 - f. Space cooling and heating temperature set point, unoccupied.
 - g. Air-damper position as percentage open.
 - h. Control-valve position as percentage open.

16. Dual-Duct, Variable-Air-Volume Terminal Air Units:
 - a. Space/area served.
 - b. Space occupied/unoccupied.
 - c. Occupied space temperature indication.
 - d. Occupied space temperature set point, occupied.
 - e. Occupied space temperature set point, unoccupied.
 - f. Hot-deck damper position as percentage open.
 - g. Cold-deck damper position as percentage open.

17. Sequence Control:
 - a. Space/area served.
 - b. Space occupied/unoccupied.

- c. Space temperature indication.
- d. Space temperature set point, occupied.
- e. Space temperature set point, unoccupied.
- f. Damper position as percentage open.
- g. Control-valve positions as percentage open.

1.9 VENTILATION SEQUENCES

A. Combustion-Air, Makeup Unit Control, Electric:

1. Initiation:

a. Input:

- 1) Device: Auxiliary contact.
- 2) Location: Served appliance.

b. Output:

- 1) Device: Hard wired.
- 2) Location: Served appliance.
- 3) Transference: Starter relay and electric solenoid.

c. Action: Start fan when appliance burner starts.

2. Space Temperature:

a. Input:

- 1) Device: Electronic multistage thermostat.
- 2) Location: Space.

b. Output:

- 1) Device: Hard wired.
- 2) Location: Unit control panel.
- 3) Transference: Electric multistage contactors.

c. Action: Sequence electric coil stages to maintain [75 deg F (24 deg C)] <Insert value> space temperature.

B. Combustion-Air, Makeup Unit Control, [Hydronic] [Steam]:

1. Initiation:

a. Input:

- 1) Device: Auxiliary contact.
- 2) Location: Served appliance.

- b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay and electric solenoid.
 - c. Action: Start fan when appliance burner starts.
2. Space Temperature:
- a. Input:
 - 1) Device: Electronic thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - c. Action: Modulate control valve to maintain [75 deg F (24 deg C)] <Insert value> space temperature set point.
- C. Gravity Roof Ventilator:
- 1. Input:
 - a. Device: [**Occupancy sensor**] [**Electric thermostat**].
 - b. Location: Space.
 - 2. Output:
 - a. Device: Hard wired.
 - b. Location: Control damper.
 - c. Transference: Damper actuator.
 - 3. Action: Open control damper when space [**is occupied**] [**temperature rises above set point**].
- D. Exhaust Fan: [**Occupancy sensor**] [**Light switch**] [**Room thermostat**].
- 1. Input:
 - a. Device: [**Occupancy sensor**] [**Light switch**] [**Electric thermostat**].
 - b. Location: Space.
 - 2. Output:
 - a. Device: Hard wired.
 - b. Location: Motor controller.

- c. Transference: Starter relay.
 3. Action: Cycle fan on when [**space is occupied**] [**lights are turned on**] [**space temperature rises above set point**].
- E. Kitchen Exhaust Fan: Occupancy sensor.
 1. Input:
 - a. Device: Occupancy sensor.
 - b. Location: Space.
 2. Output:
 - a. Device: Hard wired.
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
 3. Action: Start fan and energize makeup air unit when space is occupied.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230993.11

SECTION 230994 - INDUSTRIAL CONTROL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Provide all labor, equipment, and material necessary for complete and fully operational control system, as shown on the drawings and as specified herein.
- B. The control system shall include all control devices, sensors, valves, actuators, gauges, meters, control panels, and control wiring and instrument air piping as specified and required to fulfill the intent of the drawings and specifications. Coordinate all work with the equipment suppliers and the Division 26 installers.
- C. Provide all completion services as specified, including final system performance verification, to ensure that the system functions as specified. Completion services shall be in accordance with Division 01 requirements.
- D. Refer to other Division 23 and to Division 26 sections for requirements for interfacing controls and instrumentation with mechanical equipment and systems.
- E. Conform to Division 26 sections for raceways, cables and conductors, terminations and splices, boxes, cabinets, supports, hangers, seals, and other applicable requirements governing the installation of the electrical components of the controls systems.

1.3 REFERENCE STANDARDS

- A. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.
 - 1. American National Standards Institute
 - a. ANSI/NFPA 70 - National Electrical Code.
 - 2. Instrument Society of America (ISA):
 - a. ISA-S5.1: Standard for Instrumentation Symbols and Identification.

3. International Building Code (IBC) with the Denver Amendments.
4. International Fire Code (IFC) with the Denver Amendments.
5. National Fire Protection Association (NFPA):
 - a. NFPA 30 – Flammable and Combustible Liquids Code.
6. Underwriters' Laboratories (UL):
 - a. Provide electrical components and assemblies which have been UL listed and labeled.

1.4 ACTION SUBMITTALS

- A. Submit with bid a statement of qualifications including: Reference projects of a similar nature and scope, including contract amounts, and resumes of key personnel who will be assigned to this project.
- B. Submit shop drawings and product data under provisions of Section 230400 "Basic HVAC Requirements".
- C. Submit the following not less than ten (10) days prior to beginning any installation:
 1. Product Data: Submit for all components. Include manufacturer's installation instructions.
 - a. Include data substantiating that materials comply with requirements.
 2. Control system schematic and system riser diagram, complete with valve schedules and a written description of the control sequence referring to the control components identified on drawings in sequence by tag number.
 3. General outline drawings of equipment showing overall dimensions, location of major components and weights.
 4. Specification sheets on programmable controller equipment.
 5. Software documentation including written description of the program, source code, memory maps, written description of sub-routines, interrupts, and listing of database information.
 6. Schematic diagrams for electrical items showing external connections, terminal block numbers, internal wiring diagrams, one-line diagrams, and point-to-point wiring diagrams including wire identification on each item of instrumentation.
 7. Control panel drawings, including: layout of graphic panel face, with all switches, LED's, and instruments; detailed internal panel layout including all instrumentation components and wire ways.
 8. A bill of materials and a spare parts list.
- D. For automatic valve actuators, include calculations demonstrating that actuators for valves larger than 2-inch size will have ample positioning force to ensure positive performance for opening, including consideration of tendency of valves to stick in the closed position (particularly when having been kept in the closed position for long periods of time).

- E. Submit the results of functional and diagnostic tests and calibrations to the DEN Project Manager for final system acceptance.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- B. Project Record Documents:
 - 1. Revise shop drawings to reflect actual installation and operating sequences.
 - 2. Include data specified in "Submittals" in final "Record Documents" form.
 - 3. At completion of work, submit report of checkout of control systems.
- C. Operation and Maintenance Data:
 - 1. Submit prior to system demonstration by Contractor.
 - 2. Include Operating Instructions for starting, stopping, adjustment, and regulation.
 - 3. Inspection and Maintenance Instructions, including schedules and procedures for equipment replacement, adjustments, cleaning and cleaning materials, protection, testing, calibration and calibration tolerances.
 - 4. Operating Instructions, including equipment characteristics, and operating procedures.
 - 5. Maintenance Instructions and Procedures: Schedule of routine maintenance, maintenance procedures, and trouble-shooting.
 - 6. Parts list and recommended spare parts list.
 - 7. Warranty arrangements.
 - 8. Include interconnection wiring diagrams for complete field installed system with identified and tag numbered system components and devices.
 - 9. Include keyboard and graphic illustrations and step-by-step procedures indexed for each operator function.

1.6 QUALITY ASSURANCE

- A. Control System Supplier: Shall have a complete engineering, sales, installation, and service organization with successful experience in the design, system application programming, installation, and start-up of at least five (5) similar systems.

- B. Electrical and Mechanical Installation: Shall be by trained electricians and mechanics in the continuous employment of an installer whose normal business is the installation of automatic control systems.
- C. Regulatory Requirements: Control wiring shall comply with all applicable codes and regulations and Division 26 Sections.

1.7 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements".

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Provide products in sizes and of capacities indicated, and as required by the application, conforming to manufacturers' standard materials and components as published in their product information.
- B. All furnished products, including those listed in the Specifications by manufacturer and model number, will be acceptable subject to meeting all contract requirements.

2.2 APPROVED SUPPLIERS

- A. Manufacturers: Subject to compliance with requirements, provide industrial control systems by one of the following:
 1. Custom Controls, Inc., Kansas City, MO.
 2. Control Instruments, Inc., Atlanta, GA.
 3. **<Insert manufacturer's name>**
 4. or approved equal.

2.3 CONTROL WIRING

- A. Electrical Wiring: Provide as required for the control system, including electrical interlock wiring. Comply with the National Electrical Code, local codes, and Division 26 Sections of these specifications. Provide transient protection for all outdoor control circuits.

2.4 CONTROL TRANSFORMERS

- A. Provide control transformers as required for a complete and fully operational control system.
- B. Transformers to have adequate capacity for all connected controls. Input and output voltages to be as required for the control power voltage available, and the voltages required by the control components.

2.5 INSTRUMENT AIR SUPPLY

- A. Provide instrument air supply to provide clean, dry, control quality instrument air to the control system. System operating pressure to be 150 psig.
- B. Provide duplex air compressor as indicated. Size compressor to provide adequate air for the system without operating more than 50 percent of the time. The air compressor shall be of the instrument air quality type operating at not more than 500 fpm piston speeds and low temperature to minimize oil vaporization and carryover.
- C. Provide receiver tanks complete with ASME label, pressure gauge, relief valve, automatic drain trap piped to convenient drain, and necessary openings as indicated on drawings. Size compressor receiver tank to require no more than ten starts per hour of an individual compressor. Receiver tanks shall comply with applicable state and local codes, as well as OSHA standards.
- D. Dryers: Provide dryers to remove condensable contaminants from the air, such as oil and water. Provide dryer for full system capacity.
 - 1. Aftercooler Dryer: Mechanical refrigeration non-cycling type rated at not less than 1/4 HP with a refrigeration capacity to assure a dew point of 10 degrees F at 150 psi with inlet air at 150 psi and 100 degrees F, operating at 100 degrees F ambient temperature. Pressure drop across unit not to exceed 2.75 psi at rated capacity.
 - 2. Regenerative Desiccant Dryer: Dual pressure vessel towers containing activated alumina desiccant beds. Air flow rated shall be less than 60 ft./min. at 150 psig, with minimum contact time of 4.5 seconds. Operating pressure drop shall be less than 3 psi at rated flow, output pressure dew point less than -40 degrees F. Provide with front-mounted electrical control box with solid state timer set for 10 minute regeneration cycle time.
 - 3. Assembly shall include the following:
 - a. Integral 40 micron particulate afterfilter.
 - b. Automatic condensate drain trap.
 - c. Green "power on" pilot light.
 - d. Red "high air temperature" warning pilot light.
 - e. Provision for connection of a remote alarm.
- E. Provide the following instrument air accessories: Submicron filter assembly, including replaceable cartridge type filter with transparent bowl and metal bowl guard. Filter

element shall be effective in removing 98 percent of any oil leaving the Aftercooler, and solid particles as small as 0.6 microns. Provide a trap to automatically discharge any liquid contaminants retained in the filter bowl.

- F. For duplex air compressor, provide an electric alternator system that will:
 - 1. Alternate the lead/lag compressor on each start.
 - 2. Energize the lag compressor in the event that the lead compressor either fails to start, or fails to deliver sufficient air capacity.
- G. Provide combination starter(s) with the compressor.

2.6 CONTROL AIR PIPING

- A. Steel Piping: PVC coated schedule 40 seamless steel piping, welded, or threaded connections as indicated.
- B. Seamless Copper Tubing: Type K or L, ANSI/ASTM B 88; with cast-bronze solder joint fittings, ANSI B16.18; or wrought copper solder-joint fittings, ANSI B16.22; except brass compression type fittings at connections to equipment.
- C. Polyethylene Tubing: Black, flame retardant, virgin polyethylene, conforming to modified ASTM D1693 test.
 - 1. Fittings: UL approved rod or forged brass rated to 200 psig at 100 degrees F.
 - 2. Joints: Compression or barbed type.

2.7 PRESSURE GAGE TAPS

- A. Gage Cock: Tee or lever handle, brass for maximum 250 psig.
- B. Needle Valve: Stainless Steel for maximum 250 psig.
- C. Pulsation Damper: Pressure snubber, brass with 1/4 inch connections.

2.8 DIAL THERMOMETERS

- A. [4-1/2] <Insert size> inch diameter dial in stainless steel case, adjustable angle with front recalibration, bimetallic helix actuated with silicone fluid damping, white with black markings and black pointer, hermetically sealed Lexan lens, stainless steel stem, one percent of full scale accuracy, calibrated in degrees F.

2.9 THERMOMETER SUPPORTS

- A. Socket: 304 stainless steel separable sockets for thermometer stems with or without extensions as required, and with cap and chain.

2.10 STATIC PRESSURE GAGES

- A. [4-1/2] <Insert size> inch diameter (unless otherwise indicated) dial in metal case, diaphragm actuated, glycerin filled, black figures on white background, front recalibration adjustment with tubing, static pressure tips. Pressure gauges shall be graduated in psi. Range shall be from 0 to 150 percent of the system operating pressure at the point where the gauge is installed.

2.11 PRIMARY FLOW ELEMENTS

- A. Fixed installation flow meter, Panametrics Model DF868-1-11-10100-0 or approved equivalent, digital display with graphic capability, data logging capability, two 4-20mA (0-20mA) isolated outputs and RS232 output, Single Channel, 100-120VAC power supply, NEMA 4X weatherproof epoxy coated enclosure with window and external keyboard suitable for Class I, Div. 2 Groups A,B,C,D hazardous areas, four software selectable frequency(rate) or pulse(totalizer) assignable outputs.
- B. Clamp-on transducers, hazardous location, FM approved. Class I, Div. 1, Groups C & D, shear wave for 2 inch (50 mm) and larger pipe.
1. Manufacturers: Subject to compliance with requirements, provide industrial control systems by one of the following:
- a. Panametrics, Model C-PB-10-N-B-AX.
 - b. <Insert manufacturer's name>
 - c. or approved equal.
- C. Universal clamping fixture, with transducer brackets and chains for single or double traverse installations for use on pipes 2 inch to 24 inch (50 mm to 600 mm) O.D.
1. Manufacturers: Subject to compliance with requirements, provide by one of the following:
- a. Panametrics, Model UC-F-P-24-0.
 - b. <Insert manufacturer's name>
 - c. or approved equal.
- D. Pair of transducer cables, 50 feet (15.25 m) length with BNC connectors and flying leads for connection to Model DF868 flow meter.
1. Manufacturers: Subject to compliance with requirements, provide one of the following:
- a. Panametrics, Model 704-658-50.
 - b. <Insert manufacturer's name>
 - c. or approved equal.
- E. Standard silicone grease coupling for fixed/temporary installations, temperature range: -40 to 65 deg C.

1. Manufacturers: Subject to compliance with requirements, provide one of the following:
 - a. Panametrics, Model CPL-1
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.
 2. Flow probe:
 - a. Manufacturers: Subject to compliance with requirements, provide one of the following:
 - 1) Thermal Instrument Company, Model 62.
 - 2) **<Insert manufacturer's name>**
 - 3) or approved equal.
- F. Provide manufacturer's field engineer on site for 3 days for startup calibration and instructing the DEN Project Manager's personnel.

2.12 POSITIVE DISPLACEMENT FLOW METERS

- A. The Flow Meters listed below shall be of the double case, straight through, rotary vane, positive displacement type.
- B. Meters shall have steel housing, standard trim, and Viton seals. Meters shall be rated for 150 PSI maximum working pressure and have 150 lb. ANSI RF flanges. Meter shall have a +/- 0.25 percent linearity and +/- 0.02 percent repeatability over the flow range shown below. Meters shall be equipped with the following accessories:
 1. Automatic Temperature Compensator, field adjustable for different products with deactivation.
 2. Preset Counter with a 4 SPDT microswitch and control handle kit.
 3. Large numerical counter and ticket printer. Ticket printer shall have a self-closing weatherproof cover.
 4. High resolution photo-electric pulse transmitter, 100 pulses per gallon plus one verification pulse per revolution.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Smith Meter, Models E3-S1 and G6-S1.
 2. Brooks Instrument Co., Models B-72DB and B-92DEB.
 3. **<Insert manufacturer's name>**
 4. or approved equal.

2.13 TURBINE FLOW METERS

- A. Magnetic pickup type full bore turbine. ANSI 150 psig flanged carbon steel body with all stainless steel internals. All electronics, including magnetic pick-up and

pre-amplifier, and all electrical connections shall be in [**NEMA-7 explosion-proof**]
<Insert type> enclosure.

- B. Flowmeter K-factor accuracy of +/- 0.15% over a 10:1 flow range, repeatability of +/- 0.02%.
- C. Provide with set-stop type [fuel] <Insert type> loading flow control valve and [fuel] <Insert type> loading totalizer/controller of the same manufacturer as the flow meter, as specified in the following.
- D. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Smith Meter Inc., GL - Series.
 - 2. Brooks Instrument Co., Parity Series.
 - 3. <Insert manufacturer's name>
 - 4. or approved equal.

2.14 [**LOADING STATION**] <Insert type> FLOW CONTROL VALVES

- A. Two-stage set stop type flow limiting control valve to control delivery flow rate and limit pressure surges on batch delivery shutdown.
- B. ANSI 150 psig carbon steel body with all stainless steel internals, and Viton seals. Self-contained hydraulic pilot or piston type flow control with dual 120 VAC solenoids for 2-stage flow control and gradual flow shutdown. Valves will be controlled by the batch totalizer/controller.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Smith Meter Co., Model 210 Electro-Hydraulic Set-stop Valve.
 - 2. Brooks Instrument Co., Model 788 DVC.
 - 3. or approved equal.

2.15 [**LOADING STATION**] <Insert type> TOTALIZER/CONTROLLERS

- A. Electronic loading station flow totalizer/controller, connected to turbine flow meter and set stop flow control valve, [**hazardous service; Class 1, Division 1, Group D,**] [**Type 4X weather and corrosion resistant**] enclosure, 120 VAC power supply. Unit shall be of the same manufacturer as the loading station flow meter and set stop valve.
- B. Features: 2-line LCD or Vacuum Fluorescent display; ticket printer; sealed keypad for entering operator ID number, access code, delivery flow rate, and preset total delivery; temperature compensation per API standard tables; digital valve control; permissive interface to dead-man switch and truck grounding, overfill and line connection safeties; EIA RS-485 communication port.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of

the following:

1. Smith Meter, Inc., Accuload II - STD
2. Brooks Instrument Co., Petrocount IMS Control Unit and IMS Remote Access Unit.
3. **<Insert manufacturer's name>**
4. or approved equal.

2.16 [REFUELER] OVERFILL PROTECTION AND GROUNDING SYSTEM

- A. Electronic safety interlock system for [refueler] **<Insert type>** loading stations incorporating: a dead-man switch, verification of grounding connection to enable initiation of loading, and overfill protection incorporating an optic high level probe. An override keyswitch shall be provided to enable loading of [refuelers] **<Insert type>** not equipped with a compatible interface. Green (permit) and red (non-permit) indicating lights shall be located on the controller enclosure.
- B. Override keyswitch shall override the overfill protection and grounding verification functions only. Override keyswitch shall not override the dead-man switch.
- C. All controller electronics shall be located in a **[NEMA-7 explosion-proof] <Insert type>** enclosure. All wiring between the controller and the [refueler] **<Insert type>**, and all [refueler] **<Insert type>** mounted components shall be U.L. listed as intrinsically safe.
- D. **[Refueler] <Insert type>** trucks shall be fitted with compatible components to enable system operation.
- E. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Scully. ST-35-115 ELK/D overfill protection controller.
 2. ST-47-1155 ELK Groundhog.
 3. **<Insert manufacturer's name>**
 4. or approved equal.

2.17 FLOW SWITCHES

- A. Thermal Flow Switch: Solid state electronic thermal flow switch, 4000 psi maximum working pressure, 316 stainless thermal flow probe, 1" NPT fitting, **[explosion-proof] <Insert type>** switch enclosure.
 1. Electrical: 120 VAC power supply, DPDT relay output. Switch threshold point adjustable from 0.05 to 0.5 ft./sec.
 2. Operating Environment: **[Class 1, Division 1, Group D,]** ambient temperature from -40 to + 160 degrees F.
 3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Flow Technology Inc., Uniprobe Model UP-01.
 - b. Fluid Components, Inc., Model FR72-4.
 - c. **<Insert manufacturer's name>**
 - d. or approved equal.
- B. Vane Operated Flow Switch: Multi-layer vane for use in pipe sizes from 1-1/2" to 8" diameter. 2000 psig maximum operating pressure, 1/1/2" NPT fitting.
1. Electrical: SPDT snap acting micro switch rated at 5 amps at 125 V AC. **[NEMA-7 explosion-proof] <Insert type>** switch enclosure.
 2. Operating Environment: **[Class 1, Division 1, Group D,]** ambient temperature from -40 to +160 degrees F.
 3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. W. E. Anderson, Model-V4-2-U.
 - b. Magnetrol, Model F10.
 - c. **<Insert manufacturer's name>**
 - d. or approved equal.
- C. Vane Operated Flow Switch: Tee mounted vane actuated flow switch for use in pipe sizes from 1/2" to 1-1/2" diameter.
1. Electrical: SPDT snap acting micro switch rated at 5 amps at 125 VAC. **[NEMA-7 explosion-proof] <Insert type>** switch enclosure.
 2. Operating Environment: **[Class 1, Division 1, Group D,]** ambient temperature from -40 to +160 degrees F.
 3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. W. E. Anderson, Model V6.
 - b. Magnetrol, Model F50.
 - c. **<Insert manufacturer's name>**
 - d. or approved equal.
 4. Service: **[Sump Separator Pumps] <Insert type>**.

2.18 ELECTRIC LEVEL SWITCHES

- A. Electronic Thermal Level Switches: Solid state electronic thermal level switch, 316 stainless steel probe, 316 stainless NPT fitting, level accuracy of +/- 1/16 inch, response time of 1.0 sec. or less.
1. Electrical 120 VAC power supply, SPDT relay output rated at 2 amps at 120 VAC. **[NEMA-7 explosion-proof] <Insert type>** enclosure.
 2. Operating Environment: **[Class 1, Division 1, Group D,]** ambient temperature from -20 to +160 degrees F.
 3. Probe with level accuracy of +/- 1/4 inch and response time of 5.0 sec. or less may be used where listed.

4. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. 1.0 sec. response: Fluid Components Inc., Model FR72LL.
 - b. 5.0 sec. response: Fluid Components Inc., Model 8-66.
 - c. or approved equal.

- B. External Cage Float Type Level Switches: Float activated magnetic level switch with carbon steel float cage, 316 stainless steel float and 400 stainless steel magnetic sleeve.
 1. Electrical: 2 mercury switches (1-N.O. and 1-N.C.) within NEMA 7 and 9 enclosure.
 2. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Magnetrol, Model 75.
 - b. Mercoïd, Model 201.
 - c. SOR Inc., Model 101.
 - d. **<Insert manufacturer's name>**
 - e. or approved equal.

2.19 WATER/[FUEL] INTERFACE LEVEL SWITCHES

- A. Provided with each filter-separator as shown under Division 23.
- B. Associated control wiring provided under this Section.

2.20 TANK LEVEL GAUGING

- A. Temperature compensated hydrostatic tank level gauging system utilizing three pressure transmitters and RTD temperature probe. Provide hydrostatic interface unit at each tank, complete with pressure and temperature transmitters.
- B. Pressure Transmitters: Rosemont Model 3001 C hydrostatic pressure transmitter: +/- 0.02 percent full scale accuracy, 316 stainless steel isolating diaphragm, suitable for use in **[Class 1, Division 1, Group D]** **<Insert application>** application, 316 stainless steel drain/vent spacer.
- C. Hydrostatic Interface Unit: Rosemont Model 7501 HIU, software configurable, 7-digit liquid crystal display, **[explosion proof]** **<Insert type>** enclosure, and digital communication bus to tank scanning unit. Provide with isolated contact outputs for high, intermediate, and low level. Level setpoints shall be adjustable. **[Provide RS-485 interface modules to interface HIU's to PC-based front end via MODBUS network.]**
- D. System Software: Rosemont Model 3801 Smart Tank System Software. Tank gauging software package shall reside under and operate through the tank farm operator interface executive software package. Software protocol shall be provided to the

software integrating contractor as required for compatible interface. The software package shall be capable of:

1. Concurrent operation, background scanning, and report and display generation. Software shall pull data from each of the HIU's to enable viewing all measured and programmed tank parameters on a real-time basis. Operator shall be able to perform diagnostic tests, and to configure tanks. Provide the following display screens as part of the software package: tank constants, strapping table, tank scanning unit detail, alarm log, tank detail, tank summary, tank groups, alarm summary, tank configurations, and tank diagnostics/status and report generation.
- E. Hand Held Interface: Provide two hand held interface units that can be connected to an HIU to enter, display, and alter tank information, and to view all measured and calculated data for the tank.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Rosemont, Model 268 smart interface.
 - b. Foxboro, PC-DOS based Tank Expert System.
 - c. **<Insert manufacturer's name>**
 - d. or approved equal.

2.21 PRESSURE TRANSMITTERS

- A. Electronic 2-wire, explosion-proof pressure indicating transmitter. Provide with isolation and nulling valves as required. Transmitter span shall be adjustable over a 5:1 ratio, with the system operating pressure approximately in the center of the transmitter span. Maximum over pressure rating of not less than 900 psig. 316 stainless steel body and wetted parts.
- B. Electronic pressure transducer shall provide 4-20 MA output signal proportional to measured pressure. Accuracy shall be +/- 0.25 percent of calibrated span, stability of +/- 0.25% of range for 6 months. Provide with integral scale calibrated from 0-300 psig. All electrical components shall be in [FM approved Class 1, Div. 1, Group D explosion proof and] NEMA 4X enclosure.
- C. Operating Environment: [**Class 1, Division 1, Group D,**] ambient temperature -40 to +160 degrees F.
- D. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Foxboro, Model 821GM.
 2. Rosemont, Model 1151GP.
 3. **<Insert manufacturer's name>**
 4. or approved equal.

2.22 PRESSURE SWITCHES

- A. Adjustable range [**explosion-proof**] <Insert type> pressure switch. Operating pressures up to 2 psig, stainless steel wetted parts, viton seals, 1/4 inch NPT pressure connection. All electrical components in NEMA 7 and 9 weathertight enclosure.
- B. Electrical: Hermetically sealed SPDT switch rated 15 amps at 125 VAC. U.L. Listed for [**Class 1, Division 1, Group D**] <Insert type> location.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. SOR, Models 6L-K45, 6L-K5 and 6L-K3.
 - 2. <Insert manufacturer's name>
 - 3. or approved equal.

2.23 DIFFERENTIAL PRESSURE SWITCHES

- A. Adjustable range opposed piston, explosion proof differential pressure switch. Operating differential pressures up to 2 psig, stainless steel wetted parts, 1/4 inch NPT pressure connections. All electrical parts in NEMA-7 weather tight enclosure.
- B. Electrical: Hermetically sealed SPDT switch rated 15 amps at 125 VAC. U.L. Listed for [**Class 1, Div. 1, Group D**] <Insert application> location.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. SOR, Models 13S-K5 and 14S-K5.
 - 2. <Insert manufacturer's name>
 - 3. or approved equal.

2.24 TEMPERATURE TRANSMITTERS

- A. 100 Ohm platinum RTD with unit mounted 2-wire 4-20 MA transmitter. NEMA 7 and 9 enclosure, U.L. Listed for [**Class 1, Division 1, Group D**] <Insert application> service. Accuracy to +/- 0.2% of span, repeatability to +/- 0.1% of span. Provide with 24 VDC power supply.
- B. Transmitter span shall be adjustable from 70 to 210 degrees F, range shall be adjustable to 360 degrees F.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Foxboro, 893 Series.
 - 2. Rosemont, Model 444.
 - 3. <Insert manufacturer's name>
 - 4. or approved equal.

2.25 CONTROL RELAYS

- A. Plug-in type general purpose control relays with coil voltage and number of contacts as required and as indicated on drawings. Where the number of contacts required exceeds the number available on a single relay, provide cascaded relays. Provide with plug-in relay socket with numbered wire terminals corresponding to the relay pin numbers. Contacts shall be rated for a minimum of 10 amps at 125 VAC.
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Square D.
 - 2. Potter-Brumfield.
 - 3. Struthers-Dunn.
 - 4. **<Insert manufacturer's name>**
 - 5. or approved equal.

2.26 TIMING RELAYS

- A. Plug-in type electronic timing relays for timing function, coil voltage and number of contacts as indicated on drawings. Provide with plug-in relay socket with numbered wire terminals corresponding to the relay pin numbers. Contacts shall be rated for a minimum of 10 amps at 125 VAC.
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Square D.
 - 2. Potter-Brumfield.
 - 3. **<Insert manufacturer's name>**
 - 4. or approved equal.

2.27 DC POWER SUPPLY

- A. Provide regulated DC power supply for all two- and three-wire transmitters as required. Power supply to be located in NEMA-4 enclosure [**outside of the hazardous zone**].
- B. Power supply to be rated for operation in ambient conditions from -40 to +160 degrees F. Input power of 115 VAC +/- 10 percent.

2.28 CURRENT LOOP INDICATORS

- A. Panel mounted loop-powered 3-1/2 digit LCD indicator, with trailing "dummy zero" and adjustable decimal point. Indication shall be in standard engineering units (GPM and PSIG) proportional to 4-20 ma input signal.
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Action Instruments, Model V-560.
2. **<Insert manufacturer's name>**
3. or approved equal.

2.29 INDICATING TOTALIZING RECORDERS

A. 100 MM Strip Chart Recorders:

1. Programmable electronic 2-variable recorder: 4-20 ma inputs; 40 character, 2-line vacuum fluorescent digital display; 9-digit totalizer; retransmission of input variable. Displayed, totalized, and recorded variables shall be in standard programmed engineering units. Accuracy of +/- 0.1% of span. Provide with hand held programmer.
2. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Chessel, Model 345.
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.

B. 10-Inch Circular Chart Recorders:

1. Programmable electronic totalizer controller: four 4-20 ma inputs; 40-character, 2-line vacuum fluorescent digital display; 9-digit totalizer, calculation of derived variables. Displayed, totalized, and recorded variables shall be in standard programmable engineering units. Accuracy of +/- 0.25% of span.
2. Totalizer shall sum 4 retransmitted 4-20 ma flow signals and shall display, totalize and record the total system flow rate.
3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Chessel, Model 390.
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.

2.30 OXYGEN SENSING AND ALARMS

A. Oxygen deficiency sensor and control unit: Control unit shall accept input from single or dual oxygen sensors (provide single sensor for each control unit) and activate 3 different color LED's at individual programmable alarm levels. (Yellow - caution, amber - warning, red - alarm).

1. Controller shall contain 3-digit LED display, and 2 control buttons to enable display of measured level and alarm set points for each channel, and to enable changing the alarm setpoints for each channel.
2. Electrical: Input power requirement: 100 VA at 115 VAC. Auxiliary alarm relays for each alarm level for each channel (6 - total) rated at 5 amps at 115 VAC. Controller enclosure: [**Explosion proof; Class-1, Division - 1, Group D**] **<Insert**

application>

3. Alarm Indication: Provide alarm indication panel at valve pit entrance, immediately below hatch. Alarm indication panel shall contain 3 alarm indication pilot lights, visible from outside of the valve pit (green - power on, amber - caution/warning, red - alarm) and a lamp test pushbutton, accessible from outside of the valve pit. Alarm indication panel shall be **[Explosion proof; Class-1, Division - 1, Group D]** <Insert application>.

2.31 FLOW CONTROL VALVES (FCV)

- A. The Flow Control Valves listed below shall be a combination rate of flow control and **[fuel]** <Insert type> shutoff valve with solenoid override shutoff and both open and closed position switches.
 1. Valve shall automatically limit the rate of flow to a predetermined maximum regardless of fluctuations in upstream or downstream pressure, and it shall close tight when actuating pressure is applied. Valve shall be a hydraulically-operated, pilot-controlled, diaphragm type globe pattern valve. Main valve body shall be cast steel with 150 lb. ANSI B16.5 flanges and stainless steel trim. Valve shall be rated for 275 psi working pressure. Main valve shall have a single renewable seat and a resilient disc with a rectangular cross section being contained on three and one-half sides by a disc retainer and disc guide. Valve stem shall be guided at both ends by a bearing in the valve cover and an integral bearing in the valve seat. The diaphragm assembly shall be the only moving part and shall form a sealed chamber in the upper portion of the valve, separating operating pressure from line pressure. Diaphragm shall consist of nylon fabric bonded with synthetic rubber and shall not be used as a seating surface. If diaphragm becomes damaged, the valve shall close tight. Packing glands and/or stuffing boxes are not permitted. All necessary repairs shall be possible without removing the valve from the line. Valve shall be equipped with a position indicator.
 2. Pilot control shall be a direct-acting diaphragm valve designed to close when the actuating pressure differential increases beyond the spring setting. Actuating differential pressure shall be produced by a thin-edged stainless steel orifice plate installed in an orifice flange located at valve inlet. Pilot control system shall also contain a diaphragm actuated three-way auxiliary valve which, when closed, automatically closes the main valve. Pilot valves shall have bronze bodies with stainless steel internal trim. Tubing and fittings shall be stainless steel minimum 1/2 inch diameter. Pilot supply line shall include a strainer.
 3. Two position switches shall be provided. One switch shall close when the valve is in the full closed position. The second switch shall close when the valve is open. Switch trip point shall be adjustable. Switches shall be DP-DT Type rated for 15 amps, 125 volts AC. Switches shall have aluminum housing with stainless steel trim. Switches shall be rated **[Class 1, Division 1, Group D, explosion-proof]** <Insert application> and weatherproof.
 4. Solenoid valves shall have brass body, stainless steel trim. Valves shall have watertight and explosion-proof **[(Class 1, Group D)]** <Insert application> enclosure. Valves shall operate on 115 volts AC. Main valve shall close when the solenoid is de-energized. Both opening and closing speeds shall be adjustable.
 5. Valves shall be a Model 40AF-2C-2 Combination Rate of Flow Control and **[Fuel]**

<Insert type> Shutoff Valves as manufactured by Cla-Val Co., Newport Beach, California.

2.32 PRESSURE CONTROL VALVES (PCV)

- A. Pressure control valves shall maintain a constant upstream or downstream pressure as indicated, closing to limit or opening to relieve excess pressure, and shall maintain close pressure limits without causing surges. Provide valves with solenoid override shutoff as indicated, and 2 position indicating limit switches.
1. Valve shall be a hydraulically-operated, diaphragm actuated globe pattern valve. Valve body shall be cast steel with 150 lb. ANSI B16.5 flanges and stainless steel trim. Valve shall be rated for 275 psi working pressure. Valve shall contain a resilient synthetic rubber disc with a rectangular cross section, contained on three and one-half sides by a disc retainer and disc guide forming a tight seal against a single renewable seat insert. Valve stem shall be guided at both ends by a bearing in the valve cover and an integral bearing in the valve seat. The diaphragm assembly shall be the only moving part and shall form a sealed chamber in the upper portion of the valve, separating operating pressure from line pressure. Diaphragm shall consist of nylon fabric bonded with synthetic rubber and shall not be used as a seating surface. If diaphragm becomes damaged, the valve shall close tight. Packing glands and/or stuffing boxes are not permitted, and there shall be no pistons operating the valve or pilot controls. All necessary repairs shall be possible without removing the valve from the line. Valve shall be equipped with a position indicator.
 2. Pilot control shall be a direct- or reverse-acting adjustable, spring-loaded diaphragm valve designed to permit or restrict flow as required when controlling pressure exceeds spring setting. Pilot control system shall operate such that as excess line pressure is dissipated or limited, the main valve shall close to a positive, drip-tight seating. Pilot valves shall have bronze bodies with stainless steel internal trim. Tubing and fittings shall be stainless steel minimum 1/2 inch diameter. Pilot supply line shall include a flow clean strainer.
 3. Valves shall be as manufactured by Cla-Val Co., Newport Beach, California.

2.33 PRESSURE DIFFERENTIAL CONTROL VALVES (PDCV)

- A. Pressure differential control valves shall respond to differential changes across control pilot. All increase in differential above a set point shall cause the main valve to open. Valve shall modulate to maintain a relatively constant differential pressure. Main valve shall be a hydraulically-operated, diaphragm-actuated globe pattern valve. Valve body shall be cast steel with 150 lb. ANSI B16.5 flanges and stainless steel trim. Valve shall be rated for 275 psi working pressure. Valve shall contain a resilient synthetic rubber disc with a rectangular cross section, contained on three and one-half sides by a disc retainer and disc guide forming a tight seal against a single renewable seat insert. Valve stem shall be guided at both ends by a bearing in the valve cover and an integral bearing in the valve seat. The diaphragm assembly shall be the only moving part and shall form a sealed chamber in the upper portion of the valve, separating operating pressure from line pressure. Diaphragm shall consist of nylon fabric bonded

with synthetic rubber and shall not be used as a seating surface. Packing glands and/or stuffing boxes are not permitted, and there shall be no pistons operating the valve or pilot controls. All necessary repairs shall be possible without removing the valve from the line. Valve shall be equipped with a position indicator.

- B. Pilot control shall be a pressure differential control. Pilot valves shall have bronze bodies with stainless steel internal trim. Tubing and fittings shall be stainless steel. Pilot supply line shall include a strainer and orifice assembly. Differential control adjustment shall be provided.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Cla-Val Co., Newport Beach, California, Model 250AF Differential Pressure Relief Valves.
 - 2. **<Insert manufacturer's name>**
 - 3. or approved equal.

2.34 TANK VALVES

- A. Valves: Fail closed/Fail safe, through-conduit gate valve to provide positive fire safe shutoff of both inlet and outlet lines. Actuators shall be sized to operate the valves at the pressures and flows encountered, and shall be selected to provide ample force to overcome the tendency of valves (particularly when kept in the closed position for long periods of time) to resist actuation.
 - 1. Valve flanges shall be 150 lb. class, ANSI B16.5; Fire safety listing shall be to API-6FA.
 - 2. Gate and seats: Reverse-ported, moly-disulfide treated, steel slab gate; two hardened steel floating seats, each with TFE face inserts and two peripheral elastomer O-rings; T94 valve trim.
 - 3. Actuators: Valves shall be provided with pneumatic actuators for operation with 150 psig instrument air supply, as specified below.
 - 4. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. W-K-M, Saf-T-Seal Through-Conduit Gate Valve.
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.
- B. Actuators for 12" Valves: Spring return, pneumatic diaphragm type actuator for normally closed/fail safe valve operation.
 - 1. Actuator shall be fire safe listed with valve to API-6FA.
 - 2. Actuators shall be sized for operation with 150 psig nominal instrument air supply. Provide 2 position indicating limit switches with actuator (1 for full open and 1 for full closed indication). Provide 3-way **[explosion proof]** **<Insert type>** solenoid with 120 VAC coil, mounted on piped to actuator. Solenoid shall have minimum 1/2 inch ports, solenoid coil shall be rated for continuous energization.

3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. W-K-M, Saf-T-Gard Diaphragm Actuator.
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.

- C. Actuators for 20" and 30" valves: Spring return, pneumatic piston type actuator and bonnet plate assembly for adaptation to W-K-M reverse acting gate valve. Valve operation shall be normally closed/fail safe.
 1. Actuator and valve assembly shall be fire safe to API-6FA.
 2. Actuators shall be sized for 150 psig nominal, instrument air supply. Provide 2 position indication limit switches with actuator (1 for full open and 1 for full closed indication). Provide 3-way [**explosion-proof**] **<Insert type>** solenoid with 120 VAC coil, mounted on and piped to actuator. Solenoid shall have minimum 1/2 inch ports for 20 inch valves and 3/4 inch ports for 30" valves. Solenoid coil shall be rated for continuous energization.
 3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Axelson, MHA Piston Pneumatic Actuator and Bonnet plate assembly.
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.

2.35 EMERGENCY FUEL SHUTOFF (EFSO) VALVES

- A. EFSO Valves shall be butterfly valves as specified in Section 220523. Provide with compatible actuators as specified below.

- B. Pneumatic Cylinder Actuators: Provide spring return type pneumatic cylinder actuators for operation on 100 psig dry nitrogen supply. Actuator shall be configured for normally closed valve operation.
 1. Size actuator such that valve will fully open against system pressure within 10 sec. after energizing three-way solenoid valve, and will fully close off, bubble tight, against system design flows within five (5) seconds of de-energizing three-way solenoid valve.
 2. The central housing of the actuator shall be of one-piece integral construction to eliminate possibility of bearing misalignment. A weather-tight vent shall be provided in the housing to prevent possible pressure build-up. Piston and rods shall be of cold-finished, ground, and polished steel. All bearing surfaces shall be coated with a lubricant that includes a corrosion inhibitor. Actuator shall be designed to withstand constant operating pressure in an ambient environment from -20 to +200 degrees F.
 3. Provide 2 explosion proof limit switches with actuator (1 for full open and 1 for full closed indication). Provide explosion proof 3-way E-P solenoid, with 24 VDC coil with actuator. Solenoid shall be sized for valve operation as described, and coil shall be rated for continuous energization.

4. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. GH Bettis.
 - b. **<Insert manufacturer's name>**
 - c. or approved equal.

2.36 ELECTRIC MOTORIZED VALVE ACTUATORS

- A. Provide electric motorized 90 degrees actuators where indicated. Actuators shall be sized to operate the valves at the pressures and flows encountered, and shall be selected to provide ample force to overcome the tendency of valves (particularly when kept in the closed position for long periods of time) to resist actuation. Actuators shall be electric motor driven in both directions, and shall incorporate both limit switch and torque limit de-energization.
- B. Actuator motors shall be 460 V, 3 phase. Actuator shall be suitable for outdoor mounting in an ambient environment from -20 to +100 degrees F.
- C. Provide with local mechanical position indicator; local open/close/stop, and local/remote control switches, terminals for remote open/close control operation, and limit switches for full open and full closed indication.
- D. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Limitorque.
 2. Auma.
 3. **<Insert manufacturer's name>**
 4. or approved equal.

2.37 PROGRAMMABLE LOGIC CONTROLLER

- A. A programmable controller manufactured to NEMA ICS 3, with component circuit boards manufactured to NEMA ICS 2. Programmable controller system shall be microprocessor based with solid state memory. Programmable controller system shall include CPU's, multiplexers, programmer interface, I/O modules, power supply, and all power and data cables to function as a complete system.
- B. Basic Configuration: Dual CPU's configured as "on line" processor and "hot" back-up, with both local and remote I/O modules connected to CUP's via a multiplexed data trunk. CUP's shall interface with the master PC-based operator station via direct data link operating at not less than 57.6 K Baud. Provide interface hardware as required for installation in PC expansion slot.
- C. Central Processing Units (CPU's): The CPU's shall be self-contained units that will provide Ladder Rung program execution and support local or remote programming. The CUP's will provide I/O scanning, and support peripheral communication. Each CPU shall as a minimum, support up to 3000 I/O points distributed in up to 20 I/O

racks, both local and remote. Each CPU shall have a memory capacity of not less than 48K, 16 bit words. The on line CPU will communicate with the I/O modules via multiplexed twin axial data trunk operating at not less than 57.6 K Baud. The programming instruction set shall support the following functions as a minimum:

1. Language characteristics: Ladder diagram, code listing, or extended BASIC language.
2. Logic operations: AND, OR, XOR, NOT, IF, THEN, ELSE, GO TO, GREATER THAN, LESS THAN.
3. Math operations: Addition, subtraction, division, multiplication, square root, absolute value, truncate, round, exponentiation, natural logarithm, common logarithm, and trigonometric functions.
4. The processor mode shall be selected by a front panel mounted keyswitch, and shall include run, program, and test modes.

D. Input/Output System: Provide complete I/O stations, both local and remote, as indicated on the drawings and as required for system operation. Each I/O station shall be complete including all required power supplies, backplane, communication interface module, and I/O point modules. Provide the indicated number of input and output points of each type for each I/O station, plus a minimum of 25 percent but not less than two spare I/O points of each type. (No spare analog output points need be provided.) The I/O modules shall include the following features:

1. Isolation shall be used between all internal logic and external power circuits. The isolation shall meet the minimum specification of 1500 VRMS.
2. Each I/O module shall contain visual indication of ON/OFF status of individual input and output points.
3. Discrete output modules shall be provided with self-contained fuses for overload and short circuit protection of the module.
4. Each I/O module shall contain built-in wire duct and shall be of "dead-front" construction.

E. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Square D Company, Model 500.
2. Allen Bradley, 1785 PLC-5/60.
3. Texas Instruments, Model 565.
4. **<Insert manufacturer's name>**
5. or approved equal.

2.38 OPERATOR INTERFACE HARDWARE

A. System operator interface shall be through either of 2 personal computers interconnected via fiber-optic data trunk. The master PC shall be located in the Control Building, as shown on the plans, and the second to be located in the airport operations center.

B. Master/Server CPU: 80386 based PC with 80387 co-processor, and minimum 16 MB

of RAM, with a clock speed of not less than 33 mHz. Provide with: 120 MB hard disk, and 1.2 MB 5-1/4 inch and 1.44 MB 3-1/2 inch floppy drives, 101 character ASCII standard keyboard VGA driver board, and 5 communication ports, and Ethernet board.

- C. Remote Monitor CPU: 80386 based PC with 80387 co-processor and minimum 4 MB of RAM, with a clock speed of not less than 30 Hz. Provide with: 120 MB hard disk, and 1.2 MB 5-1/4 inch and 1.44 MB 3-1/2 inch floppy drives, 101 character ASCII Standard keyboard and VGA driver board, and Ethernet board.
- D. Display Driver CPU's: 80386 based PC with 80387 co-processor, 2 MB of RAM, and a clock speed of 20 MHz. Provide with 20 MB hard disk and 1.2 MB, 5-1/4 inch floppy drive, and Ethernet interface board.

2.39 OPERATOR INTERFACE SOFTWARE

- A. Microsoft-Windows based color-graphic supervisory operator interface software package to facilitate monitoring of the **[fueling]** <Insert type> systems operation, and selection of systems operating parameters. The system software shall drive four independent monitor screens at the master control station, and network the **[fueling]** <Insert type> system monitoring functions to a remote monitoring station via an Ethernet network.
- B. Provide interface drivers for the following **[fueling]** <Insert type> system software packages. If the interface driver does not currently exist in the supervisory software package, the Contractor shall write the required driver.
 - 1. Programmable Logic Controller (PLC) monitoring and programming software.
 - 2. Hydrostatic Tank Gauging System software package.
 - 3. Remote **[fuel]** <Insert type> loading station inventory control software package.
 - 4. Leak detection system monitoring software package.
 - 5. Corrosion protection system monitoring software package.
- C. System operation shall be through a mouse. Real-time graphic displays of the entire **[fueling]** <Insert type> system, based on the system flow diagrams will update displayed variable values once per second. All system alarms shall be displayed in a protected area of the selected alarm monitor and the remote monitor station. Alarm logs shall be automatically directed to the alarm printer. The system shall record and display trend logs for up to four selected variables on a single screen, and record trend logs for up to 32 simultaneous selected variables. Displayed trend logs shall update on a real-time basis. The software package shall support custom report generation through compatible interface with Lotus 1-2-3 or other similar package.
- D. The Installer shall provide all software required for efficient operation of all functions required by this specification. Software shall be modular in design for flexibility in expansion or revision of the system.
- E. System software will consist of real-time operating system containing all points and functions as described herein. The most current operating system, including the most current parameter changes and modifications, will be contained on the disk, to provide

their operator with the most current source of data to reload CPU and controller memory after power loss or system failure.

- F. The system shall use English language for each point identification. To facilitate different building operators, the system shall accept multiple English language identifiers for each system operator.
- G. The system shall recognize all inputs as functions or commands to be performed. The system's handling of operator inputs, such as requests to start a motor, output a log, change a time program, acknowledge an alarm, or do any of the other commands described in this specification, shall be in a similar format.
- H. Operator access to the system shall be via user defined passwords providing at least five access levels. Each operator shall gain access to the system by entering a unique name and password combination.
- I. A help program shall be provided to list program commands and inputs/outputs available to an operator for the access level cleared for that operator.
- J. Input Process:
 - 1. Select from menu one of four general types of commands based upon password clearance, command points, information points, build parameters, and modify parameters. Commands not available by password clearance shall be detected from video display.
 - 2. Enter memory changes through keyboard or graphically through use of the mouse.
 - 3. Select entry modes, Aid or Direct, based on operator's degree of capability and familiarity with system.
 - 4. Aid Mode shall prompt operator through each step indicating available options.
 - 5. Direct Mode shall allow experienced operator to input command string directly.
 - 6. Enter commands as alpha/numeric character strings, or graphically via menu selection with the mouse. Where commands require data for limits, setpoint, and time, enter value in same engineering units as controlled variable.
 - 7. Operator input shall not inhibit alarm reporting. Echo input on associated output device, to either execute or abort.
- K. Information Access: Obtain point status information from any designated output device with access command. Point status consists of point identification, numerical value (analog points) and associated engineering units, and individual function label indicating that point is on or off or in Alarm Normal condition. Output includes date and time of execution.
- L. The system shall have the ability to download new or modified system parameters from the central console to each Controller and its resident software. Upon receipt of these new parameters, the Controller shall change its operating database to reflect the new parameters and will operate under these parameters until again modified.
- M. Database Creation and Modification: The operator shall have as a minimum, the capability to:

1. Add and delete points.
 2. Modify any point parameter.
 3. Change, add, or delete English language descriptors.
 4. Change, add, or delete engineering units.
 5. Change, add, or delete points in start/stop programs trend logs, etc.
 6. Select analog alarm limits.
 7. Adjust analog differentials.
 8. Create custom relationships between points, such that the user can implement software interlocks, master/slave relationships, and virtual points.
 9. Create back-up copies of the system database, and reload the database into the system.
 10. Create and modify graphics through graphics builder algorithm via the mouse and function icons, and Autocad import capability.
- N. Database Save/Restore:
1. Provide program which allows saving or restoring of operating data.
 2. **Hard drive** shall save or restore system operating data.
- O. Report Generation: Through compatible interface with Lotus 1-2-3 or equivalent package.
1. The system shall contain a full test editor for the creation of custom reports.
 2. All reports created shall have full access to the systems database for the purpose of embedding any selected point into a report location for ease of display and view.
 3. The system shall permit full programmability for report generation. The following logical and mathematical operators must be provided: Greater than, less than, equal to, not equal to, add, subtract, multiply, divide, square root, and/or comparators, absolute value, and modulus. All of the above operators shall be capable of being used in an easy to follow English language based program to trigger generation and/or change formats of specific reports.
 4. The system shall allow for report grouping so that predefined or selected reports may be generated by a single request.
 5. The report generator shall have the ability to conduct mathematical calculations at report time so not to burden the CPU with processing which will not be required until generation time.
 6. A report shall be configurable to ask for user input that can be used in the calculation and generation of a report.
 7. The system must include a programmable looping function to allow for the repeated generation of one report containing different data.
 8. A report must be capable of being configured to invoke another executable software programs at generation time.
 9. All report programs shall be capable of time of day, day of week, or day of year scheduling.
- P. Points Editor:
1. The system shall incorporate a full screen forms based points editor which shall allow for both a terse system name and a verbose English language name to be

- assigned for all points configured in the system.
2. The number of points that are configurable for any device shall only be limited by hard disk space.
 3. All points in the system shall be accessible via an on-line directory for immediate use to avoid the need for a points reference notebooks or any other written material.
 4. Point grouping shall be allowed so that operator defined groups allows the recall by name to view the status of a preselected group of points.
 5. Automatic and manual storage and reload ability of full programming database and points configuration for stand-alone controllers.

Q. Color Graphic or CAD Configuration:

1. The system shall allow for CAD creation of all as build documentation via CAD software. This must allow for all job drawings, to be used directly by the system for its graphics.
2. There must be supplied standard full screen stencils, commonly used symbols and useful shapes to assist in graphic construction. It shall be possible copy shapes and symbols from one graphic to another via Windowing by simply outlining the shape or symbol with a mouse and moving it to the new window. To minimize graphic construction time this must be allowable without the need to exit either window.
3. All graphic panels shall be allowed to be linked in any order configured by the user to provide for hierarchical logical system penetration. This linking shall be defined to occur automatically or through a user defined selectable point on a graphic panel. The user must also be capable of selecting any graphic via the use of a pull down window anywhere in the system.
4. The number of system points or animations to be displayed on a specific graphic is limited only by available memory or screen size. There shall be no restriction as to which graphics may contain which system database point.
5. Status indication of a graphic object may be through the use of operator selected colors, patterns, or dynamic animations. There shall be no limit as to the number of events that may be defined to trigger a graphic indication or animation. Animations shall include but not be limited to objects changing representation, objects changing screen location, objects changing size in proportion to a database value, bar graphics, line graphics, objects rotation proportional to a database value, level display, object blinking or changing color, text changing, or the changing of a complete graphic panel.
6. Operator interface to enable the commanding of modifying of control devices or database points from a graphic must allow a form of real life control panel interaction. This panel shall allow the operator the ability to define dynamic animations per defined objects such as, but not limited to, toggle switches, slide switches, pointing devices, push buttons, rotary switches, analog gauges, digital gauges, analog bar indicator or popup mouse keypads. All animations will function in their real life sense for device modification, database point modification, report generation, or system program interaction through the movement of an animation or the entry of data via an on screen digital pad with only a mouse. There shall be no limit as to the number of animations per graphic or the number of animations per object.

R. Alarms:

1. There shall be a full screen forms based alarm definition screen that allows the user to define each alarm level and the action that will take place if this level is met. The system must allow a minimum of 32 alarm levels that the operator may specify. The alarm summary display shall list the last 60 alarm entries.
2. Alarm processing must occur via simple range testing with the option of logical or complex mathematical expressions to meet more complex needs. Under no circumstances shall another system application stop the processing sequence of alarm processing. The system shall be capable of multirange checks on point values.
3. Actions which may be programmed to take place automatically on the event of an alarm condition to notify the operator must be capable of but not limited to the following:
 - a. Display of the appropriate graphic panel, with the option of representing the alarm with an animation, in which the operator may both view the problem and take corrective measures using the interactive mouse.
 - b. Produce an audible "ICON" which must indicate the number of alarms that are currently pending.
 - c. Generate an operator customized report.
 - d. Display a minimum 64 character (custom per point) alarm message box to the screen.
 - e. Any of the above ((a or b) and c and d) shall be configurable to occur simultaneously.
4. The number of alarms, which may be defined in the system or on any one specific point, shall be limited only by hard disk space.
5. The state at which a point is considered in alarm shall be user definable. This will allow the user to define the state change that will trigger an alarm condition in the system.
6. From a pull down menu the user must be able to acknowledge many point in alarm, all points which are in alarm, all points in a specific level which are in alarm, all points between selected levels which are in alarm, all points which have returned to normal or all points that were in alarm but have returned to normal.
7. The system shall permit the definition of which users are allowed to acknowledge an alarm and which users are allowed to view an alarm. Security features must be configurable for each alarm in the system so that a user, even though given a specific level password, can be locked out from viewing or acknowledging a specific alarm.

S. Spreadsheet:

1. The system shall provide the real time and concurrent ability to analyze, manipulate, and/or graph data from its database with its fully functional spreadsheet application. This application must run concurrently with other system applications.
2. The user shall be able to enter, calculate or manipulate any data directly from the system database within a spreadsheet using the full functionality of Lotus 1-2-3

- while also being offered the ability to have any resultant of an operation within the spread sheet modify a system database point.
3. It shall be possible for a spreadsheet to spawn a communications link with a controller for the purposes of gathering data for a calculation or charting function.
- T. Programmability:
1. The system shall possess the ability to be programmed to spawn specific functions and/or control decisions automatically.
 2. The systems programming language shall be capable of conducting full mathematical operations and bullion logical expressions on all points in the systems database. It shall be a high level, English language based, easy to learn, operating system. All calculations must be the ability to be spawned based on system runtime events such as time, date, calculated value, or operator request. All calculations shall be global to all system applications for the purposes of graphic representation, data transfer, alarm indications, and report generation.
 3. Mathematical operations or functions supported shall include at a minimum: Absolute value, average value, exponential, factorial, fractional truncation, log base 10, trigonometric, maximum/minimum, natural log, rounding, scientific notation, and square root.
 4. The systems programmability shall allow for the collection of data from all field panels connected to all 5 operating subsystems. Times and occurrence of such a collection must be 100% configurable by the operator in the following formats:
 - a. Time based: his would occur when information is stored at preprogrammed intervals by the operator.
 - b. Change of Value based: The collection of data would occur when a system database point changes beyond a threshold that was predefined by the operator via the systems programmability.
 - c. Field Panel Request: The collection of data by the system would occur when a request to collect is issued by a direct connected or remote field panel.
 - d. Programmed Request: The collection of data would occur based on a result calculated by the systems operator defined programs.
- U. Functions Execution/Communications:
1. The system must permit but not be limited to simultaneous operation of a minimum of four of the following functions:
 2. Alarm processing/definition, graphic creation/interaction, system program execution, schedule modification, spreadsheet operation, report generation/creation.
 3. All system communication speeds to both local and remote panels shall be user selectable from 300 baud to 57.6 K baud. All local system spawn communications shall contain error checking to minimize corrupt data transmission. Any remote telemetry communication devices shall utilize internal error checking.
- V. Advisories:

1. Lockout summary that contains status of points in locked out condition.
2. Continuously interrogate system hardware and programmable control units for failure or tampering and report if operation or not operational.
3. Power failure detection, time and date.
4. System communication failure with operator device, field interface unit, point, programmable control unit.

W. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Iconics, Genesis Control Series.
2. U.S. Data, Factory Link software package.
3. Wonderware, InTouch Version 3.2.
4. or approved equal.

2.40 LIMIT SWITCHES

A. Provide limit switches and accessories (cams, triggers, etc.) to indicate valve positions as indicated on the drawings and as specified herein. Provide switches that are U.L. listed for **[Class 1, Division 1, Group D]** <Insert application> application, and shall be suitable for a minimum of 5 amps at 120 VAC.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Square-D.
2. Allen-Bradley.
3. <Insert manufacturer's name>
4. or approved equal.

2.41 LEVEL TRANSMITTER

A. RF capacitance type level transmitter for **[Class 1, Division 1, Group D]** <Insert application> application in an outdoor environment; 115 VAC power supply; 4-20 ma DC transmitter output; transmitter enclosure shall meet NEMA 4, 7 and 9 requirements.

2.42 LEVEL SWITCHES

A. Magnetic float type level switches: sliding magnetic float(s) shall activate switches located in probe tube. Provide with relay output contacts rated for minimum 5 amps at 120 VAC. Assembly shall be U.L. listed for **[Class 1, Division 1, Group D]** <Insert application> application, and shall be suitable for outdoor operation.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Magnetrol.

2. B/W Magnetek.
3. **<Insert manufacturer's name>**
4. or approved equal.

PART 3 - EXECUTION

3.1 GENERAL

- A. Install all system components in accordance with manufacturers' recommendations, roughing in drawings and details on drawings. Provide all necessary interconnections, services, and adjustments necessary for a complete and operable system.
- B. All electrical work shall be in accordance with the NEC and Division 26 of these Specifications.
- C. All setpoints shown on the drawings and in the operating sequences are approximate initial values only. All setpoints shall be adjustable.

3.2 EXAMINATION

- A. Verify that systems are ready to receive work.
- B. Beginning of installation means installer accepts existing conditions.

3.3 INSPECTION

- A. Inspect work in progress in accordance with project documents.

3.4 DELIVERY, STORAGE AND HANDLING

- A. Provide factory shipping cartons for each piece of equipment and control device. Provide factory applied plastic end caps on each length of pipe and tube. Maintain cartons and end caps through shipping, storage and handling as required to prevent equipment and pipe-end damage, and to eliminate dirt and moisture from equipment and inside of pipe and tube. Store equipment and materials inside and protected from weather.

3.5 IDENTIFICATION SYSTEM

- A. Piping and Wiring: Tag control piping and wiring at each end, and at necessary junction points. Match the tagging number indicated on the shop drawings.

3.6 ELECTRIC WIRING

- A. All electric wiring shall be in accordance with ANSI/NFPA 70, and Division 26 Sections.
- B. Control Wiring: Install control wiring, without splices between terminal points, color-coded, and numbered on both ends. Install in neat, workmanlike manner, securely fastened. Install in accordance with Division 26 Sections.
 - 1. Install circuits over 25-volt with color-coded 90 degrees F, 600 volt insulation, minimum No. 14 AWG wire in conduit.
 - 2. Install circuits under 25-volt with color-coded minimum No. 16 wire in conduit with high temperature (105 degrees F (41 degrees C)) plastic insulation on each conductor and plastic sheath over all. Provide shielded cables where indicated on plans or where required by the instrument provided.
 - 3. Provide surge protection on all control and control power circuits routed outside of the control building. Surge protection shall consist of surge suppressors, transient protectors and optical isolated relays as applicable.

3.7 INSTRUMENT AIR SUPPLY

- A. Mount compressor and tank unit on vibration isolation consisting of springs, with minimum of one inch static deflection and one inch clearance to floor. Isolate air supply with wire-braid reinforced rubber hose.
- B. Supply instrument air from compressor units through filter, dryers, pressure relief valve, with pressure gages, and shutoff and bypass valves.
- C. Install pressure regulating station consisting of pressure regulating valve, particle filter, valved bypass, pressure gage on inlet and outlet, and pressure relief valve.
- D. Locate refrigerated air dryer in discharge air line from tank, and desiccant dryer in discharge line from refrigerated dryer. Mount refrigerated dryer on wall on rubber in shear mounts. Install pressure regulator downstream of dryer. Pipe automatic drain to nearest floor drain.

3.8 CONTROL AIR PIPING

- A. Tubing, pipe and fittings shall conform to Specifications for air piping.
- B. Main instrument air line from compressor to **[fuel] <Insert type>** tanks shall be PVC coated steel pipe. Route pipe in same trench as electrical conduit. All other instrument air piping shall be copper, minimum 1/2 inch diameter or steel pipe, minimum 3/4 inch diameter, except for final connections to actuators, which shall be wire braid reinforced rubber tubing of not over 2 feet in length.
- C. All tubing shall be run parallel to building and equipment lines and shall be continuously supported. Tubing may be supported from walls, pipe racks, walkways or piping. When supporting tubing from insulated pipe the tubing shall be supported

outside the insulation. When tubing spans open areas it shall be continuously supported from punched angle supports made for such purpose.

- D. All tubing shall be stretched to straighten without reducing the O.D. of the tubing. All bends shall be made with mechanical tubing benders to avoid flattening of bends. Tubing shall be installed so that sags and low spots are avoided.
- E. Piping and tubing shall be installed to use as few fittings as possible.
- F. All air lines shall be blown out before installation. After piping is installed, it shall be pressured to 200 psi and all joints soap-tested for leaks.

3.9 INSTALLATION - SOFTWARE

- A. Load and debug all software required for an operable control system as specified, including database, operational parameters, system and application programs.

3.10 DATA CABLES

- A. General: Install all signal transmission components in accordance with ANSI C2, Form 511A, and Division 26 requirements.
- B. Keep cable runs as short as possible, allowing extra length for connections to terminal boards.
- C. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter. Use sleeves or grommets to protect cables from vibration at points where they pass around sharp corners or through penetrations.
- D. Grounding shall be in accordance with ANSI C2. All ground wire shall be copper.
- E. Provide transient protection for all non-fiber optic data cables exiting the control building. Transient protection devices shall be compatible with the type of data cable and the communication baud rate.

3.11 CONTROL PANELS

- A. Mount control panels adjacent to associated equipment on vibration-free walls or free-standing angle iron supports. One cabinet may accommodate more than one system. Provide engraved plastic nameplates for instrument and controls inside cabinet and engraved lamoid nameplates on cabinet face.

3.12 TESTING

- A. General: Provide DEN Project Manager-approved operation and acceptance testing of the complete system in accordance with Section [017515 "**System Startup, Testing and Training**"] <Insert section>. The DEN Project Manager's representative will

witness all tests.

- B. Field Test: When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. All testing, calibrating, adjusting, and final field tests shall be completed by the Installer. Provide a detailed cross-check of each sensor within the system by making a comparison between the reading at the sensor and a standard traceable to the National Bureau of Standards. Provide a cross-check of each control point within the system by making a comparison between the control command and the field controlled device. Verify that all systems are operable from local controls in the specified failure mode upon PLC failure or loss of power.

1. Submit the results of functional and diagnostic tests and calibrations to the DEN Project Manager for final system acceptance.

3.13 COMPLETION SERVICES

- A. Start-Up Service: Start up system in accordance with manufacturers' recommendations, and in accordance with Section [017515 "System Startup, Testing and Training"] <Insert section>.
- B. Adjustment: Upon completion of the project, adjust and validate all instruments and other equipment provided under this Section.
- C. Demonstrations: Upon completion of the work, demonstrate system operation to DEN Project Manager's designated representative, for verification of proper operation.
- D. Training: Provide minimum eighty (80) hours of training for DEN Project Manager's operating personnel. Training shall include explanation of drawings and operation and maintenance manuals, walk-through of the job to locate control components, and explanation of adjustment, calibration, and replacement procedures.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement will be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this section. The cost of the work

described in this section shall be included in the Lump Sum Contract price.

END OF SECTION 230800

SECTION 231113 - FACILITY FUEL-OIL PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Fuel-oil pipes, tubes, and fittings.
 - 2. Double-containment piping and fittings.
 - 3. Piping specialties.
 - 4. Manual fuel-oil shutoff valves.
 - 5. Specialty valves.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- B. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
- C. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, and dimensions of individual components and profiles.
 - 2. Include, where applicable, rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. For valves, include pressure rating, capacity, settings, and electrical connection data of selected models. Provide manufacturers catalog information. Indicate

- valve data and ratings.
4. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For fuel-oil piping.
1. Include system layout, pipe sizes, location, plans, elevations sections, hangers, and supports for multiple pipes.
 2. Include details of location of anchors, alignment guides, and expansion joints and loops.
 3. Scale: [1/4 inch per foot (1:50)] <Insert scale>.
- C. Delegated-Design Submittal: For fuel-oil piping indicated to comply with performance requirements and design criteria.
1. Include analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 2. Detail fabrication and assembly of anchors and seismic restraints.
 3. Design Calculations: Calculate requirements for selecting seismic restraints.
 4. Detail fabrication and assembly of pipe anchors, hangers, supports for multiple pipes, and attachments of the same to building structure.

1.5 INFORMATIONAL SUBMITTALS

Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Plans and details, drawn to scale, on which fuel-oil piping is shown and coordinated with other installations, using input from installers of the items involved.
- B. Site Survey: Plans, drawn to scale, on which fuel-oil piping and tanks are shown and coordinated with other services and utilities.
- C. Brazing certificates.
- D. Welding certificates.
 1. Include welders certification of compliance with [ASME SEC 9] [AWS D1.1.] [NCPWB Standard Procedure Specifications] <Insert requirement> and section 059990 "Welding".
- E. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Spool drawings shall be submitted in compliance with Division 01 requirements. Other file formats will not be accepted.
- F. Pneumatic Leak Test:

1. Contractor shall submit drawings and procedures of the pneumatic leak test to the DEN Project Manager no later than two (2) weeks prior to testing. Contractor may not proceed with tests unless approved in writing by the DEN Project Manager.

G. Field quality-control reports. Include the following:

1. Test procedures used.
2. Test results that comply with requirements.
3. Failed test results and corrective action taken to achieve requirements.

H. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For fuel-oil equipment and accessories to include in emergency, operation, and maintenance manuals.

1. Include installation instructions, spare parts lists [, **exploded assembly views**].

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual location of piping system, storage tanks, and system components.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Provide [**two**] **<Insert quantity>** repacking kits for each size valve.

1.8 QUALITY ASSURANCE

A. Valves: Manufacturer's name and pressure rating marked on valve body.

B. Brazing: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

C. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

D. Pipe Welding Qualifications: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code.

E. Conform to [**applicable**] [**EPA Regulations**] **<Insert requirements>** for installation of fuel oil system.

- F. Provide certificate of compliance from **[authority having jurisdiction]** **<Insert requirements>** indicating approval of installation of fuel oil system.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Lift and support fuel-oil storage tanks only at designated lifting or supporting points, as shown on Shop Drawings. Do not move or lift tanks unless empty.
- B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- C. Store pipes and tubes with protective PE coating to avoid damaging the coating and to protect from direct sunlight.
- D. Store PE pipes and valves protected from direct sunlight.

1.10 FIELD CONDITIONS

- A. Interruption of Existing Fuel-Oil Service: Do not interrupt fuel-oil service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary fuel-oil supply according to requirements indicated:
1. Notify DEN Project Manager no fewer than **[two]** **<Insert number>** days in advance of proposed interruption of fuel-oil service.
 2. Do not proceed with interruption of fuel-oil service without DEN Project Manager's written permission.

1.11 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of flexible, double-containment piping and related equipment that fail in materials or workmanship within specified warranty period.
1. Failures due to defective materials or workmanship for materials including piping, dispenser sumps, watertight sump entry boots, terminations, and other end fittings.
 2. Warranty Period: Minimum **[10]** **[30]** **<Insert number>** years from date of Substantial Completion.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Comply with ASME B31.9, "Building Services Piping," for fuel-oil piping materials, installation, testing, and inspecting.
- C. Fuel-Oil Valves: Comply with UL 842 and have service mark initials "WOG" permanently marked on valve body.
- D. Comply with requirements of the EPA and of state and local authorities having jurisdiction. Include recording of fuel-oil piping.

2.2 PERFORMANCE REQUIREMENTS

- A. Maximum Operating-Pressure Ratings: 3-psig (21-kPa) fuel-oil supply pressure at oil-fired appliances.
- B. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design restraints and anchors and multiple pipe supports and hangers for fuel-oil piping.

2.3 PIPES, TUBES, AND FITTINGS

- A. See "Outdoor Piping Schedule" and "Indoor Piping Schedule" articles for where pipes, tubes, fittings, and joining materials are applied in various services.
- B. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
 - 1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
 - 2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M, for butt and socket welding.
 - 3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
 - 4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - a. Material Group: 1.1.
 - b. End Connections: Threaded or butt welding to match pipe.
 - c. Lapped Face: Not permitted underground.
 - d. Gasket Materials: Asbestos free, ASME B16.20 metallic, or ASME B16.21 nonmetallic, gaskets compatible with fuel oil.
 - e. Bolts and Nuts: ASME B18.2.1, cadmium-plated steel.

5. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.
 - a. Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.

2.4 DOUBLE-CONTAINMENT PIPE AND FITTINGS

A. Flexible, Double-Containment Piping: Comply with UL 971.

1. Both the primary and secondary piping systems shall be installed and integrity tested in accordance with the manufacturer's published installation instructions.
2. Design:
 - a. The piping system shall consist of a UL/ULC listed flexible inner primary pipe contained within a ULC listed flexible outer containment pipe, each making connection within a series of surface access containment chambers. All piping runs shall be continuous, whereby there shall be no fittings or piping connections for either the primary or secondary containment pipe which are not visible or accessible from aboveground. The secondary containment piping shall be sized to allow complete removal of the primary piping without excavation. The secondary containment system shall provide watertight containment of the tank's piping and its associated fittings, and of the piping runs.
 - b. Product Compatibility: All components of the Double-Wall Piping System shall be compatible with the products to be stored.
 - c. Corrosion Resistance: All components of the Double-wall Piping System shall be made of non-corrosive materials, or if metallic, such as the fittings and couplings, isolated from corrosion causing agents.
3. Structural Integrity: The outer secondary containment system shall be of such design and materials to have sufficient strength to withstand the maximum underground burial loads and tested in accordance with AASHTO M294. The flexible inner primary piping system shall be capable of withstanding liquid pressure five times greater than the designed operating pressures.
4. Integrity Testing: The outer secondary containment systems shall undergo an air pressure hold test (3 to 5 psi) after installation and before the final backfill. The flexible inner primary piping system shall be subject to 60 psi air pressure hold test prior to final backfill.
5. Monitoring Capability: The design of the secondary containment system shall permit any leak in the primary piping system to be detected by a leak detection system.
6. Access Chambers: Surface access containment chambers shall be located at the tank containing the tank's submersible pump and, where indicated, at locations of terminations of the piping runs. These access chambers shall meet the following requirements:

- a. Provide product-tight connection.
 - b. Provide product-tight pipe and conduit exits.
 - c. Provide sufficient strength to keep out surrounding backfill material.
 - d. Made of non-corrosive, product-compatible and dielectric materials.
7. Aboveground Terminations: Where piping runs transition from buried to aboveground extensions, flexible secondary containment tube shall be terminated by installation of a riser pipe and termination plug, incorporating compression seal and plug with female ports as required for aboveground extension of hard piping.
8. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
- a. Environ Products, Inc.
 - b. OPW.
 - c. Total Containment, Inc.- Enviroflex.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
9. Pipe Materials: PVDF complying with ASTM D 3222 for carrier pipe with mechanical couplings to seal carrier, and PE pipe complying with ASTM D 4976 for containment piping.
10. **[Fiberglass] [PE]** sumps.
11. Watertight sump entry boots, pipe adapters with test ports and tubes, coaxial fittings, and couplings.
12. Minimum Operating Pressure Rating: **10 psig** (69 kPa).
13. Plastic to Steel Pipe Transition Fittings: Factory-fabricated fittings with plastic end matching or compatible with carrier piping, and steel pipe end complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
14. Include design and fabrication of double-containment pipe and fitting assemblies with provision for field installation of cable leak-detection system in annular space between carrier and containment piping.
- B. Rigid, Double-Containment Piping: Comply with UL 971.
1. All underground fuel piping shall be provided as a double containment system. Containment piping and fittings shall be by the same manufacturer.
 2. All underground fuel piping shall be provided as a double containment system. Containment piping and fittings shall be by the same manufacturer.
 3. Underground Piping:
 - a. Underground piping shall be double contained (pipe-in-a-pipe). All containment pipe shall be nonmetal, FRP or approved equivalent. **[Carrier pipe shall be welded steel for sizes larger than 4-inch, with materials and assembly as specified by this Section.]** For sizes 4-inch and smaller, carrier pipe may consist of UL labeled FRP piping material, of type and manufacture suitable for hydrocarbon piping service and rated for a working pressure of 100 psig. FRP carrier piping shall conform to ASTM D-1599, D-2310, and D-2996 as applicable, with fittings, adhesives and curing, proof testing performance, and jointing methods in conformance

with requirements specified. Where FRP carrier piping is used, include all required adapters required for connections to valves or other equipment components, and transitions to steel piping sections.

- b. Except for in-line fittings, fittings for non-metallic piping shall be of the compression molded type, manufactured by use of an epoxy molding compound. Molding compound shall be reinforced with a minimum of 45% chopped glass fiber. In-line fittings shall be filament-wound.
 - 1) Adhesives and curing agents shall be UL Listed DS-8000 series products, with adhesives heat cured in accordance with UL requirements and the manufacturer's instructions.
- c. Nonmetallic pipe and fittings shall be joined using matching tapered spigot and bell/coupling joining system, installed in conformity with manufacturer's instructions. For joining any piping cut in the field, Contractor shall prepare ends by use of a special tapering tool available from the piping products manufacturer, designed to produce proper taper for engagement with fittings.
- d. The inner carrier pipe shall be supported within the containment pipe with doughnut type support rings designed to permit constrained movement of the inner pipe due to thermal expansion. The support rings shall be designed to permit gravity flow of fluids in the annulus between the carrier pipe and containment pipe. The spacing of the support rings shall be determined by the piping system manufacturer to provide adequate support and constraint of the carrier pipe and insure structural integrity of the containment pipe at the burial depths shown on the drawings.
- e. Containment pipe joining methods shall be as recommended by the piping system manufacturer for the system installed.
- f. All double containment pipe fittings shall be designed to permit gravity flow of liquids in the annulus between the carrier pipe and the containment pipe. All fittings shall be prefabricated at the factory for field installation.
- g. Double containment piping fittings and joining methods shall permit radiographic inspection (for steel pipe) and visual inspection of inner carrier pipe under compressed air and hydrostatic tests prior to final closure of the outer containment pipe. Upon completion of all testing and inspection work (and any repairs made necessary), along with field wrapping of joints of steel carrier piping, containment pipe joint closure sleeves shall be positioned as required and sealed in accordance with manufacturer's recommendations. Submit step-by-step procedures to the DEN Project Manager for review and approval.
- h. The double-contained piping system installation shall include coordination of the piping system installation with the leak detection system specified.
- i. For double contained piping system terminations in pits, tank vaults and at risers to aboveground continuations, provide gland seal closures equivalent to the following:
 - 1) PermAlert ESP Drawing DP-107.
 - 2) or approved equal.

4. **Manufacturers:** Subject to compliance with requirements, provide products by

one of the following:

- a. [Ameron International; Fiberglass Pipe Group.](#)
 - b. [Conley Corporation.](#)
 - c. [Perma-Pipe, Inc.](#)
 - d. [Smith Fiberglass; a Brand of National Oilwell Varco.](#)
 - e. [Tricon Piping Systems Inc.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
5. RTRP: ASTM D 2996 or ASTM D 2997 carrier and containment piping and mechanical couplings to seal carrier and containment piping or individually bonded joints.
- a. Minimum Operating-Pressure Rating for RTRP **NPS 2 and NPS 3** (DN 50 and DN 80): **150 psig** (1035 kPa).
 - b. Minimum Operating-Pressure Rating for RTRP **NPS 4 and NPS 6** (DN 100 and DN 150): **125 psig** (860 kPa). Compliance with UL 971 is not required for **NPS 6** (DN 150) and larger piping.
 - c. Fittings: RTRF complying with ASTM D 2996 or ASTM D 2997 and made by RTRP manufacturer; watertight sump entry boots, termination, or other end fittings.
6. Leak-Detection System: Include design and fabrication of double-containment pipe and fitting assemblies with provision for field installation of cable leak-detection system in annular space between carrier and containment piping.

2.5 FLANGED INSULATING JOINTS

- A. Flanged insulating assemblies shall be used for electrostatically isolating cathodically protected pipeline from cathodically unprotected assemblies. Subject to compliance with requirements, provide one of the following:
1. LineBacker Type "E" as manufactured by Pipeline Seal and Insulator, Inc.
 2. or approved equal.
- B. Insulating joint shall consist of a full face insulating gasket, insulating bolt sleeves and double quantity of insulating washers and stainless steel washers.
- C. Insulating materials shall be as follows:
1. Gasket: NEMA Grade G10 retainer conforming to ASTM D 229 with Teflon ring seal on each side of the retainer. Minimum dielectric strength shall be 500 volts per mil (VPM). Compressive strength shall be 50,000 psi. Water absorption shall not exceed 0.05 percent.
 2. Sleeves: Shall be 1/32-inch wall thickness, length to suit two class 150 lb. weld neck flanges, insulating gaskets and valve body thickness. Sleeve shall provide "full" insulation of studs; minimum dielectric strength shall be 500 VPM. Material shall be NEMA Grade G10.

3. Insulating washers: NEMA Grade G10, 1/8-inch thick (minimum).

D. Install in accordance with requirements in Article 3 of this Section.

2.6 CASING INSULATORS AND END SEALS

A. Provide concentric insulators in pipe casing at intervals recommended by the insulator manufacturer to support pipe without sags along the flow line gradient shown on the drawings or as directed by the DEN Project Manager.

B. Insulators shall keep inner double-containment piping and vapor return piping in concentric alignment throughout the casing length without obstructing continuous draining and venting capabilities of the casing.

C. Install one full insulator within 6 inches of each end of casing.

D. Firmly bolt insulators around the pipe without damaging the pipe or its coating.

E. Provide casing insulators of such sizes to properly fit the pipe within the casing.

F. End seals shall have one-piece flexible S-shaped seal with stainless steel bands and clamps.

G. Subject to compliance with requirements, provide one of the following:

1. Model A12G-2 steel insulators, 12 inch wide steel band with polyvinyl chloride liner and 2-inch wide reinforced plastic runners and Model S End Seals as manufactured by Pipeline Seal and Insulator, Inc.
2. or approved equal.

2.7 PIPING SPECIALTIES

A. Metallic Flexible Connectors:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [American Flexible Hose Co., Inc.](#)
 - b. [Flexicraft Industries.](#)
 - c. [FLEX-ING, Inc.](#)
 - d. [Hose Master, LLC.](#)
 - e. [Metraflex Company \(The\).](#)
 - f. [Proco Products, Inc.](#)
 - g. [Tru-Flex Metal Hose LLC.](#)
 - h. [Unaflex.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.

2. Listed and labeled for aboveground and underground applications by an NRTL acceptable to authorities having jurisdiction.
3. Stainless-steel bellows with woven, flexible, bronze or stainless-steel, wire-reinforcing protective jacket.
4. Minimum Operating Pressure: **150 psig** (1035 kPa).
5. End Connections: Socket, flanged, or threaded end to match connected piping.
6. Maximum Length: **30 inches** (762 mm.)
7. Swivel end, **50-psig** (345-kPa) maximum operating pressure.
8. Factory-furnished anode for connection to cathodic protection.

B. Nonmetallic Flexible Connectors:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [American Flexible Hose Co., Inc.](#)
- b. [Flexicraft Industries.](#)
- c. [FLEX-ING, Inc.](#)
- d. [Tru-Flex Metal Hose LLC.](#)
- e. **<Insert manufacturer's name>**.
- f. or approved equal.

2. Listed and labeled for underground applications by an NRTL acceptable to authorities having jurisdiction.
3. PTFE bellows with woven, flexible, bronze, or stainless-steel, wire-reinforcing protective jacket.
4. Minimum Operating Pressure: **150 psig** (1035 kPa).
5. End Connections: Socket, flanged, or threaded end to match connected piping.
6. Maximum Length: **30 inches** (762 mm.)
7. Swivel end, **50-psig** (345-kPa) maximum operating pressure.
8. Factory-furnished anode.

C. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for **NPS 2 (DN 50)** and smaller; flanged ends for **NPS 2-1/2 (DN 65)** and larger.
3. Strainer Screen: **[60] [80]**-mesh startup strainer and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: **125 psig** (860 kPa).

D. Basket Strainers:

1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for **NPS 2 (DN 50)** and smaller; flanged ends for **NPS 2-1/2 (DN 65)** and larger.
3. Strainer Screen: **[60] [80]**-mesh startup strainer and perforated stainless-steel basket with 50 percent free area.

4. CWP Rating: 125 psig (860 kPa).

E. T-Pattern Strainers:

1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
2. End Connections: Grooved ends.
3. Strainer Screen: [60] [80]-mesh startup strainer and perforated stainless-steel basket with 57 percent free area.
4. CWP Rating: 750 psig (5170 kPa).

F. Manual Air Vents:

1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection: NPS 1/2 (DN 15).
5. Discharge Connection: NPS 1/8 (DN 6).
6. CWP Rating: 150 psig (1035 kPa).
7. Maximum Operating Temperature: 225 deg F (107 deg C).

2.8 JOINING MATERIALS

- A. Joint Compound and Tape for Threaded Joints: Suitable for fuel oil.
- B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- C. Brazing Filler Metals: Alloy with melting point greater than 1000 deg F (540 deg C) complying with AWS A5.8/A5.8M. Brazing alloys containing more than 0.05 percent phosphorus are prohibited.
- D. Bonding Adhesive for RTRP and RTRF: As recommended by piping and fitting manufacturer.

2.9 SPECIALTY VALVES

A. Pressure Relief Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Anderson Greenwood; Division of Tyco Flow Control.
 - b. Fulflo Specialties, Inc.
 - c. Webster Fuel Pumps & Valves; a division of Capital City Tool, Inc.
 - d. OPW.
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.

2. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
3. Body: Brass, bronze, or cast steel.
4. Springs: Stainless steel, interchangeable.
5. Seat and Seal: Nitrile rubber.
6. Orifice: Stainless steel, interchangeable.
7. Factory-Applied Finish: Baked enamel.
8. Maximum Inlet Pressure: [150 psig (1035 kPa)] <Insert pressure>.
9. Relief Pressure Setting: [60 psig (414 kPa)] <Insert pressure>.

B. Oil Safety Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Anderson Greenwood; Division of Tyco Flow Control.](#)
 - b. [Fulflo Specialties, Inc.](#)
 - c. [OPW.](#)
 - d. [Webster Fuel Pumps & Valves; a division of Capital City Tool, Inc.](#)
 - e. <Insert manufacturer's name>.
 - f. or approved equal.
2. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
3. Body: Brass, bronze, or cast steel.
4. Springs: Stainless steel.
5. Seat and Diaphragm: Nitrile rubber.
6. Orifice: Stainless steel, interchangeable.
7. Factory-Applied Finish: Baked enamel.
8. Manual override port.
9. Maximum Inlet Pressure: [60 psig (414 kPa)] <Insert pressure>.
10. Maximum Outlet Pressure: [3 psig (21 kPa)] <Insert pressure>.

C. Emergency Shutoff Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [EMCO Wheaton; a Gardner Denver company.](#)
 - b. [Franklin Fueling Systems.](#)
 - c. [OPW.](#)
 - d. <Insert manufacturer's name>.
 - e. or approved equal.
2. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
3. [Single] [Double] poppet valve.
4. Body: ASTM A 126, cast iron.
5. Disk: FPM.
6. Poppet Spring: Stainless steel.

7. Stem: Plated brass.
8. O-Ring: FPM.
9. Packing Nut: PTFE-coated brass.
10. Fusible link to close valve at **165 deg F** (74 deg C).
11. Thermal relief to vent line pressure buildup due to fire.
12. Air test port.
13. Maximum Operating Pressure: **0.5 psig** (3.45 kPa).

2.10 MECHANICAL LEAK-DETECTION VALVES

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Franklin Fueling Systems](#).
 2. [Red Jacket Pumps; a division of Veeder-Root](#).
 3. **<Insert manufacturer's name>**.
 4. or approved equal.
- B. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
- C. Body: ASTM A 126, cast iron.
- D. O-Rings: Elastomeric compatible with fuel oil.
- E. Piston and Stem Seals: PTFE.
- F. Stem and Spring: Stainless steel.
- G. Piston Cylinder: burnished brass.
- H. Indicated Leak Rate: Maximum **3 gph** (3 mL/s) at **10 psig** (69 kPa).
- I. Leak Indication: Reduced flow.

2.11 LEAK-DETECTION AND MONITORING SYSTEM

- A. Cable and Sensor System: Comply with UL 1238.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Caldwell Instruments Inc.](#)
 - b. [Containment Solutions, Inc.](#)
 - c. [Franklin Fueling Systems](#).
 - d. [Gems Sensors & Controls](#).
 - e. [Highland Tank & Manufacturing Company, Inc.](#)
 - f. [INCON](#).
 - g. [In-Situ, Inc.](#)

- h. [MSA; Instrument Div.](#)
 - i. [Perma-Pipe, Inc.](#)
 - j. [Pneumercator Inc.](#)
 - k. [Tyco Thermal Controls LLC.](#)
 - l. [Veeder-Root; a Danaher Corporation company.](#)
 - m. <Insert manufacturer's name>.
 - n. or approved equal.
2. Calibrated leak-detection and monitoring system with probes and other sensors and remote alarm panel for fuel-oil piping.
 3. Include fittings and devices required for testing.

2.12 LABELING AND IDENTIFYING

- A. Detectable Warning Tape: Acid- and alkali-resistant PE film warning tape manufactured for marking and identifying underground utilities, a minimum of **6 inches (152 mm)** wide and **4 mils (0.1 mm)** thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to **30 inches (762 mm)** deep; colored yellow.

2.13 CAUTIONARY SIGNAGE

- A. For installations in which above-ground fuel system piping or storage vessels are exposed to temperatures of 10 degrees F or less, provide conspicuous signs or painted warnings adjacent to fuel system fill stations stating as follows:
 1. **CAUTION: FUEL ADDED TO STORAGE MUST BE FORMULATED TO PROVIDE COLD-WEATHER POUR-POINT OF FROM -12 TO -15 DEGREES F**

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas for compliance with requirements for installation tolerances and other conditions affecting performance of fuel-oil piping.
- B. Examine installation of fuel-burning equipment and fuel-handling and storage equipment to verify actual locations of piping connections before installing fuel-oil piping.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.
- B. Verify that excavations are to required grade, dry, and not over-excavated.

3.3 PREPARATION

- A. Close equipment shutoff valves before turning off fuel oil to premises or piping section.
- B. Comply with NFPA 30 and NFPA 31 requirements for prevention of accidental ignition.
- C. Ream pipe and tube ends. Remove burrs. **[Bevel plain end ferrous pipe.]**
- D. Remove scale and dirt, on inside and outside, before assembly.
- E. Prepare piping connections to equipment with flanges or unions.
- F. Excavate in accordance with Division 31 for work of this Section.
- G. Backfill in accordance with Division 31 for work of this Section.

3.4 HANDLING PIPE

- A. Shipping, delivering, and installing pipe and accessories shall be handled in such manner as to ensure a sound undamaged condition. Particular care shall be taken not to injure pipe coating and containment pipe when storing pipe, lowering it into trench and when backfilling.
- B. No other pipe or materials of any kind shall be placed inside a pipe or fitting after the coating has been applied.
- C. Storage rack materials shall be 6 inches in bearing width and placed not more than 6 feet apart.
- D. Do not rack pipe more than four sections in height.
- E. Protect and prevent movement of all racked pipe by use of suitable padded material between sections.
- F. All trucks handling coated pipe shall have properly padded bolsters, padded chains, and padded binders so as to not damage the coating.
- G. Pipe shall not be dropped or rolled off the truck, but shall be carefully lowered onto skids using padded mechanical equipment.
- H. Coated, wrapped, and double-contained sections of pipe must be lifted with nylon slings of approved width and shall not be dragged or pulled into position.

3.5 LAYING UNDERGROUND PIPE

- A. Lay, embed, and maintain all underground pipelines to the flow-line elevation and grades shown on the drawings or as approved by the DEN Project Manager. Pipelines shall be graded uniformly between invert elevations.
- B. Excavation, backfill, and compaction shall be in accordance with Division 31. Trench backfill from not less than six inches below the bottom of the pipe to not less than six inches above the top of the pipe shall consist of bedding material as specified.
- C. The full length of each section of pipe shall rest solidly upon the bedding material.
- D. Any pipe that has the grade or joint disturbed after being laid shall be taken up and relaid.
- E. Do not lay pipe in water or when trench conditions are, in the judgment of the DEN Project Manager, unsuitable.
- F. Anchor pipe during installation to prevent flotation prior to backfilling and placing into service.
- G. When work is not in progress, securely close open ends of pipe or fittings using approved expanding type watertight plugs to prevent trench water, earth, or other foreign substance from entering the pipe or fittings.
- H. **[Pipe coating shall be inspected with an electronic holiday tester in accordance with Section 15195 prior to backfilling.]**

3.6 WELDING

- A. Welding electrodes shall be designed and made for use with the specific pipe metal to which it is applied and shall conform to the applicable AWS Specifications for welding rods and electrodes. Welding electrodes shall be suitably shielded.
- B. Welding shall be accomplished by the use of the shielded metallic arc process and shall be performed in strict accordance with the requirements of ANSI B31.9.

3.7 PIPING INSTALLATION - GENERAL

- A. Install in accordance with manufacturer's instructions **[and AP1 1615]**.
- B. Provide non-conducting dielectric fittings wherever jointing dissimilar metals. Install to NACE RP-01-69.

NACE RP-01-69 - Control of External Corrosion on Underground or Submerged Piping Systems.

- C. Route piping in orderly manner and maintain gradient.
- D. Install interior piping to conserve building space and not interfere with use of space.

- E. Group piping whenever practical at common elevations.
- F. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.
- G. Provide clearance for installation of insulation and access to valves and fittings.
- H. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08.
- I. Establish elevations of buried piping outside the building to ensure not less than [3] <Insert depth> ft of cover.
- J. Where pipe support members are welded to structural building framing, scrape, brush clean, weld, and apply one coat of zinc rich primer.
- K. Prepare pipe, fittings, supports, and accessories not prefinished, ready for finish painting. Refer to Division 09.
- L. Identify piping systems, including underground piping. Refer to Section 230553 "Identification for HVAC Piping and Equipment".
- M. Install valves with stems upright or horizontal, not inverted.
- N. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.
- O. Lever handle valves: Install valve handle so that the handle opens in the direction of fluid flow.

3.8 OUTDOOR PIPING INSTALLATION

- A. Install Underground Fuel-Oil Piping Buried:
 - 1. Under Compacted Backfill: [18 inches (457 mm)] <Insert dimension> below finished grade.
 - 2. Under Asphalt 2 Inches (51 mm) Thick: 8 inches (203 mm) below bottom of asphalt.
 - 3. Under 4 Inches (102 mm) of Reinforced Concrete in Areas Subject to Vehicle Traffic: 4 inches (102 mm) below bottom of concrete.
 - 4. If fuel-oil piping is installed with less than [12 inches (305 mm)] <Insert dimension> of cover to finished grade, install in containment piping.
 - 5. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.
- B. Steel Piping with Protective Coating:
 - 1. Apply joint cover kits to pipe after joining, to cover, seal, and protect joints.
 - 2. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer. Review protective coating damage with DEN Project

- Manager prior to repair.
3. Replace pipe having damaged PE coating with new pipe.
- C. Install double-containment, fuel-oil pipe at a minimum slope of 1 percent downward toward fuel-oil storage tank sump.
 - D. Install vent pipe at a minimum slope of 2 percent downward toward fuel-oil storage tank sump.
 - E. Assemble and install entry boots for pipe penetrations through sump sidewalls for liquid-tight joints.
 - F. Install metal pipes and tubes, fittings, valves, and flexible connectors at piping connections to AST and UST.
 - G. Install fittings for changes in direction in rigid pipe.
 - H. Install system components with pressure rating equal to or greater than system operating pressure.

3.9 INDOOR PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction to allow for mechanical installations.
- C. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings at a height that allows sufficient space for ceiling panel removal.
- F. Install piping free of sags and bends.
- G. Install fittings for changes in direction and branch connections.
- H. Comply with requirements for equipment specifications for roughing-in requirements.
- I. Conceal pipe installations in walls, pipe spaces, or utility spaces; above ceilings; below grade or floors; and in floor channels unless indicated to be exposed to view.
- J. Prohibited Locations:

1. Do not install fuel-oil piping in or through HVAC ducts and plenums, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
 2. Do not install fuel-oil piping in solid walls or partitions.
- K. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
- L. Connect branch piping from top or side of horizontal piping.
- M. Install unions in pipes NPS 2 (DN 50) and smaller at final connection to each piece of equipment and elsewhere as indicated. Unions are not required on flanged devices.
- N. Do not use fuel-oil piping as grounding electrode.
- O. Install sleeves and sleeve seals for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- P. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.10 VALVE INSTALLATION

- A. Install manual fuel-oil shutoff valves on branch connections to fuel-oil appliance.
- B. Install valves in accessible locations.
- C. Install oil safety valves at inlet of each oil-fired appliance.
- D. Install pressure relief valves in distribution piping between the supply and return lines.
- E. Install one-piece, bronze ball valve with hose end connection at low points in fuel-oil piping. Comply with requirements in Section 230523.12 "Ball Valves for HVAC Piping."
- F. Install manual air vents at high points in fuel-oil piping.
- G. Install emergency shutoff valves at dispensers.

3.11 PIPING JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs

and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. Welded Joints: Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators according to "Quality Assurance" Article.
1. Bevel plain ends of steel pipe.
 2. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.
- E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tubing" Chapter.
- F. Flanged Joints: Install gasket material, size, type, and thickness for service application. Install gasket concentrically positioned.
- G. Flared Joints: Comply with SAE J513. Tighten finger tight then use wrench according to fitting manufacturer's written instructions. Do not overtighten.
- H. Fiberglass-Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.

3.12 FLANGED INSULATING JOINTS

- A. Install insulating joints at the locations indicated on the drawings. Where not shown on the drawings, they shall be installed at the first flange (within the structure) nearest to the structure's wall or the first flange wherever underground piping comes aboveground.
- B. Flange assemblies shall provide a minimum resistance of one million ohms measured between each stud and both flanges when tested in the dry condition.

3.13 HANGER AND SUPPORT INSTALLATION

- A. Pipe hanger and support and equipment support materials and installation requirements are specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
 1. NPS 1-1/4 (DN 32) and Smaller: Maximum span, 84 inches (2130 mm); minimum rod size, 3/8 inch (10 mm).
 2. NPS 1-1/2 (DN 40): Maximum span, 108 inches (2740 mm); minimum rod size, 3/8 inch (10 mm).

3. **NPS 2 (DN 50)**: Maximum span, **10 feet (3 m)**; minimum rod size, **3/8 inch (10 mm)**.
 4. **NPS 2-1/2 (DN 65)**: Maximum span, **11 feet (3.4 m)**; minimum rod size, **1/2 inch (13 mm)**.
 5. **NPS 3 (DN 80)**: Maximum span, **12 feet (3.7 m)**; minimum rod size, **1/2 inch (13 mm)**.
 6. **NPS 4 (DN 100)**: Maximum span, **13 feet (4 m)**; minimum rod size, **5/8 inch (16 mm)**.
- C. Support vertical steel pipe at each floor and at spacing not greater than **15 feet (4.5 m)**.
- D. Install hangers for horizontal, drawn-temper copper tubing with the following maximum spacing and minimum rod sizes:
1. **NPS 3/4 (DN 20) and Smaller**: Maximum span, **60 inches (1524 mm)**; minimum rod size, **3/8 inch (10 mm)**.
 2. **NPS 1 (DN 25)**: Maximum span, **72 inches (1830 mm)**; minimum rod size, **3/8 inch (10 mm)**.
 3. **NPS 1-1/4 (DN 32)**: Maximum span, **84 inches (2130 mm)**; minimum rod size, **3/8 inch (10 mm)**.
 4. **NPS 1-1/2 and NPS 2 (DN 40 and DN 50)**: Maximum span, **96 inches (2440 mm)**; minimum rod size, **3/8 inch (10 mm)**.
 5. **NPS 2-1/2 (DN 65)**: Maximum span, **108 inches (2740 mm)**; minimum rod size, **1/2 inch (13 mm)**.
 6. **NPS 3 (DN 80)**: Maximum span, **10 feet (3 m)**; minimum rod size, **1/2 inch (13 mm)**.
 7. **NPS 4 (DN 100)**: Maximum span, **11 feet (3.4 m)**; minimum rod size, **5/8 inch (16 mm)**.
- E. Support vertical copper tube at each floor and at spacing not greater than **10 feet (3 m)**.
- 3.14 LEAK-DETECTION AND MONITORING SYSTEM INSTALLATION
- A. Install leak-detection and monitoring system. Install alarm panel inside building where indicated.
 - B. Double-Containment, Fuel-Oil Piping: Install leak-detection sensor [**probes at low points in piping**] [**cable probes in interstitial space of double-containment piping**].
- 3.15 CONNECTIONS
- A. Where installing piping adjacent to equipment, allow space for service and maintenance.
 - B. Install unions, in piping **NPS 2 (DN 50)** and smaller, adjacent to each valve and at final connection to each piece of equipment having threaded pipe connection.

- C. Install flanges, in piping NPS 2-1/2 (DN 65) and larger, adjacent to flanged valves and at final connection to each piece of equipment having flanged pipe connection.
- D. Connect piping to equipment with shutoff valve and union. Install union between valve and equipment.
- E. Install flexible piping connectors at final connection to burners or oil-fired appliances.

3.16 LABELING AND IDENTIFYING

- A. Nameplates, pipe identification, valve tags, and signs are specified in Section 230553 "Identification for HVAC Piping and Equipment."
- B. Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplates and signs on or near each service regulator, service meter, and earthquake valve.
 - 1. Text: In addition to identifying unit, distinguish between multiple units; inform operator of operational requirements; indicate safety and emergency precautions; and warn of hazards and improper operations.
- C. Install detectable warning tape directly above fuel-oil piping, [12 inches (304 mm)] <Insert dimension> below finished grade, except [6 inches (152 mm)] <Insert dimension> below subgrade under pavements and slabs. Terminate tracer wire in an accessible area, and identify as "tracer wire" for future use with plastic-laminate sign.
 - 1. Piping: Over underground fuel-oil distribution piping.

3.17 FIELD QUALITY CONTROL

Pipe test pressures in this article are required by NFPA 31. Verify requirements with authorities having jurisdiction.

- A. Pressure Test Piping: Minimum hydrostatic or pneumatic test-pressures measured at highest point in system:
 - 1. Fuel-Oil Distribution Piping: Minimum [5 psig (34.5 kPa)] <Insert dimension> for minimum [30] <Insert time> minutes.
 - 2. Fuel-Oil, Double-Containment Piping:
 - a. Carrier Pipe: Minimum [5 psig (34.5 kPa)] <Insert dimension> for minimum [30] <Insert time> minutes.
 - b. Containment Conduit: Minimum [5 psig (34.5 kPa)] <Insert dimension> for minimum [60] <Insert time> minutes.
 - 3. Suction Piping: Minimum 20-in. Hg (68 kPa) for minimum [30] <Insert time> minutes.
 - 4. Isolate storage tanks if test pressure in piping will cause pressure in storage tanks to exceed 10 psig (69 kPa).

- B. Inspect and test fuel-oil piping according to NFPA 31, "Tests of Piping" Paragraph, and in accordance with Leak Testing article below, and according to requirements of authorities having jurisdiction.
- C. Test leak-detection and monitoring system for accuracy by manually operating sensors and checking against alarm panel indication.
- D. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- E. Bleed air from fuel-oil piping using manual air vents.
- F. Fuel-oil piping and equipment will be considered defective if it does not pass tests and inspections.
- G. Prepare test and inspection reports.

3.18 LEAK TESTING:

- A. Provide temporary equipment for testing, including pump and gages. Test piping system before insulation is installed, wherever feasible, and remove control devices before testing. Subject entire piping systems to leak tests, either as a whole, or in sections; but leave no part untested.
- B. Test gauges shall have a range that provide for the test pressure to be in the middle third of the gauge scale.
- C. Contractor shall provide written notification to the DEN Project Manager and DEN Inspector at least 48 hours before performing leak test. Perform all tests in the presence of the authorized City representative.
- D. Hydrostatic Leak Test:
 - 1. Perform hydrostatic leak test on all piping systems.
 - 2. Hydrostatic Leak Test Procedure:
 - a. Leak test procedures shall comply with ASME B31.9.
 - b. Fill piping systems with clear water, vent all air, and pressurize at 150% of operating pressure, (but not less than 100 psi) for 2 hours. Test fails if leakage is observed, or pressure drop exceeds 5% of test pressure.
- E. Pneumatic Leak Test:
 - 1. General: Pneumatic leak tests shall only be used on piping with restricted access, under freezing conditions, or where water leakage would damage critical DEN operational equipment. Contractor shall submit a written request for test in accordance with the Submittals article of this Section.
 - 2. Pneumatic Test Procedure:
 - a. Contractor shall submit safety plan for pneumatic testing prior to test.

- b. General: Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations:
 - 1) The piping system does not contain cast iron pipe or plastic pipe subject to brittle failure.
 - 2) The system does not contain soldered or solvent cement joints over NPS 2.
 - 3) The test pressure does not exceed 150 psig.
 - c. Test Medium: The gas shall be nonflammable and nontoxic.
 - d. Preliminary Test: Prior to application of full pneumatic test pressure, a preliminary test of not more than 10 psig shall be applied to reveal possible major leaks. Pneumatic Test Pressure:
 - 1) Except as limited in subparagraph below, the test pressure shall not exceed 1.25 times the design pressure. Pressure shall be applied in several stages, allowing time for the system to reach equilibrium at each stage.
 - 2) The test pressure shall not exceed the maximum allowable pneumatic test pressure for any vessel, pump, valve, or other component in the system under test.
 - e. Examination for Leakage: After the preliminary test, pressure shall be raised in stages of not more than 25% up to full pneumatic test pressure, allowing time for equalization of strains and detection of major leaks at each stage. Following the application of test pressure for at least 10 minutes, the pressure may be reduced to design pressure and examination shall be made for leakage of the piping. Leaks may be detected by soap bubble, halogen gas, scented gas, test gage monitoring, ultrasonic, or other suitable means. If leaks are found, pressure shall be vented, appropriate repair or replacement shall be made, and the pneumatic test repeated until no leakage is found.
 - f. Contractor shall measure the surface temperature of the pipe for the duration of testing. The pneumatic test will be deemed successful only when the test pressure can be held at a constant pipe surface temperature for a period of no less than 10 continuous minutes. Record of the pipe temperatures and pressures during the duration of the test shall be submitted to the DEN Project Manager following completion of the test.
3. Testing shall be witnessed by DEN Mechanical Inspector and DEN Project Manager or Designated Representative.
 4. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.
 5. Drain test water from piping systems after testing and repair work that has been completed.
 6. Prepare written report of testing procedures and result.

3.19 OUTDOOR PIPING SCHEDULE

- A. Underground Fuel-Oil Piping: **[Flexible]** **[Rigid]**, double-containment piping. Size indicated is carrier-pipe size.
- B. Underground fuel-oil-tank fill and vent piping shall be **[one of]** the following:
1. **[NPS 2 (DN 50)]** **<Insert pipe size>** and Smaller: Steel pipe, steel or malleable-iron threaded fittings, and threaded joints. Coat pipe and fittings with protective coating for steel piping.
 2. **[NPS 2-1/2 (DN 65)]** **<Insert pipe size>** and Larger: Steel pipe, steel welding fittings, and welded joints. Coat pipe and fittings with protective coating for steel piping.
- C. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- D. Aboveground fuel-oil piping shall be **[one of]** the following:
1. **[NPS 2 (DN 50)]** **<Insert pipe size>** and Smaller: Steel pipe, steel or malleable-iron threaded fittings, and threaded joints.
 2. **[NPS 2-1/2 (DN 65)]** **<Insert pipe size>** and Larger: Steel pipe, steel welding fittings, and welded joints.
 3. **[Annealed]** **[Drawn]**-temper copper tube with wrought-copper fittings and brazed joints.

3.20 INDOOR PIPING SCHEDULE

- A. Aboveground fuel-oil piping shall be **[one of]** the following:
1. **[NPS 1/2 (DN 15)]** **<Insert pipe size>** and Smaller: Annealed-temper copper pipe, wrought copper fittings, and brazed or flared joints.
 2. **[NPS 5/8 to NPS 2 (DN 18 to DN 50)]** **<Insert pipe size>**: **[Steel pipe, steel or malleable-iron threaded fittings, and threaded joints]**

3.21 **[NPS 2-1/2 (DN 65)]** **<Insert pipe size>** and Larger: **[Steel pipe, steel fittings, and welded or flanged joints]** SHUTOFF VALVE SCHEDULE

- A. Valves for aboveground distribution piping **NPS 2 (DN 50)** and smaller shall be **[one of]** the following:
1. One-piece, bronze ball valve with bronze trim.
 2. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
- B. Distribution piping valves for pipe **NPS 2-1/2 (DN 65)** and larger shall be **[one of]** the following:
1. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
 2. Bronze, **[nonlubricated]** **[lubricated]** plug valve.

- C. Valves in branch piping for single appliance shall be **one of** the following:
1. One-piece, bronze ball valve with bronze trim.
 2. Two-piece, **full** **regular**-port, bronze ball valves with bronze trim.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 231113

SECTION 231123 - FACILITY NATURAL-GAS PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Pipes, tubes, and fittings.
 - 2. Piping specialties.
 - 3. Piping and tubing joining materials.
 - 4. Valves.
 - 5. Pressure regulators.
 - 6. Service meters.
 - 7. Concrete bases.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

1.4 PERFORMANCE REQUIREMENTS

- A. Minimum Operating-Pressure Ratings:
 - 1. Piping and Valves: [100 psig (690 kPa)] <Insert value> minimum unless otherwise indicated.
 - 2. Service Regulators: [65 psig (450 kPa)] [100 psig (690 kPa)] <Insert value> minimum unless otherwise indicated.

3. Minimum Operating Pressure of Service Meter: [5 psig (34.5 kPa)] [10 psig (69 kPa)] [20 psig (138 kPa)] [65 psig (450 kPa)] <Insert value>.
 - B. Natural-Gas System Pressure within Buildings: [0.5 psig (3.45 kPa) or less] [More than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa)] [More than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa)] <Insert pressure range>.
 - C. Natural-Gas System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa), and is reduced to secondary pressure of 0.5 psig (3.45 kPa) or less.
 - D. Natural-Gas System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa), and is reduced to secondary pressure of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa).
 - E. Natural-Gas System Pressures within Buildings: Three pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa), and is reduced to secondary pressures of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa), and is reduced again to pressures of 0.5 psig (3.45 kPa) or less.
 - F. Design values of fuel gas supplied for these systems are as follows:
 1. Nominal Heating Value: 834 Btu/ 1,000 cu. ft.
 2. Nominal Specific Gravity: 0.65.
 - G. Delegated Design: Design restraints and anchors for natural-gas piping and equipment, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- 1.5 ACTION SUBMITTALS
- A. Product Data: For each type of the following:
 1. Piping specialties.
 2. Corrugated, stainless-steel tubing with associated components.
 3. Valves. Include pressure rating, capacity, settings, and electrical connection data of selected models.
 4. Pressure regulators. Indicate pressure ratings and capacities, and settings of selected models.
 5. Service meters. Indicate pressure ratings and capacities. Include bypass fittings, bypass fittings and meter bars, meter bars, supports.
 6. Dielectric fittings.
 7. Include data substantiating that materials comply with requirements.
 - B. Shop Drawings: For facility natural-gas piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion

joints and loops. [**Show different pressure zones and indicate pressure for each zone.**]

1. Shop Drawing Scale: [**1/4 inch per foot (1:50)**] **<Insert scale>**.
2. Detail mounting, supports, and valve arrangements for[**service meter assembly and**] pressure regulator assembly.
3. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.

C. Delegated-Design Submittal: For natural-gas piping and equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Detail fabrication and assembly of seismic restraints.
2. Design Calculations: Calculate requirements for selecting seismic restraints.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans and details, drawn to scale, on which natural-gas piping is shown and coordinated with other installations, using input from installers of the items involved.
- B. Site Survey: Plans, drawn to scale, on which natural-gas piping is shown and coordinated with other services and utilities.
- C. Qualification Data: For qualified professional engineer.
- D. Installer certificates for piping systems.
- E. Welding certificates. Include welders certification of compliance with [**ASME SEC 9**] [**AWS D1.1.**] **<Insert requirement>** and section 059990 "Welding".
- F. Field quality-control reports. Indicate and interpret test results for compliance with performance requirements.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For natural gas specialties and accessories, [**motorized gas valves**] [**pressure regulators**] [**and**] [**service meters**] to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 QUALITY ASSURANCE

- A. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
- C. ANSI Standard: Comply with ANSI Z223.1, "National Fuel Gas Code."
- D. FM Standard: Provide components listed in FM's "Fire Protection Approval Guide" if specified to be FM approved.
- E. IAS Standard: Provide components listed in IAS's "Directory of A. G. A. and C. G. A Certified Appliances and Accessories" if specified to be IAS listed.
- F. UL Standard: Provide components listed in UL's "Gas and Oil Equipment Directory" if specified to be UL listed.
- G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Handling Flammable Liquids: Remove and dispose of liquids from existing natural-gas piping according to requirements of authorities having jurisdiction. Handle cautiously to avoid spillage and ignition. Notify fuel gas supplier. Handle flammable liquids used by Installer with proper precautions and do not leave on premises from end of one day to beginning of next day.
- B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- C. Store and handle pipes and tubes having factory-applied protective coatings to avoid damaging coating, and protect from direct sunlight.
- D.

1.10 PROJECT CONDITIONS

- A. Perform site survey, research public utility records, and verify existing utility locations. Contact utility-locating service for area where Project is located.
- B. Interruption of Existing Natural-Gas Service: Do not interrupt natural-gas service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide purging and startup of natural-gas supply according to requirements indicated:

1. Notify DEN Project Manager no fewer than **[five (5)] <Insert number>** days in advance of proposed interruption of natural-gas service.
2. Do not proceed with interruption of natural-gas service without DEN Project Manager's written permission.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces. Comply with requirements in Section 083113 "Access Doors and Frames."

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

See Part 3 piping schedule articles to determine where pipes, tubes, fittings, and joining materials are applied in various services.

- A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
 1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
 2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
 3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
 4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - a. Material Group: 1.1.
 - b. End Connections: Threaded or butt welding to match pipe.
 - c. Lapped Face: Not permitted underground.
 - d. Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
 - e. Bolts and Nuts: ASME B18.2.1, carbon steel aboveground and stainless steel underground.
 5. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.

- a. Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.
6. Mechanical Couplings:
 - a. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1) Dresser Piping Specialties; Division of Dresser, Inc.
 - 2) Smith-Blair, Inc.
 - 3) **<Insert manufacturer's name>**.
 - 4) or approved equal.
 - b. **[Stainless-steel] [Steel]** flanges and tube with epoxy finish.
 - c. Buna-nitrile seals.
 - d. **[Stainless-steel] [Steel]** bolts, washers, and nuts.
 - e. Coupling shall be capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
 - f. Steel body couplings installed underground on plastic pipe shall be factory equipped with anode.
- B. Corrugated, Stainless-Steel Tubing: Comply with ANSI/IAS LC 1.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. OmegaFlex, Inc.
 - b. Parker Hannifin Corporation; Parflex Division.
 - c. Titeflex.
 - d. Tru-Flex Metal Hose Corp.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
 2. Tubing: ASTM A 240/A 240M, corrugated, Series 300 stainless steel.
 3. Coating: PE with flame retardant.
 - a. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1) Flame-Spread Index: **[25] <Insert value>** or less.
 - 2) Smoke-Developed Index: **[50] [450] <Insert value>** or less.
 4. Fittings: Copper-alloy mechanical fittings with ends made to fit and listed for use with corrugated stainless-steel tubing and capable of metal-to-metal seal without gaskets. Include brazing socket or threaded ends complying with ASME B1.20.1.
 5. Striker Plates: Steel, designed to protect tubing from penetrations.
 6. Manifolds: Malleable iron or steel with factory-applied protective coating. Threaded connections shall comply with ASME B1.20.1 for pipe inlet and corrugated tubing outlets.
 7. Operating-Pressure Rating: **5 psig (34.5 kPa)**.

C. Drawn-Temper Copper Tube: Comply with [ASTM B 88, Type K (ASTM B 88M, Type A)] [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 837, Type G].

1. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
2. Brazing Filler Metals: AWS A5.8, Silver Classification BAg-1. Filler metal containing phosphorus is prohibited.
3. Bronze Flanges and Flanged Fittings: ASME B16.24, Class 150.
 - a. Gasket Material: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
 - b. Bolts and Nuts: ASME B18.2.1, carbon steel or stainless steel.
4. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of 0.022 inch (0.56 mm) thick.

D. Annealed-Temper Copper Tube: Comply with [ASTM B 88, Type K (ASTM B 88M, Type A)] [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 837, Type G].

1. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
2. Brazing Filler Metals: AWS A5.8, Silver Classification BAg-1. Filler metal containing phosphorus is prohibited.
3. Flare Fittings: Comply with ASME B16.26 and SAE J513.
 - a. Copper fittings with long nuts.
 - b. Metal-to-metal compression seal without gasket.
 - c. Dryseal threads complying with ASME B1.20.3.
4. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of 0.022 inch (0.56 mm) thick.

E. Tin-Lined Copper Tube: ASTM B 280, seamless, annealed, with interior tin-plated lining.

1. Flare Fittings: Comply with ASME B16.26 and SAE J513.
 - a. Copper fittings with long nuts.
 - b. Metal-to-metal compression seal without gasket.
 - c. Dryseal threads complying with ASME B1.20.3.
2. Brazing Filler Metals: AWS A5.8, Silver Classification BAg-1. Filler metal containing phosphorus is prohibited.

2.2 PIPING SPECIALTIES

A. Appliance Flexible Connectors:

1. Indoor, Fixed-Appliance Flexible Connectors: Comply with ANSI Z21.24.
2. Indoor, Movable-Appliance Flexible Connectors: Comply with ANSI Z21.69.
3. Outdoor, Appliance Flexible Connectors: Comply with ANSI Z21.75.
4. Corrugated stainless-steel tubing with polymer coating.

5. Operating-Pressure Rating: 0.5 psig (3.45 kPa).
6. End Fittings: Zinc-coated steel.
7. Threaded Ends: Comply with ASME B1.20.1.
8. Maximum Length: 72 inches (1830 mm.)

B. Quick-Disconnect Devices: Comply with ANSI Z21.41.

1. Copper-alloy convenience outlet and matching plug connector.
2. Nitrile seals.
3. Hand operated with automatic shutoff when disconnected.
4. For indoor or outdoor applications.
5. Adjustable, retractable restraining cable.

C. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: [40] [60]-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig (862 kPa).

D. Basket Strainers:

1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: [40] [60]-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig (862 kPa).

E. T-Pattern Strainers:

1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
2. End Connections: Grooved ends.
3. Strainer Screen: [40] [60]-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
4. CWP Rating: 750 psig (5170 kPa).

F. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.

2.3 PROTECTIVE COATING

A. Furnish pipe and fittings with factory-applied, corrosion-resistant polyethylene coating

for use in corrosive atmosphere.

2.4 JOINING MATERIALS

- A. Joint Compound and Tape: Suitable for natural gas.
- B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- C. Brazing Filler Metals: Alloy with melting point greater than 1000 deg F (540 deg C) complying with AWS A5.8/A5.8M. Brazing alloys containing more than 0.05 percent phosphorus are prohibited.

2.5 MANUAL GAS SHUTOFF VALVES

- A. See "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles for where each valve type is applied in various services.
- B. General Requirements for Metallic Valves, NPS 2 (DN 50) and Smaller: Comply with ASME B16.33.
 - 1. CWP Rating: [125 psig (862 kPa)] <Insert pressure>.
 - 2. Threaded Ends: Comply with ASME B1.20.1.
 - 3. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
 - 4. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 - 5. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch (25 mm) and smaller.
 - 6. Service Mark: Valves 1-1/4 inches (32 mm) to NPS 2 (DN 50) shall have initials "WOG" permanently marked on valve body.
- C. General Requirements for Metallic Valves, NPS 2-1/2 (DN 65) and Larger: Comply with ASME B16.38.
 - 1. CWP Rating: [125 psig (862 kPa)] <Insert pressure>.
 - 2. Flanged Ends: Comply with ASME B16.5 for steel flanges.
 - 3. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 - 4. Service Mark: Initials "WOG" shall be permanently marked on valve body.
- D. Gas Stops: Bronze body with AGA stamp, plug type with bronze plug and flat or square head, ball type with chrome-plated brass ball and lever handle, or butterfly valve with stainless-steel disc and fluorocarbon elastomer seal and lever handle; 2-psig (13.8-kPa) minimum pressure rating.
- E. One-Piece, Bronze Ball Valve with Bronze Trim: MSS SP-110.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [BrassCraft Manufacturing Company; a Masco company.](#)
 - b. [Conbraco Industries, Inc.; Apollo Div.](#)
 - c. [Lyall, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
 2. Body: Bronze, complying with ASTM B 584.
 3. Ball: Chrome-plated brass.
 4. Stem: Bronze; blowout proof.
 5. Seats: Reinforced TFE; blowout proof.
 6. Packing: Separate packnut with adjustable-stem packing threaded ends.
 7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 8. CWP Rating: 600 psig (4140 kPa).
 9. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
- F. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [BrassCraft Manufacturing Company; a Masco company.](#)
 - b. [Conbraco Industries, Inc.; Apollo Div.](#)
 - c. [Lyall, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
 2. Body: Bronze, complying with ASTM B 584.
 3. Ball: Chrome-plated bronze.
 4. Stem: Bronze; blowout proof.
 5. Seats: Reinforced TFE; blowout proof.
 6. Packing: Threaded-body packnut design with adjustable-stem packing.
 7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 8. CWP Rating: 600 psig (4140 kPa).
 9. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

G. Two-Piece, Regular-Port Bronze Ball Valves with Bronze Trim: MSS SP-110.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [BrassCraft Manufacturing Company; a Masco company.](#)
 - b. [Conbraco Industries, Inc.; Apollo Div.](#)
 - c. [Lyall, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
2. Body: Bronze, complying with ASTM B 584.
3. Ball: Chrome-plated bronze.
4. Stem: Bronze; blowout proof.
5. Seats: Reinforced TFE.
6. Packing: Threaded-body packnut design with adjustable-stem packing.
7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
8. CWP Rating: **600 psig** (4140 kPa).
9. Listing: Valves **NPS 1** (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

H. Bronze Plug Valves: MSS SP-78.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Lee Brass Company.](#)
 - b. [McDonald, A. Y. Mfg. Co.](#)
 - c. **<Insert manufacturer's name>.**
 - d. or approved equal.
2. Body: Bronze, complying with ASTM B 584.
3. Plug: Bronze.
4. Ends: Threaded, socket, or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
5. Operator: Square head or lug type with tamperproof feature where indicated.
6. Pressure Class: **125 psig** (862 kPa).
7. Listing: Valves **NPS 1** (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
8. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

I. Cast-Iron, Nonlubricated Plug Valves: MSS SP-78.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [McDonald, A. Y. Mfg. Co.](#)
 - b. [Mueller Co.; Gas Products Div.](#)
 - c. [Xomox Corporation; a Crane company.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Body: Cast iron, complying with ASTM A 126, Class B.
 3. Plug: Bronze or nickel-plated cast iron.
 4. Seat: Coated with thermoplastic.
 5. Stem Seal: Compatible with natural gas.
 6. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 7. Operator: Square head or lug type with tamperproof feature where indicated.
 8. Pressure Class: **125 psig** (862 kPa).
 9. Listing: Valves **NPS 1 (DN 25)** and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
- J. Cast-Iron, Lubricated Plug Valves: MSS SP-78.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Flowserve.](#)
 - b. [Homestead Valve; a division of Olson Technologies, Inc.](#)
 - c. [McDonald, A. Y. Mfg. Co.](#)
 - d. [Milliken Valve Company.](#)
 - e. [Mueller Co.; Gas Products Div.](#)
 - f. [R&M Energy Systems, A Unit of Robbins & Myers, Inc.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
 2. Body: Cast iron, complying with ASTM A 126, Class B.
 3. Plug: Bronze or nickel-plated cast iron.
 4. Seat: Coated with thermoplastic.
 5. Stem Seal: Compatible with natural gas.
 6. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 7. Operator: Square head or lug type with tamperproof feature where indicated.
 8. Pressure Class: **125 psig** (862 kPa).
 9. Listing: Valves **NPS 1 (DN 25)** and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
- K. PE Ball Valves: Comply with ASME B16.40.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Kerotest Manufacturing Corp.](#)
 - b. [Lyall, R. W. & Company, Inc.](#)
 - c. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - d. **<Insert manufacturer's name>.**
 - e. or approved equal.
2. Body: PE.
3. Ball: PE.
4. Stem: Acetal.
5. Seats and Seals: Nitrile.
6. Ends: Plain or fusible to match piping.
7. CWP Rating: [80 psig (552 kPa)] **<Insert pressure>.**
8. Operating Temperature: [Minus 20 to plus 140 deg F (Minus 29 to plus 60 deg C)] **<Insert temperature range>.**
9. Operator: Nut or flat head for key operation.
10. Include plastic valve extension.
11. Include tamperproof locking feature for valves where indicated on Drawings.

L. Valve Boxes:

1. Cast-iron, two-section box.
2. Top section with cover with "GAS" lettering.
3. Bottom section with base to fit over valve and barrel a minimum of 5 inches (125 mm) in diameter.
4. Adjustable cast-iron extensions of length required for depth of bury.
5. Include tee-handle, steel operating wrench with socket end fitting valve nut or flat head, and with stem of length required to operate valve.

2.6 MOTORIZED GAS VALVES

A. Automatic Gas Valves: Comply with ANSI Z21.21.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [ASCO Power Technologies, LP; Division of Emerson.](#)
 - b. [Dungs, Karl, Inc.](#)
 - c. [Eaton Corporation; Controls Div.](#)
 - d. [Eclipse Combustion, Inc.](#)
 - e. [Honeywell International Inc.](#)
 - f. [Johnson Controls.](#)
 - g. **<Insert manufacturer's name>.**
 - h. or approved equal.
2. Body: Brass or aluminum.
3. Seats and Disc: Nitrile rubber.

4. Springs and Valve Trim: Stainless steel.
5. Normally closed.
6. Visual position indicator.
7. **[Electrical] [Mechanical]** operator for actuation by appliance automatic shutoff device.

B. Electrically Operated Valves: Comply with UL 429.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. ASCO Power Technologies, LP; Division of Emerson.
 - b. Dungs, Karl, Inc.
 - c. Eclipse Combustion, Inc.
 - d. Goyen Valve Corp.; Tyco Environmental Systems.
 - e. Magnatrol Valve Corporation.
 - f. Parker Hannifin Corporation; Climate & Industrial Controls Group; Skinner Valve Div.
 - g. Watts Regulator Co.; Division of Watts Water Technologies, Inc.
 - h. **<Insert manufacturer's name>**.
 - i. or approved equal.
2. Pilot operated.
3. Body: Brass or aluminum.
4. Seats and Disc: Nitrile rubber.
5. Springs and Valve Trim: Stainless steel.
6. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, and replaceable.
7. NEMA ICS 6, Type 4, coil enclosure.
8. Normally closed.
9. Visual position indicator.

2.7 EARTHQUAKE VALVES

A. Earthquake Valves: Comply with ASCE 25.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Vanguard Valves, Inc.
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
2. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
3. Maximum Operating Pressure: **5 psig** (34.5 kPa).
4. Cast-aluminum body with nickel-plated chrome steel internal parts.
5. Nitrile-rubber valve washer.
6. Sight windows for visual indication of valve position.
7. Threaded end connections complying with ASME B1.20.1.

8. Wall mounting bracket with bubble level indicator.

B. Earthquake Valves: Comply with ASCE 25.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Pacific Seismic Products, Inc.](#)
- b. **<Insert manufacturer's name>**.
- c. or approved equal.

2. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.

3. Maximum Operating Pressure: [0.5 psig (3.45 kPa)] [7 psig (48 kPa)] [60 psig (414 kPa)].

4. Cast-aluminum body with stainless-steel internal parts.

5. Nitrile-rubber, reset-stem o-ring seal.

6. Valve position, open or closed, indicator.

7. Composition valve seat with clapper held by spring or magnet locking mechanism.

8. Level indicator.

9. End Connections: Threaded for valves NPS 2 (DN 50) and smaller; flanged for valves NPS 2-1/2 (DN 65) and larger.

2.8 PRESSURE REGULATORS

A. General Requirements:

1. Single stage and suitable for natural gas.
2. Steel jacket and corrosion-resistant components.
3. Elevation compensator.
4. End Connections: Threaded for regulators NPS 2 (DN 50) and smaller; flanged for regulators NPS 2-1/2 (DN 65) and larger.

B. Service Pressure Regulators: Comply with ANSI Z21.80.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [Actaris.](#)
- b. [American Meter Company.](#)
- c. [Fisher Control Valves and Regulators; Division of Emerson Process Management.](#)
- d. [Invensys.](#)
- e. [Richards Industries; Jordan Valve Div.](#)
- f. **<Insert manufacturer's name>**.
- g. or approved equal.

2. Body and Diaphragm Case: Cast iron or die-cast aluminum.

3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: [100 psig (690 kPa)] <Insert pressure>.

C. Line Pressure Regulators: Comply with ANSI Z21.80.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Actaris](#).
 - b. [American Meter Company](#).
 - c. [Eclipse Combustion, Inc.](#)
 - d. [Fisher Control Valves and Regulators; Division of Emerson Process Management](#).
 - e. [Invensys](#).
 - f. [Maxitrol Company](#).
 - g. [Richards Industries; Jordan Valve Div.](#)
 - h. <Insert manufacturer's name>.
 - i. or approved equal.
2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: [2 psig (13.8 kPa)] [5 psig (34.5 kPa)] [10 psig (69 kPa)] <Insert pressure>.

- D. Appliance Pressure Regulators: Comply with ANSI Z21.18.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Canadian Meter Company Inc.](#)
 - b. [Eaton Corporation; Controls Div.](#)
 - c. [Harper Wyman Co.](#)
 - d. [Maxitrol Company.](#)
 - e. [SCP, Inc.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 2. Body and Diaphragm Case: Die-cast aluminum.
 3. Springs: Zinc-plated steel; interchangeable.
 4. Diaphragm Plate: Zinc-plated steel.
 5. Seat Disc: Nitrile rubber.
 6. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
 7. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.
 8. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.
 9. Maximum Inlet Pressure: [1 psig (6.9 kPa)] [2 psig (13.8 kPa)] [5 psig (34.5 kPa)] **<Insert pressure>**.

2.9 SERVICE METERS

- A. Diaphragm-Type Service Meters: Comply with [ANSI B109.1] [ANSI B109.2].
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Actaris.](#)
 - b. [American Meter Company.](#)
 - c. [Invensys.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Case: Die-cast aluminum.
 3. Connections: Steel threads.
 4. Diaphragm: Synthetic fabric.
 5. Diaphragm Support Bearings: Self-lubricating.
 6. Compensation: Continuous temperature[**and pressure**].
 7. Meter Index: [**Cubic feet**] [**Liters**] [**Cubic feet and liters**].
 8. Meter Case and Index: Tamper resistant.
 9. Remote meter reader compatible.
 10. Maximum Inlet Pressure: [100 psig (690 kPa)] **<Insert pressure>**.
 11. Pressure Loss: Maximum [0.5-inch wg (124 Pa)] [2.0-inch wg (498 Pa)] **<Insert pressure differential>**.

12. Accuracy: Maximum plus or minus [1.0] <Insert number> percent.
- B. Rotary-Type Service Meters: Comply with ANSI B109.3.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [American Meter Company](#).
 - b. [Invensys](#).
 - c. <Insert manufacturer's name>.
 - d. or approved equal.
 2. Case: Extruded aluminum.
 3. Connection: Flange.
 4. Impellers: Polished aluminum.
 5. Rotor Bearings: Self-lubricating.
 6. Compensation: Continuous temperature[and pressure].
 7. Meter Index: [Cubic feet] [Liters] [Cubic feet and liters].
 8. Tamper resistant.
 9. Remote meter reader compatible.
 10. Maximum Inlet Pressure: [100 psig (690 kPa)] <Insert pressure>.
 11. Accuracy: Maximum plus or minus [2.0] <Insert number> percent.
- C. Turbine Meters: Comply with ASME MFC-4M.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [American Meter Company](#).
 - b. [Invensys](#).
 - c. <Insert manufacturer's name>.
 - d. or approved equal.
 2. Housing: Cast iron or welded steel.
 3. Connection Threads or Flanges: Steel.
 4. Turbine: Aluminum or plastic.
 5. Turbine Bearings: Self-lubricating.
 6. Compensation: Continuous temperature[and pressure].
 7. Meter Index: [Cubic feet] [Liters] [Cubic feet and liters].
 8. Tamper resistant.
 9. Remote meter reader compatible.
 10. Maximum Inlet Pressure: [100 psig (690 kPa)] <Insert pressure>.
 11. Accuracy: Maximum plus or minus [2.0] <Insert number> percent.
- D. Service-Meter Bars:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Actaris](#).

- b. [American Meter Company](#).
 - c. [Lyall, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Mueller Co.; Gas Products Div.](#)
 - f. [Perfection Corporation; a subsidiary of American Meter Company](#).
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
2. Malleable- or cast-iron frame for supporting service meter.
 3. Include offset swivel pipes, meter nuts with o-ring seal, and factory- or field-installed dielectric unions.
 4. Omit meter offset swivel pipes if service-meter bar dimensions match service-meter connections.
- E. Service-Meter Bypass Fittings:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Lyall, R. W. & Company, Inc.](#)
 - b. [Williamson, T. D., Inc.](#)
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Ferrous, tee, pipe fitting with capped side inlet for temporary natural-gas supply.
 3. Integral ball-check bypass valve.
- ## 2.10 DIELECTRIC FITTINGS
- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.
- B. Dielectric Unions:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Capitol Manufacturing Company](#).
 - b. [Central Plastics Company](#).
 - c. [Hart Industries International, Inc.](#)
 - d. [Jomar International Ltd.](#)
 - e. [Matco-Norca, Inc.](#)
 - f. [McDonald, A. Y. Mfg. Co.](#)
 - g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
 - h. [Wilkins; a Zurn company](#).
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.

2. Description:

- a. Standard: ASSE 1079.
- b. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F** (82 deg C)] [150 psig (1035 kPa)] [250 psig (1725 kPa)].
- c. End Connections: Solder-joint copper alloy and threaded ferrous.

C. Dielectric Flanges:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Capitol Manufacturing Company.](#)
- b. [Central Plastics Company.](#)
- c. [Matco-Norca, Inc.](#)
- d. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
- e. [Wilkins; a Zurn company.](#)
- f. **<Insert manufacturer's name>.**
- g. or approved equal.

2. Description:

- a. Standard: ASSE 1079.
- b. Factory-fabricated, bolted, companion-flange assembly.
- c. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F** (82 deg C)] [150 psig (1035 kPa)] [175 psig (1200 kPa)] [300 psig (2070 kPa)].
- d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Advance Products & Systems, Inc.](#)
- b. [Calpico, Inc.](#)
- c. [Central Plastics Company.](#)
- d. [Pipeline Seal and Insulator, Inc.](#)
- e. **<Insert manufacturer's name>.**
- f. or approved equal.

2. Description:

- a. Nonconducting materials for field assembly of companion flanges.
- b. Pressure Rating: [150 psig (1035 kPa)] **<Insert pressure>.**
- c. Gasket: Neoprene or phenolic.
- d. Bolt Sleeves: Phenolic or polyethylene.
- e. Washers: Phenolic with steel backing washers.

2.11 LABELING AND IDENTIFYING

- A. Detectable Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of **6 inches (150 mm)** wide and **4 mils (0.1 mm)** thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to **30 inches (750 mm)** deep; colored yellow.
- B. Reference Section 230553 "Identification of HVAC Piping and Equipment".

2.12 CONCRETE BASES

- A. Description: Precast, reinforced concrete base, made of 3000-psi- minimum, 28-day compressive strength concrete, and measuring 4 inches thick and 4 inches larger in each dimension than supported item, unless otherwise indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for natural-gas piping system to verify actual locations of piping connections before equipment installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Close equipment shutoff valves before turning off natural gas to premises or piping section.
- B. Perform leakage test as specified in Article 3 to determine that all equipment is turned off in affected piping section.
 - 1. Comply with ANSI Z223.1, "Prevention of Accidental Ignition" Paragraph.
- C. Inspect natural-gas piping according to **[NFPA 54] [the International Fuel Gas Code]** to determine that natural-gas utilization devices are turned off in piping section affected.
- D. Comply with **[NFPA 54] [the International Fuel Gas Code]** requirements for prevention of accidental ignition.

3.3 OUTDOOR PIPING INSTALLATION

- A. Comply with **[NFPA 54] [the International Fuel Gas Code]** for installation and purging of natural-gas piping.
- B. Install underground, natural-gas piping buried at least **[36 inches (900 mm)] <Insert value>** below finished grade. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.
 - 1. If natural-gas piping is installed less than **36 inches (900 mm)** below finished grade, install it in containment conduit.
- C. Steel Piping with Protective Coating:
 - 1. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.
 - 2. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
 - 3. Replace pipe having damaged PE coating with new pipe.
- D. Copper Tubing with Protective Coating:
 - 1. Apply joint cover kits over tubing to cover, seal, and protect joints.
 - 2. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
- E. Install fittings for changes in direction and branch connections.
- F. Install pressure gage **[downstream] [upstream and downstream]** from each service regulator. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."

3.4 SERVICE ENTRANCE PIPING

- A. Extend fuel gas piping and connect to fuel gas distribution for service entrance to building.
 - 1. Exterior fuel gas distribution system piping, service pressure regulator, and service meter will be provided by gas utility.
- B. Install dielectric fitting downstream from and adjacent to each service meter unless meter is supported from service-meter bar with integral dielectric fitting. Install shutoff valve downstream from and adjacent to dielectric fitting. Refer to Section 230500 "Common Work Results for HVAC" for dielectric fittings.

3.5 INDOOR PIPING INSTALLATION

- A. Comply with **[NFPA 54] [the International Fuel Gas Code]** for installation and purging of natural-gas piping.

- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- C. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
- D. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- E. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- F. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- G. Locate valves for easy access.
- H. Install natural-gas piping at uniform grade of 2 percent down toward drip and sediment traps.
- I. Install piping free of sags and bends.
- J. Install fittings for changes in direction and branch connections.
- K. Verify final equipment locations for roughing-in.
- L. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.
- M. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
 - 1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches (75 mm) long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.
- N. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.
- O. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.
- P. Concealed Location Installations: Except as specified below, install concealed natural-gas piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints as described in Part 2. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.

1. Above Accessible Ceilings: Natural-gas piping, fittings, valves, and regulators may be installed in accessible spaces without containment conduit, subject to approval of authorities having jurisdiction, whether or not such spaces are used as plenums. Do not locate valves above ceilings.
 2. In Floors: Install natural-gas piping with welded or brazed joints and protective coating in cast-in-place concrete floors, subject to approval of authorities having jurisdiction. Cover piping to be cast in concrete slabs with minimum of 1-1/2 inches (38 mm) of concrete. Piping may not be in physical contact with other metallic structures such as reinforcing rods or electrically neutral conductors. Do not embed piping in concrete slabs containing quick-set additives or cinder aggregate.
 3. In Floor Channels: Install natural-gas piping in floor channels, subject to approval of authorities having jurisdiction. Channels must have cover and be open to space above cover for ventilation.
 4. In Walls or Partitions: Do not install concealed piping in solid partitions. Protect tubing installed inside partitions or hollow walls from physical damage using steel striker barriers at rigid supports.
 - a. Exception: Tubing passing through partitions or walls does not require striker barriers.
 5. Prohibited Locations:
 - a. Do not install natural-gas piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
 - b. Do not install natural-gas piping in solid walls or partitions.
- Q. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
- R. Connect branch piping from top or side of horizontal piping.
- S. Install unions in pipes **NPS 2 (DN 50)** and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.
- T. Install corrugated, stainless-steel tubing system according to manufacturer's written instructions. Include striker plates to protect tubing from puncture where tubing is restrained and cannot move.
- U. Do not use natural-gas piping as grounding electrode.
- V. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.
- W. Install pressure gage [**downstream**] [**upstream and downstream**] from each line regulator. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."

- X. Install flanges on valves, specialties, and equipment having NPS 2-1/2 and larger connections.
- Y. Install vent piping for gas pressure regulators and gas trains, extend outside building, and vent to atmosphere. Terminate vents with turned-down, reducing-elbow fittings with corrosion-resistant insect screens in large end.
- Z. Install containment conduits for gas piping below slabs, within building, in gastight conduits extending minimum of 4 inches outside building, and vented to atmosphere. Terminate vents with turned-down, reducing-elbow fittings with corrosion-resistant insect screens in large end. Prepare and paint outside of conduits with coal-tar, epoxy-polyamide paint according to SSPC-Paint 16.
- AA. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- BB. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- CC. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.6 SERVICE-METER ASSEMBLY INSTALLATION

- A. Install service-meter assemblies aboveground[, **on concrete bases**].
- B. Install metal shutoff valves upstream from service regulators. Shutoff valves are not required at second regulators if two regulators are installed in series.
- C. Install strainer on inlet of service-pressure regulator and meter set.
- D. Install service regulators mounted outside with vent outlet horizontal or facing down. Install screen in vent outlet if not integral with service regulator.
- E. Install pressure gauge [**downstream**] [**upstream and downstream**] from each service pressure regulator.
- F. Install metal shutoff valves upstream from service meters. Install dielectric fittings downstream from service meters.
- G. Install service meters downstream from pressure regulators.
 - 1. Service meters with connections NPS 1 and smaller on meter bars.
 - 2. Service meters with connections larger than NPS 1 supported from piping or set on concrete bases.

- H. Install metal bollards to protect meter assemblies. Comply with requirements in Section 055000 "Metal Fabrications" for pipe bollards.

3.7 VALVE INSTALLATION

- A. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing, aluminum, or copper connector.
- B. Install underground valves with valve boxes.
- C. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.
- D. Install earthquake valves aboveground outside buildings according to listing.
- E. Install anode for metallic valves in underground PE piping.

3.8 PIPING JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded Joints:
 - 1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
 - 2. Cut threads full and clean using sharp dies.
 - 3. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.
 - 4. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
 - 5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. Welded Joints:
 - 1. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
 - 2. Bevel plain ends of steel pipe.
 - 3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.
- E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter.
 - 1. Brazed Joints: Make with brazing alloy with melting point greater than 1000oF.
 - 2. Brazing alloys containing phosphorus are prohibited.

- F. Flanged Joints: Install gasket material, size, type, and thickness appropriate for natural-gas service. Install gasket concentrically positioned.
- G. Flared Joints: Cut tubing with roll cutting tool. Flare tube end with tool to result in flare dimensions complying with SAE J513. Tighten finger tight, then use wrench. Do not overtighten.
- H. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
 - 1. Plain-End Pipe and Fittings: Use butt fusion.
 - 2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.9 HANGER AND SUPPORT INSTALLATION

- A. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- C. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
 - 1. NPS 1 (DN 25) and Smaller: Maximum span, 96 inches (2438 mm); minimum rod size, 3/8 inch (10 mm).
 - 2. NPS 1-1/4 (DN 32): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
 - 3. NPS 1-1/2 and NPS 2 (DN 40 and DN 50): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
 - 4. NPS 2-1/2 to NPS 3-1/2 (DN 65 to DN 90): Maximum span, 10 feet (3 m); minimum rod size, 1/2 inch (13 mm).
 - 5. NPS 4 (DN 100) and Larger: Maximum span, 10 feet (3 m); minimum rod size, 5/8 inch (15.8 mm).
- D. Install hangers for horizontal drawn-temper copper tubing with the following maximum spacing and minimum rod sizes:
 - 1. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
 - 2. NPS 1/2 and NPS 5/8 (DN 15 and DN 18): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
 - 3. NPS 3/4 and NPS 7/8 (DN 20 and DN 22): Maximum span, 84 inches (2134 mm); minimum rod size, 3/8 inch (10 mm).
 - 4. NPS 1 (DN 25): Maximum span, 96 inches (2440 mm); minimum rod size, 3/8 inch (10 mm).
- E. Install hangers for horizontal, corrugated stainless-steel tubing with the following maximum spacing and minimum rod sizes:

1. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
2. NPS 1/2 (DN 15): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
3. NPS 3/4 (DN 20) and Larger: Maximum span, 96 inches (2440 mm); minimum rod size, 3/8 inch (10 mm).

3.10 CONNECTIONS

- A. Connect to utility's gas main according to utility's procedures and requirements.
- B. Drawings indicate general arrangement of fuel gas piping, fittings, and specialties.
- C. Install piping adjacent to appliances to allow service and maintenance.
- D. Install natural-gas piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.
- E. Install piping adjacent to appliances to allow service and maintenance of appliances.
- F. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches (1800 mm) of each gas-fired appliance and equipment. Install union between valve and appliances or equipment.
- G. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.
- H. Ground equipment.
 1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.
 2. Do not use gas pipe as grounding electrode.

3.11 LABELING AND IDENTIFYING

- A. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for piping and valve identification.
- B. Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplate or sign on or near each service meter, pressure regulator, and specialty valve.
 1. Text: In addition to name of identified unit, distinguish between multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations.

- C. Install detectable warning tape directly above gas piping, **12 inches** (300 mm) below finished grade, except **6 inches** (150 mm) below subgrade under pavements and slabs.

3.12 PAINTING

- A. Comply with requirements in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting" for painting interior and exterior natural-gas piping.

- B. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.

1. Alkyd System: MPI EXT 5.1D.

- a. Prime Coat: Alkyd anticorrosive metal primer.
- b. Intermediate Coat: Exterior alkyd enamel matching topcoat.
- c. Topcoat: Exterior alkyd enamel **[(flat)] [(semigloss)] [(gloss)]**.
- d. Color: **[Gray]** <Insert color>.

- C. Paint exposed, interior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.

1. Latex Over Alkyd Primer System: MPI INT 5.1Q.

- a. Prime Coat: **[Alkyd anticorrosive]** **[Quick-drying alkyd]** metal primer.
- b. Intermediate Coat: Interior latex matching topcoat.
- c. Topcoat: Interior latex **[(flat)] [(low sheen)] [(eggshell)] [(satin)] [(semigloss)] [(gloss)]**.
- d. Color: **[Gray]** <Insert color>.

2. Alkyd System: MPI INT 5.1E.

- a. Prime Coat: **[Alkyd anticorrosive]** **[Quick-drying alkyd]** metal primer.
- b. Intermediate Coat: Interior alkyd matching topcoat.
- c. Topcoat: Interior alkyd **[(flat)] [(eggshell)] [(semigloss)] [(gloss)]**.
- d. Color: **[Gray]** <Insert color>.

- D. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

3.13 CONCRETE BASES

- A. Concrete Bases: Anchor equipment to concrete base **[according to seismic codes at Project]**.

1. Locate bases at service meters and service regulators.
2. Excavate earth and make level beds to support bases. Set bases level with top surface projecting approximately 3 inches (75 mm) above grade.

3. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.
4. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on [18-inch (450-mm)] <Insert dimension> centers around the full perimeter of the base.
5. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
6. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
7. Install anchor bolts to elevations required for proper attachment to supported equipment.
8. Use [3000-psi (20.7-MPa)] <Insert value>, 28-day, compressive-strength concrete and reinforcement as specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

3.14 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
 1. Test, inspect, and purge natural gas according to [NFPA 54] [the International Fuel Gas Code] and authorities having jurisdiction, and as per TESTING PIPING SYSTEMS Article below.
- C. Natural-gas piping will be considered defective if it does not pass tests and inspections.
- D. Repair leaks and defects with new materials and retest system until satisfactory results are obtained.
- E. Report test results promptly and in writing to DEN Project Manager and authorities having jurisdiction.
- F. Verify capacities and pressure ratings of service meters, pressure regulators, valves, and specialties.
- G. Verify correct pressure settings for pressure regulators.
- H. Verify that specified piping tests are complete.
- I. Prepare test and inspection reports.

3.15 TESTING PIPING SYSTEMS

- A. Perform all tests in the presence of the authorized City representative when required. Contractor shall provide inspector 48-hour prior notice of test; also notify DEN Project Manager.

- B. No piping or joint shall be left untested. All leaks shall be repaired and the piping system shall be re-tested until satisfactory results are obtained.
- C. Pneumatic Leak Test:
1. General: Pneumatic leak tests shall only be used on natural gas piping, piping with restricted access, piping exposed to freezing conditions, or where water leakage would damage critical DEN operational equipment. Contractor shall submit a written request for test in accordance with the SUBMITTALS Article of this specification section.
 2. Test all natural gas piping prior to initial operation, to assure tightness. The test medium shall be air, or inert gas. Pipe joints shall be left exposed for examination during the test. A pressure test shall be maintained for a period of twelve (12) hours and precautions shall be taken to avoid excessive pressure. The test pressure to be used shall be no less than 1-1/2 times the proposed maximum working pressure, but not less than 10 psig, irrespective of design pressure. There shall be no loss of pressure during test. The piping system shall be visually examined for signs of leakage or other defects. All exposed joints shall be checked by means of a soap bubble test or other foaming agent test. In the event repairs or additions are made following the pressure test, the affected piping shall be retested. After test is completed and prior to putting piping systems into operation, completely purge system. Purging medium may be same as piping medium as long as piping medium can be introduced at a moderately rapid and continuous rate
 3. Pneumatic Test Procedure:
 - a. Contractor shall submit safety plan for pneumatic testing prior to test.
 - b. General: Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations:
 - 1) The piping system does not contain cast iron pipe or plastic pipe subject to brittle failure.
 - 2) The system does not contain soldered or solvent cement joints over NPS 2.
 - 3) The test pressure does not exceed 150 psig.
 - c. Test Medium: The gas shall be nonflammable and nontoxic.
 - d. Preliminary Test: Prior to application of full pneumatic test pressure, a preliminary test of not more than 10 psig shall be applied to reveal possible major leaks. Pneumatic Test Pressure:
 - 1) Except as limited in 2) below, the test pressure shall not exceed 1.25 times the design pressure. Pressure shall be applied in several stages, allowing time for the system to reach equilibrium at each stage.
 - 2) The test pressure shall not exceed the maximum allowable pneumatic test pressure for any vessel, pump, valve, or other component in the system under test.

- e. Examination for Leakage: After the preliminary test, pressure shall be raised in stages of not more than 25% up to full pneumatic test pressure, allowing time for equalization of strains and detection of major leaks at each stage. Following the application of test pressure for at least 10 minutes, the pressure may be reduced to design pressure and examination shall be made for leakage of the piping. Leaks may be detected by soap bubble, halogen gas, scented gas, test gage monitoring, ultrasonic, or other suitable means. If leaks are found, pressure shall be vented, appropriate repair or replacement shall be made, and the pneumatic test repeated until no leakage is found.
 - f. Contractor shall measure the surface temperature of the pipe for the duration of testing. The pneumatic test will be deemed successful only when the test pressure can be held at a constant pipe surface temperature for a period of no less than 10 continuous minutes. Record of the pipe temperatures and pressures during the duration of the test shall be submitted to the DEN Project Manager following completion of the test.
- D. Testing shall be witnessed by DEN Mechanical Inspector and DEN Project Manager or Designated Representative.
- E. Repair piping systems that fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.
- F. Prepare written report of testing procedures and result. Submit in accordance with Section 23400 "Basic HVAC Requirements".
- 3.16 ADJUSTING
- A. Adjust controls and safety devices. Replace damaged and malfunctioning controls and safety devices.
- 3.17 DEMONSTRATION
- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain earthquake valves.
- 3.18 OUTDOOR PIPING SCHEDULE
- A. Underground natural-gas piping shall be[**one of**] the following:
 - 1. Steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
 - 2. **[Annealed] [Drawn]**-temper copper tube with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
 - B. Aboveground natural-gas piping shall be[**one of**] the following:
 - 1. Steel pipe with malleable-iron fittings and threaded joints.

2. Steel pipe with wrought-steel fittings and welded joints.
 3. **[Annealed] [Drawn]**-temper copper tube with wrought-copper fittings and brazed joints.
- C. Branch Piping in Cast-in-Place Concrete to Single Appliance: Annealed-temper copper tube with wrought-copper fittings and **[brazed] [flared]** joints. Install piping embedded in concrete with no joints in concrete.
- D. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- 3.19 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES LESS THAN 0.5 PSIG (3.45 kPa)
- A. Aboveground, branch piping **[NPS 1 (DN 25)]** <Insert pipe size> and smaller shall be **one of** the following:
1. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
 2. Annealed-temper, tin-lined copper tube with flared joints and fittings.
 3. Annealed-temper, copper tube with wrought-copper fittings and **[brazed] [flared]** joints.
 4. Steel pipe with malleable-iron fittings and threaded joints.
- B. Aboveground, distribution piping shall be **one of** the following:
1. Steel pipe with malleable-iron fittings and threaded joints.
 2. Steel pipe with wrought-steel fittings and welded joints.
 3. Drawn-temper copper tube with wrought-copper fittings and brazed joints.
- C. Underground, below building, piping shall be **one of** the following:
1. Steel pipe with malleable-iron fittings and threaded joints.
 2. Steel pipe with wrought-steel fittings and welded joints.
- D. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- E. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.
- 3.20 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES MORE THAN 0.5 PSIG (3.45 kPa) AND LESS THAN 5 PSIG (34.5 kPa)
- A. Aboveground, branch piping **[NPS 1 (DN 25)]** <Insert pipe size> and smaller shall be **one of** the following:

1. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
 2. Annealed-temper, tin-lined copper tube with flared joints and fittings.
 3. Annealed-temper, copper tube with wrought-copper fittings and **[brazed] [flared]** joints.
 4. Steel pipe with malleable-iron fittings and threaded joints.
- B. Aboveground, distribution piping shall be **[one of]** the following:
1. Steel pipe with malleable-iron fittings and threaded joints.
 2. Steel pipe with steel welding fittings and welded joints.
 3. Drawn-temper copper tube with wrought-copper fittings and brazed joints.
- C. Underground, below building, piping shall be **[one of]** the following:
1. Steel pipe with malleable-iron fittings and threaded joints.
 2. Steel pipe with wrought-steel fittings and welded joints.
- D. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat underground pipe and fittings with protective coating for steel piping.
- E. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.
- 3.21 **INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES MORE THAN 5 PSIG**
(34.5 kPa)
- A. Aboveground Piping: Maximum operating pressure more than **[5 psig (34.5 kPa)]** **<Insert pressure>**.
- B. Aboveground, Branch Piping: Steel pipe with steel welding fittings and welded joints.
- C. Aboveground, distribution piping shall be **[one of]** the following:
1. Steel pipe with steel welding fittings and welded joints.
 2. Drawn-temper copper tube with wrought-copper fittings and brazed joints.
- D. Underground, below building, piping shall be **[one of]** the following:
1. Steel pipe with malleable-iron fittings and threaded joints.
 2. Steel pipe with wrought-steel fittings and welded joints.
- E. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- F. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

3.22 UNDERGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

- A. Connections to Existing Gas Piping: Use valve and fitting assemblies made for tapping utility's gas mains and listed by an NRTL.
- B. Underground:
 - 1. PE valves.
 - 2. NPS 2 (DN 50) and Smaller: Bronze plug valves.
 - 3. NPS 2-1/2 (DN 65) and Larger: Cast-iron, [lubricated] [nonlubricated] plug valves.

3.23 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

- A. Valves for pipe sizes NPS 2 (DN 50) and smaller at service meter shall be[**one of**] the following:
 - 1. One-piece, bronze ball valve with bronze trim.
 - 2. Two-piece, [full] [regular]-port, bronze ball valves with bronze trim.
 - 3. Bronze plug valve.
- B. Valves for pipe sizes NPS 2-1/2 (DN 65) and larger at service meter shall be[**one of**] the following:
 - 1. Two-piece, [full] [regular]-port, bronze ball valves with bronze trim.
 - 2. Bronze plug valve.
 - 3. Cast-iron, nonlubricated plug valve.
- C. Distribution piping valves for pipe sizes NPS 2 (DN 50) and smaller shall be[**one of**] the following:
 - 1. One-piece, bronze ball valve with bronze trim.
 - 2. Two-piece, [full] [regular]-port, bronze ball valves with bronze trim.
 - 3. Bronze plug valve.
- D. Distribution piping valves for pipe sizes NPS 2-1/2 (DN 65) and larger shall be[**one of**] the following:
 - 1. Two-piece, [full] [regular]-port, bronze ball valves with bronze trim.
 - 2. Bronze plug valve.
 - 3. Cast-iron, [nonlubricated] [lubricated] plug valve.
- E. Valves in branch piping for single appliance shall be[**one of**] the following:
 - 1. One-piece, bronze ball valve with bronze trim.
 - 2. Two-piece, [full] [regular]-port, bronze ball valves with bronze trim.
 - 3. Bronze plug valve.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 231123

SECTION 231126 - FACILITY LIQUEFIED-PETROLEUM GAS PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Pipes, tubes, and fittings.
 - 2. Piping specialties.
 - 3. Piping and tubing joining materials.
 - 4. Valves.
 - 5. Pressure regulators.
 - 6. Service meters.
 - 7. Storage containers.
 - 8. Transport truck unloading facility specialties.
 - 9. Pumps.
 - 10. Vaporizers.
 - 11. Air mixers.
 - 12. Concrete bases.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
- D. LPG: Liquefied-petroleum gas.

1.4 PERFORMANCE REQUIREMENTS

- A. Minimum Operating-Pressure Ratings:
1. For Piping Containing Only Vapor:
 - a. Piping and Valves: [125 psig (862 kPa)] <Insert pressure> unless otherwise indicated.
 2. For Piping Containing Liquid:
 - a. Piping between Shutoff Valves: [350 psig (2413 kPa)] <Insert pressure> unless otherwise indicated.
 - b. Piping Other Than Above: [250 psig (1723 kPa)] <Insert pressure> unless otherwise indicated.
 - c. Valves and Fittings: [250 psig (1723 kPa)] <Insert pressure> unless otherwise indicated.
 3. Minimum Operating Pressure of Service Meter: [5 psig (34.5 kPa)] [10 psig (69 kPa)] [20 psig (138 kPa)] [65 psig (450 kPa)] <Insert pressure>.
 - B. LPG System Pressure within Buildings: One pressure range. [0.5 psig (3.45 kPa) or less] [More than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa)] [More than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa)].
 - C. LPG System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa) and is reduced to secondary pressure of 0.5 psig (3.45 kPa) or less.
 - D. LPG System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa) and is reduced to secondary pressure of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa).
 - E. LPG System Pressures within Buildings: Three pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa) and is reduced to secondary pressures of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa) and is reduced again to pressures of 0.5 psig (3.45 kPa) or less.
 - F. Design values of fuel gas supplied for these systems are as follows:
 1. Nominal Heating Value: <Insert value> Btu/ 1,000 cu. ft.
 2. Nominal Specific Gravity: <Insert value>
 - G. Delegated Design: Design restraints and anchors for LPG piping and equipment, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
 - H. Seismic Performance: Vaporizers and storage container supports shall withstand the effects of earthquake motions determined according to [SEI/ASCE 7] <Insert requirement>.

1. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

1.5 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Piping specialties.
2. Corrugated stainless-steel tubing with associated components.
3. Valves. Include pressure rating, capacity, settings, and electrical connection data of selected models.
4. Pressure regulators. Indicate pressure ratings and capacities, and settings of selected models.
5. Service meters. Indicate [**pressure ratings and**] capacities. Include [**bypass fittings**] [**bypass fittings and meter bars**] [**meter bars**] [**supports**].
6. Dielectric fittings.
7. Storage containers.
8. Transport truck unloading specialties.
9. Pumps.
10. Vaporizers.
11. Air mixers.
12. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For facility LPG piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion joints and loops. [**Show different pressure zones and indicate pressure for each zone.**]

1. Shop Drawing Scale: [**1/4 inch per foot (1:50)**] <Insert scale>.
2. Detail mounting, supports, and valve arrangements for [**service meter assembly and**] pressure regulator assembly.

C. Delegated-Design Submittal: For LPG piping and equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Detail fabrication and assembly of seismic restraints.
2. Design Calculations: Calculate requirements for selecting seismic restraints.

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans and details, drawn to scale, on which LPG piping is shown and coordinated with other installations, using input from installers of the items involved.

- B. Site Survey: Plans, drawn to scale, on which LPG piping is shown and coordinated with other services and utilities.
- C. Qualification Data: For qualified professional engineer.
- D. Installer certificates for piping systems.
- E. Seismic Qualification Certificates: Submit certification that vaporizer, air mixer, storage container supports, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- F. Welding certificates. Include welders certification of compliance with **[ASME SEC 9]** **[AWS D1.1.]** <Insert requirement> and section 059990 "Welding".
- G. Field quality-control reports. Indicate and interpret test results for compliance with performance requirements.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For LPG equipment, specialties, and accessories to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 QUALITY ASSURANCE

- A. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
- C. ANSI Standard: Comply with ANSI Z223.1, "National Fuel Gas Code."
- D. FM Standard: Provide components listed in FM's "Fire Protection Approval Guide" if specified to be FM approved.
- E. IAS Standard: Provide components listed in IAS's "Directory of A. G. A. and C. G. A Certified Appliances and Accessories" if specified to be IAS listed.

- F. UL Standard: Provide components listed in UL's "Gas and Oil Equipment Directory" if specified to be UL listed.
- G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Handling Flammable Liquids: Remove and dispose of liquids from existing LPG piping according to requirements of authorities having jurisdiction. Handle cautiously to avoid spillage and ignition. Notify LPG supplier. Handle flammable liquids used by Installer with proper precautions and do not leave on premises from end of one day to beginning of next day.
- B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- C. Store pipes and tubes with protective PE coating to avoid damaging coating and protect from direct sunlight.
- D. Protect stored PE pipes and valves from direct sunlight.

1.10 PROJECT CONDITIONS

- A. Perform site survey, research public utility records, and verify existing utility locations. Contact utility-locating service for area where Project is located.
- B. Interruption of Existing LPG Service: Do not interrupt LPG service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide purging and startup of LPG supply according to requirements indicated:
 - 1. Notify DEN Project Manager no fewer than **[five (5)]** <Insert number> days in advance of proposed interruption of LPG service.
 - 2. Do not proceed with interruption of LPG service without DEN Project Manager's written permission.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces. Comply with requirements in Section 083113 "Access Doors and Frames."

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

Black steel pipe has traditionally been used for gas piping. Other materials include copper, brass, and stainless steel. Use material required for specific conditions and avoid conditions detrimental to piping. Before selecting materials, contact gas supplier to find out if gas contains corrosive materials such as hydrogen sulfide, carbon dioxide, or moisture.

See Part 3 piping schedule articles to determine where pipes, tubes, fittings, and joining materials are applied in various services.

- A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedules 40 and 80, Type E or S, Grade B.
1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
 2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
 3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
 4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - a. Material Group: 1.1.
 - b. End Connections: Threaded or butt welding to match pipe.
 - c. Lapped Face: Not permitted underground.
 - d. Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
 - e. Bolts and Nuts: ASME B18.2.1, carbon steel aboveground, and stainless steel underground.
 5. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.
 - a. Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.
 6. Mechanical Couplings:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Dresser Piping Specialties; Division of Dresser, Inc.

- 2) [Smith-Blair, Inc.](#)
 - 3) **<Insert manufacturer's name>**.
 - 4) or approved equal.
- b. **[Stainless-steel] [Steel]** flanges and tube with epoxy finish.
 - c. Buna-nitrile seals.
 - d. **[Stainless-steel] [Steel]** bolts, washers, and nuts.
 - e. Coupling shall be capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
 - f. Steel body couplings installed underground on plastic pipe shall be factory equipped with anode.
- B. Corrugated, Stainless-Steel Tubing: Comply with ANSI/IAS LC 1.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [OmegaFlex, Inc.](#)
 - b. [Parker Hannifin Corporation; Parflex Division.](#)
 - c. [Titeflex.](#)
 - d. [Tru-Flex Metal Hose Corp.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
 2. Tubing: ASTM A 240/A 240M, corrugated, Series 300 stainless steel.
 3. Coating: PE with flame retardant.
 - a. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1) Flame-Spread Index: **[25] <Insert value>** or less.
 - 2) Smoke-Developed Index: **[50] [450] <Insert value>** or less.
 4. Fittings: Copper-alloy mechanical fittings with ends made to fit and listed for use with corrugated stainless-steel tubing and capable of metal-to-metal seal without gaskets. Include brazing socket or threaded ends complying with ASME B1.20.1.
 5. Striker Plates: Steel, designed to protect tubing from penetrations.
 6. Manifolds: Malleable iron or steel with factory-applied protective coating. Threaded connections shall comply with ASME B1.20.1 for pipe inlet and corrugated tubing outlets.
 7. Operating-Pressure Rating: **5 psig (34.5 kPa)**.
- C. Drawn-Temper Copper Tube: Comply with **[ASTM B 88, Type K (ASTM B 88M, Type A)] [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 837, Type G]**.
1. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
 2. Brazing Filler Metals: AWS A5.8, Silver Classification BAg-1. Filler metal containing phosphorus is prohibited.
 3. Bronze Flanges and Flanged Fittings: ASME B16.24, Class 150.

- a. Gasket Material: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
 - b. Bolts and Nuts: ASME B18.2.1, carbon steel or stainless steel.
4. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of **0.022 inch** (0.56 mm) thick.
- D. Annealed-Temper Copper Tube: Comply with [ASTM B 88, Type K (ASTM B 88M, Type A)] [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 837, Type G].
1. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
 2. Brazing Filler Metals: AWS A5.8, Silver Classification BAg-1. Filler metal containing phosphorus is prohibited.
 3. Flare Fittings: Comply with ASME B16.26 and SAE J513.
 - a. Copper fittings with long nuts.
 - b. Metal-to-metal compression seal without gasket.
 - c. Dryseal threads complying with ASME B1.20.3.
 4. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of **0.022 inch** (0.56 mm) thick.
- E. Tin-Lined Copper Tube: ASTM B 280, seamless, annealed, with interior tin-plated lining.
1. Flare Fittings: Comply with ASME B16.26 and SAE J513.
 - a. Copper fittings with long nuts.
 - b. Metal-to-metal compression seal without gasket.
 - c. Dryseal threads complying with ASME B1.20.3.
 2. Brazing Filler Metals: AWS A5.8, Silver Classification BAg-1. Filler metal containing phosphorus is prohibited.

2.2 PIPING SPECIALTIES

A. Flexible Piping Joints:

1. Approved for LPG service.
2. Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
3. Minimum working pressure of **250 psig** (1723 kPa) and **250 deg F** (121 deg C) operating temperature.
4. Flanged- or threaded-end connections to match equipment connected and shall be capable of minimum **3/4-inch** (20-mm) misalignment.
5. Maximum **36-inch** (914-mm) length for liquid LPG lines.

B. Appliance Flexible Connectors:

1. Indoor, Fixed-Appliance Flexible Connectors: Comply with ANSI Z21.24.
2. Indoor, Movable-Appliance Flexible Connectors: Comply with ANSI Z21.69.

3. Outdoor, Appliance Flexible Connectors: Comply with ANSI Z21.75.
 4. Corrugated stainless-steel tubing with polymer coating.
 5. Operating-Pressure Rating: 0.5 psig (3.45 kPa).
 6. End Fittings: Zinc-coated steel.
 7. Threaded Ends: Comply with ASME B1.20.1.
 8. Maximum Length: 72 inches (1830 mm.)
- C. Quick-Disconnect Devices: Comply with ANSI Z21.41.
1. Copper-alloy convenience outlet and matching plug connector.
 2. Nitrile seals.
 3. Hand operated with automatic shutoff when disconnected.
 4. For indoor or outdoor applications.
 5. Adjustable, retractable restraining cable.
- D. Y-Pattern Strainers:
1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
 2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
 3. Strainer Screen: [40] [60]-mesh startup strainer and perforated stainless-steel basket with 50 percent free area.
 4. CWP Rating: 125 psig (862 kPa).
- E. Basket Strainers:
1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
 2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
 3. Strainer Screen: [40] [60]-mesh startup strainer and perforated stainless-steel basket with 50 percent free area.
 4. CWP Rating: 125 psig (862 kPa).
- F. T-Pattern Strainers:
1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
 2. End Connections: Grooved ends.
 3. Strainer Screen: [40] [60]-mesh startup strainer and perforated stainless-steel basket with 57 percent free area.
 4. CWP Rating: 750 psig (5170 kPa).
- G. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.

2.3 PROTECTIVE COATING

- A. Furnish pipe and fittings with factory-applied, corrosion-resistant polyethylene coating for use in corrosive atmosphere.

2.4 JOINING MATERIALS

- A. Joint Compound and Tape: Suitable for LPG.
- B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- C. Brazing Filler Metals: Alloy with melting point greater than **1000 deg F** (540 deg C) complying with AWS A5.8/A5.8M.

2.5 MANUAL GAS SHUTOFF VALVES

- A. See "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles for where each valve type is applied in various services.
- B. Metallic Valves, **NPS 2 (DN 50)** and Smaller for Liquid Service: Comply with ASME B16.33 and UL 842.
 - 1. CWP Rating: [**250 psig** (1723 kPa)] **<Insert pressure>**.
 - 2. Threaded Ends: Comply with ASME B1.20.1.
 - 3. Socket ends for brazed joints.
 - 4. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 - 5. Listing by CSA or agency acceptable to authorities having jurisdiction for valves **1 inch** (25 mm) and smaller.
 - 6. Valves **1-1/4 inch** (32 mm) and larger shall be suitable for LPG service, with "WOG" indicated on valve body.
- C. General Requirements for Metallic Valves, **NPS 2 (DN 50)** and Smaller for Vapor Service: Comply with ASME B16.33.
 - 1. CWP Rating: [**125 psig** (862 kPa)] **<Insert pressure>**.
 - 2. Threaded Ends: Comply with ASME B1.20.1.
 - 3. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
 - 4. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 - 5. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves **1 inch** (25 mm) and smaller.
 - 6. Service Mark: Valves **1-1/4 inch** (32 mm) to **NPS 2 (DN 50)** shall have initials "WOG" permanently marked on valve body.

- D. General Requirements for Metallic Valves, **NPS 2-1/2 (DN 65)** and Larger: Comply with ASME B16.38.
1. CWP Rating: [**125 psig** (862 kPa)] **<Insert pressure>**.
 2. Flanged Ends: Comply with ASME B16.5 for steel flanges.
 3. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 4. Service Mark: Initials "WOG" shall be permanently marked on valve body.
- E. Gas Stops: Bronze body with AGA stamp, plug type with bronze plug and flat or square head, ball type with chrome-plated brass ball and lever handle, or butterfly valve with stainless-steel disc and fluorocarbon elastomer seal and lever handle; 2-psig (13.8-kPa) minimum pressure rating.
- F. One-Piece, Bronze Ball Valve with Bronze Trim: MSS SP-110.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [BrassCraft Manufacturing Company; a Masco company.](#)
 - b. [Conbraco Industries, Inc.; Apollo Div.](#)
 - c. [Lyll, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 2. Body: Bronze, complying with ASTM B 584.
 3. Ball: Chrome-plated brass.
 4. Stem: Bronze; blowout proof.
 5. Seats: Reinforced TFE; blowout proof.
 6. Packing: Separate packnut with adjustable-stem packing threaded ends.
 7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 8. CWP Rating: **600 psig** (4143 kPa).
 9. Listing: Valves **NPS 1 (DN 25)** and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for LPG service with "WOG" indicated on valve body.
- G. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [BrassCraft Manufacturing Company; a Masco company.](#)
 - b. [Conbraco Industries, Inc.; Apollo Div.](#)
 - c. [Lyll, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)

- e. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
2. Body: Bronze, complying with ASTM B 584.
 3. Ball: Chrome-plated bronze.
 4. Stem: Bronze; blowout proof.
 5. Seats: Reinforced TFE; blowout proof.
 6. Packing: Threaded-body packnut design with adjustable-stem packing.
 7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 8. CWP Rating: **600 psig** (4143 kPa).
 9. Listing: Valves **NPS 1** (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for LPG service with "WOG" indicated on valve body.
- H. Two-Piece, Regular-Port Bronze Ball Valves with Bronze Trim: MSS SP-110.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [BrassCraft Manufacturing Company; a Masco company.](#)
 - b. [Conbraco Industries, Inc.; Apollo Div.](#)
 - c. [Lyll, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 2. Body: Bronze, complying with ASTM B 584.
 3. Ball: Chrome-plated bronze
 4. Stem: Bronze; blowout proof.
 5. Seats: Reinforced TFE.
 6. Packing: Threaded-body packnut design with adjustable-stem packing.
 7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 8. CWP Rating: **600 psig** (4140 kPa).
 9. Listing: Valves **NPS 1** (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for LPG service with "WOG" indicated on valve body.
- I. Bronze Plug Valves: MSS SP-78.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Lee Brass Company.](#)
 - b. [McDonald, A. Y. Mfg. Co.](#)

- c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Body: Bronze, complying with ASTM B 584.
 3. Plug: Bronze.
 4. Ends: Threaded, socket, or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 5. Operator: Square head or lug type with tamperproof feature where indicated.
 6. Pressure Class: **125 psig** (862 kPa).
 7. Listing: Valves **NPS 1 (DN 25)** and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 8. Service: Suitable for LPG service with "WOG" indicated on valve body.
- J. Cast-Iron, Nonlubricated Plug Valves: MSS SP-78.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. McDonald, A. Y. Mfg. Co.
 - b. Mueller Co.; Gas Products Div.
 - c. Xomox Corporation; a Crane company.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Body: Cast iron, complying with ASTM A 126, Class B.
 3. Plug: Bronze or nickel-plated cast iron.
 4. Seat: Coated with thermoplastic.
 5. Stem Seal: Compatible with LPG.
 6. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 7. Operator: Square head or lug type with tamperproof feature where indicated.
 8. Pressure Class: **125 psig** (862 kPa).
 9. Listing: Valves **NPS 1 (DN 25)** and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for LPG service with "WOG" indicated on valve body.
- K. Cast-Iron, Lubricated Plug Valves: MSS SP-78.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Flowserve.
 - b. Homestead Valve; a Division of Olson Technologies, Inc.
 - c. McDonald, A. Y. Mfg. Co.
 - d. Milliken Valve Company.
 - e. Mueller Co.; Gas Products Div.
 - f. R&M Energy Systems; a subsidiary of Robbins & Myers, Inc.
 - g. **<Insert manufacturer's name>**.

- h. or approved equal.
 - 2. Body: Cast iron, complying with ASTM A 126 Class B.
 - 3. Plug: Bronze or nickel-plated cast iron.
 - 4. Seat: Coated with thermoplastic.
 - 5. Stem Seal: Compatible with LPG.
 - 6. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 - 7. Operator: Square head or lug type with tamperproof feature where indicated.
 - 8. Pressure Class: **125 psig** (862 kPa).
 - 9. Listing: Valves **NPS 1 (DN 25)** and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 - 10. Service: Suitable for LPG service with "WOG" indicated on valve body.
- L. PE Ball Valves: Comply with ASME B16.40.
- 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. **Kerotest Manufacturing Corp.**
 - b. **Lyall, R. W. & Company, Inc.**
 - c. **Perfection Corporation; a subsidiary of American Meter Company.**
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 - 2. Body: PE.
 - 3. Ball: PE.
 - 4. Stem: Acetal.
 - 5. Seats and Seals: Nitrile.
 - 6. Ends: Plain or fusible to match piping.
 - 7. CWP Rating: [**80 psig** (552 kPa)] **<Insert pressure>**.
 - 8. Operating Temperature: [**Minus 20 to plus 140 deg F** (Minus 29 to plus 60 deg C)] **<Insert temperature range>**.
 - 9. Operator: Nut or flat head for key operation.
 - 10. Include plastic valve extension.
 - 11. Include tamperproof locking feature for valves where indicated on Drawings.
- M. Valve Boxes:
- 1. Cast-iron, two-section box.
 - 2. Top section with cover with "GAS" lettering.
 - 3. Bottom section with base to fit over valve and barrel a minimum of **5 inches** (125 mm) in diameter.
 - 4. Adjustable cast-iron extensions of length required for depth of bury.
 - 5. Include tee-handle, steel operating wrench with socket end fitting valve nut or flat head and with stem of length required to operate valve.

2.6 MOTORIZED GAS VALVES

A. Hydrostatic Relief Valves: Comply with NFPA 58.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Engineered Controls International, Inc.; RegO Products.](#)
 - b. [Fisher Control Valves and Regulators; Division of Emerson Process Management.](#)
 - c. [Murray Equipment, Inc.](#)
 - d. [Sherwood; a division of Harsco Corporation.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Operating Pressure: [350 psig (2413 kPa)] **<Insert pressure>**.
3. Body: Brass.
4. Spring: Stainless steel.
5. Disc and Seat: Nitrile.
6. Brass body and stainless-steel, spring-operated valve with resilient rubber disc seat and protective cap.
7. Factory set and tested.
8. Listing: Valves listed and labeled by an NRTL acceptable to authorities having jurisdiction.
9. Valve shall reseal after relieving pressure.

B. Automatic Gas Valves: Comply with ANSI Z21.21.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [ASCO.](#)
 - b. [ASCO Power Technologies, LP; Division of Emerson.](#)
 - c. [ASCO Valve Canada; Division of Emerson Electric Canada Limited.](#)
 - d. [Dungs, Karl, Inc.](#)
 - e. [Eaton Corporation; Controls Div.](#)
 - f. [Eclipse Combustion, Inc.](#)
 - g. [Honeywell International Inc.](#)
 - h. [Johnson Controls.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Body: Brass or aluminum.
3. Seats and Disc: Nitrile rubber.
4. Springs and Valve Trim: Stainless steel.
5. Normally closed.
6. Visual position indicator.
7. **[Electrical] [Mechanical]** operator for actuation by appliance automatic shutoff device.

C. Electrically Operated Valves: Comply with UL 429.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [ASCO](#).
 - b. [ASCO Power Technologies, LP; Division of Emerson](#).
 - c. [Dungs, Karl, Inc.](#)
 - d. [Eclipse Combustion, Inc.](#)
 - e. [Goyen Valve Corp.; Tyco Environmental Systems](#).
 - f. [Magnatrol Valve Corporation](#).
 - g. [Parker Hannifin Corporation; Climate & Industrial Controls Group; Skinner Valve Div.](#)
 - h. [Watts Regulator Co.; Division of Watts Water Technologies, Inc.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Pilot operated.
3. Body: Brass or aluminum.
4. Seats and Disc: Nitrile rubber.
5. Springs and Valve Trim: Stainless steel.
6. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, replaceable.
7. NEMA ICS 6, Type 4, coil enclosure.
8. Normally closed.
9. Visual position indicator.

2.7 EARTHQUAKE VALVES

A. Earthquake Valves: Comply with ASCE 25.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Vanguard Valves, Inc.](#)
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
2. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
3. Maximum Operating Pressure: 5 psig (34.5 kPa).
4. Cast-aluminum body with nickel-plated chrome steel internal parts.
5. Nitrile-rubber valve washer.
6. Sight windows for visual indication of valve position.
7. Threaded-end connections complying with ASME B1.20.1.

B. Earthquake Valves: Comply with ASCE 25.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Pacific Seismic Products, Inc.](#)
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
2. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 3. Maximum Operating Pressure: [0.5 psig (3.45 kPa)] [7 psig (48 kPa)] [60 psig (414 kPa)].
 4. Cast-aluminum body with stainless-steel internal parts.
 5. Nitrile-rubber, reset-stem O-ring seal.
 6. Valve position, open or closed, indicator.
 7. Composition valve seat with clapper held by spring or magnet locking mechanism.
 8. Level indicator.
 9. End Connections: Threaded for valves NPS 2 (DN 50) and smaller; flanged for valves NPS 2-1/2 (DN 65) and larger.

2.8 PRESSURE REGULATORS

A. General Requirements:

1. Single stage and suitable for LPG.
2. Steel jacket and corrosion-resistant components.
3. Elevation compensator.
4. End Connections: Threaded for regulators NPS 2 (DN 50) and smaller; flanged for regulators NPS 2-1/2 (DN 65) and larger.

B. Service Pressure Regulators: Comply with ANSI Z21.80.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Actaris](#).
 - b. [American Meter Company](#).
 - c. [Fisher Control Valves and Regulators; Division of Emerson Process Management](#).
 - d. [Invensys](#).
 - e. [Richards Industries; Jordan Valve Div.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.

8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream and not exceed 150 percent of design discharge pressure at shutoff.
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: [100 psig (690 kPa)] <Insert pressure>.

C. Line Pressure Regulators: Comply with ANSI Z21.80.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Actaris.](#)
- b. [American Meter Company.](#)
- c. [Eclipse Combustion, Inc.](#)
- d. [Fisher Control Valves and Regulators; Division of Emerson Process Management.](#)
- e. [Invensys.](#)
- f. [Maxitrol Company.](#)
- g. [Richards Industries; Jordan Valve Div.](#)
- h. <Insert manufacturer's name>.
- i. or approved equal.

2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream and not exceed 150 percent of design discharge pressure at shutoff.
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: [2 psig (13.8 kPa)] [5 psig (34.5 kPa)] [10 psig (69 kPa)] <Insert pressure>.

D. Appliance Pressure Regulators: Comply with ANSI Z21.18.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Canadian Meter Company Inc.](#)
- b. [Eaton Corporation; Controls Div.](#)
- c. [Harper Wyman Co.](#)

- d. [Maxitrol Company](#).
 - e. [SCP, Inc.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
2. Body and Diaphragm Case: Die-cast aluminum.
 3. Springs: Zinc-plated steel; interchangeable.
 4. Diaphragm Plate: Zinc-plated steel.
 5. Seat Disc: Nitrile rubber.
 6. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
 7. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.
 8. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.
 9. Maximum Inlet Pressure: [1 psig (6.9 kPa)] [2 psig (13.8 kPa)] [5 psig (34.5 kPa-)] **<Insert pressure>**.

2.9 SERVICE METERS

In first paragraph below, retain first option for units having capacities of 500 cfm (3935 mL/s) and less and second for units having capacities more than 500 cfm (3935 mL/s).

- A. Diaphragm-Type Service Meters: Comply with [ANSI B109.1] [ANSI B109.2].
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Actaris](#).
 - b. [American Meter Company](#).
 - c. [Invensys](#).
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
 2. Case: Die-cast aluminum.
 3. Connections: Steel threads.
 4. Diaphragm: Synthetic fabric.
 5. Diaphragm Support Bearings: Self-lubricating.
 6. Compensation: Continuous temperature[**and pressure**].
 7. Meter Index: [**Cubic feet**] [**Liters**] [**Cubic feet and liters**].
 8. Meter Case and Index: Tamper resistant.
 9. Remote meter reader compatible.
 10. Maximum Inlet Pressure: [100 psig (690 kPa)] **<Insert pressure>**.
 11. Pressure Loss: Maximum [0.5-inch wg (124 Pa)] [2.0-inch wg (498 Pa)] **<Insert pressure differential>**.
 12. Accuracy: Maximum plus or minus [1.0] **<Insert number>** percent.
- B. Rotary-Type Service Meters: Comply with ANSI B109.3.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [American Meter Company](#).
 - b. [Invensys](#).
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Case: Extruded aluminum.
 3. Connection: Flange.
 4. Impellers: Polished aluminum.
 5. Rotor Bearings: Self-lubricating.
 6. Compensation: Continuous temperature[**and pressure**].
 7. Meter Index: [**Cubic feet**] [**Liters**] [**Cubic feet and liters**].
 8. Tamper resistant.
 9. Remote meter reader compatible.
 10. Maximum Inlet Pressure: [100 psig (690 kPa)] **<Insert pressure>**.
 11. Accuracy: Maximum plus or minus [2.0] **<Insert number>** percent.
- C. Turbine Meters: Comply with ASME MFC-4M.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [American Meter Company](#).
 - b. [Invensys](#).
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Housing: Cast iron or welded steel.
 3. Connection Threads or Flanges: Steel.
 4. Turbine: Aluminum or plastic.
 5. Turbine Bearings: Self-lubricating.
 6. Compensation: Continuous temperature[**and pressure**].
 7. Meter Index: [**Cubic feet**] [**Liters**] [**Cubic feet and liters**].
 8. Tamper resistant.
 9. Remote meter reader compatible.
 10. Maximum Inlet Pressure: [100 psig (690 kPa)] **<Insert pressure>**.
 11. Accuracy: Maximum plus or minus [2.0] **<Insert number>** percent.
- D. Service-Meter Bars:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Actaris](#).
 - b. [American Meter Company](#).
 - c. [Lyll, R. W. & Company, Inc.](#)
 - d. [McDonald, A. Y. Mfg. Co.](#)
 - e. [Mueller Co.; Gas Products Div.](#)
 - f. [Perfection Corporation; a subsidiary of American Meter Company.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.

2. Malleable- or cast-iron frame for supporting service meter.
3. Include offset swivel pipes, meter nuts with o-ring seal, and factory- or field-installed dielectric unions.
4. Omit meter offset swivel pipes if service-meter bar dimensions match service-meter connections.

E. Service-Meter Bypass Fittings:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Lyll, R. W. & Company, Inc.](#)
 - b. [Williamson, T. D., Inc.](#)
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Ferrous, tee, pipe fitting with capped side inlet for temporary LPG supply.
3. Integral ball-check bypass valve.

2.10 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Capitol Manufacturing Company.](#)
 - b. [Central Plastics Company.](#)
 - c. [Hart Industries International, Inc.](#)
 - d. [Jomar International Ltd.](#)
 - e. [Matco-Norca, Inc.](#)
 - f. [McDonald, A. Y. Mfg. Co.](#)
 - g. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
 - h. [Wilkins; a Zurn company.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Description:
 - a. Standard: ASSE 1079.
 - b. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F (82 deg C)**] [150 psig (1035 kPa)] [250 psig (1725 kPa)].
 - c. End Connections: Solder-joint copper alloy and threaded ferrous.

C. Dielectric Flanges:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Capitol Manufacturing Company.](#)
 - b. [Central Plastics Company.](#)
 - c. [Matco-Norca, Inc.](#)
 - d. [Watts Regulator Co.; a division of Watts Water Technologies, Inc.](#)
 - e. [Wilkins; a Zurn company.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
2. Description:
 - a. Standard: ASSE 1079.
 - b. Factory-fabricated, bolted, companion-flange assembly.
 - c. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F** (82 deg C)] [150 psig (1035 kPa)] [175 psig (1200 kPa)] [300 psig (2070 kPa)].
 - d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Advance Products & Systems, Inc.](#)
 - b. [Calpico, Inc.](#)
 - c. [Central Plastics Company.](#)
 - d. [Pipeline Seal and Insulator, Inc.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
2. Description:
 - a. Nonconducting materials for field assembly of companion flanges.
 - b. Pressure Rating: [150 psig (1035 kPa)] **<Insert pressure>.**
 - c. Gasket: Neoprene or phenolic.
 - d. Bolt Sleeves: Phenolic or polyethylene.
 - e. Washers: Phenolic with steel backing washers.

2.11 STORAGE CONTAINERS

- A. Description: Factory fabricated, complying with requirements in NFPA 58 and ASME Boiler and Pressure Vessel Code and bearing the ASME label. Tanks shall be rated for 250-psig (1723-kPa) minimum working pressure.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [American Welding & Tank.](#)

- b. [Hanson, Roy E. Jr. Mfg.](#)
 - c. [Trinity Industries, Inc.](#)
 - d. [United Industries Group, Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Liquid outlet and vapor inlet and outlet connections shall have shutoff valves with excess-flow safety shutoff valves and bypass and back-pressure check valves with smaller than **0.039-inch** (1-mm) drill-size hole to equalize pressure. Liquid-fill connection shall have backflow check valve.
 - a. Connections: Color-code and tag valves to indicate type.
 - 1) Liquid fill and outlet, red.
 - 2) Vapor inlet and outlet, yellow.
3. Level gage shall indicate current level of liquid in the container. Gages shall also indicate storage container contents; e.g., "Butane," "50-50 LPG Mix," or "Propane."
4. Pressure relief valves, type and number as required by NFPA 58, connected to vapor space and having discharge piping same size as relief-valve outlet and long enough to extend at least **84 inches** (2130 mm) directly overhead. Identify relief valves as follows:
 - a. Discharge pressure in **psig** (kPa).
 - b. Rate of discharge for standard air in **cfm** (L/s).
 - c. Manufacturer's name.
 - d. Catalog or model number.
5. Container pressure gage.
6. For outdoor installation, exposed metal surfaces mechanically cleaned, primed, and painted for resistance to corrosion.
7. Ladders for access to valves more than **72 inches** (1830 mm) aboveground.
8. Stainless-Steel Nameplate: Attach to aboveground storage container or to adjacent structure for underground storage container.
 - a. Name and address of supplier or trade name of container.
 - b. Water capacity in gallons and liters.
 - c. Design pressure in **psig** (kPa).
 - d. Statement, "This container shall not contain a product having a vapor pressure in excess of **<Insert maximum pressure in psig (kPa) at 100 deg F (37.8 deg C)>**."
 - e. Outside surface area in sq. ft. (sq. m).
 - f. Year of manufacture.
 - g. Shell thickness in inches (mm).
 - h. Overall length in feet (m).
 - i. OD in feet (m).
 - j. Manufacturer's serial number.
 - k. ASME Code label.

9. Felt support pads and two concrete or painted-steel saddles per storage container. Corrosion protection required at container-to-felt contact.
10. Tie straps for each saddle.
11. Straps and anchors for tie-down slab.
12. Asphalt-based coating for corrosion protection.
13. Container connections and valves protected in manway at top of storage container.
14. Manway equipped with ventilation louvers.

2.12 TRANSPORT TRUCK UNLOADING FACILITY

A. Description: Comply with requirements in NFPA 58.

1. Support structure consisting of a minimum **6-inch (150-mm)** steel channel or **6-by-4-inch (150-by-100-mm)** rectangular steel tubing, a minimum of **36 inches (914 mm)** above and below grade.
2. Liquid-fill and vapor-return, quick-disconnect fittings.
3. Liquid and vapor shutoff valves with hydrostatic relief valves mounted between the quick-disconnect fittings and shutoff valves.
4. Excess-flow safety shutoff valve in vapor-return line.
5. Backflow check valve in liquid-fill line.
6. Remote emergency shutoff valve station with underground cable to the vapor emergency shutoff valve.

2.13 PUMPS

A. Description: Factory-assembled and -tested, duplex, positive-displacement, belt drive.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Blackmer; a Dover Resources company.
 - b. Corken, Inc.; a unit of IDEX Corporation.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.

B. Pump Construction:

1. Casing: Ductile-iron casing with threaded gage tappings at inlet and outlet.
2. Internal Pressure Relief Valve: For pump protection in addition to the external pressure relief valves.
3. Impeller: Carbon or composite vane in cast-iron rotor.
4. Pump Shaft: Carbon steel.
5. Seal: Mechanical with Buna-N O-ring.
6. Pump Bearings: Ball bearings with grease fittings.
7. Baseplate: Bent carbon-steel channel or structural channel.

- C. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Motor Speeds: Single.
 3. Bearings: [**Permanently lubricated**] [**Grease-lubricated**] ball bearings.
 4. Class I, Division 1, Group D requirements per NFPA 70.
- D. Factory-Installed Piping and Specialties:
1. Pipe: ASTM A 53/A 53M, Type E or S, Grade B; Schedule 40 black steel with welded fittings and joints or Schedule 80 for threaded malleable-iron fittings and joints.
 2. Piping Specialties for Each Pump:
 - a. Bypass valve.
 - b. Isolation valves.
 - c. Unions for each connection.
 - d. Check valve.
 - e. Basket strainer.
 - f. Pressure gages for suction and discharge connections.
 - g. Hydrostatic relief valve.
 - h. Pilot-operated, pressure-regulating valve.
- E. Braided-jacket flexible connectors for suction and discharge connections.
- F. Pump and Piping Finish: For outdoor installation, exposed metal surfaces mechanically cleaned, primed, and painted for resistance to corrosion.
- G. Controls:
1. Explosion-proof controls enclosure.
 2. Magnetic starter package with automatic alternator.
 3. Pressure-activated start and stop.
 4. Lag pump starts if lead pump fails.
 5. Audible and visual indication of pump failure.
- H. Capacities and Characteristics[**for Each Pump**]:
1. Capacity: <Insert gph (mL/s)>.
 2. Minimum Working Pressure: [350 psig (2413 kPa)] <Insert pressure>.
 3. Continuous Fluid Temperature: [250 deg F (121 deg C)] <Insert temperature>.
 4. Total Dynamic Head: <Insert psig (kPa)>.
 5. Inlet and Outlet Size: <Insert NPS (DN)>.
 6. Return Size: <Insert NPS (DN)>.
 7. Pump Speed: <Insert rpm>.
 8. Motor Speed: <Insert rpm>.
 9. Motor Horsepower: <Insert value>.

10. Electrical Characteristics:

- a. Volts: **[240] [480] <Insert value>**.
- b. Phase: **[Single] [Three]**.
- c. Hertz: 60.
- d. Full-Load Amperes: **<Insert value>**.
- e. Minimum Circuit Ampacity: **<Insert value>**.
- f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.14 VAPORIZERS

- A. Description: Factory-fabricated, -assembled, and -tested vaporizer with heat exchanger sealed pressure-tight, built on a steel base; including insulated jacket, flue-gas vent, liquid fuel supply and vapor connections, and controls. Assembly shall be FMG labeled and comply with NFPA 58 and NFPA 70.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. Algas-SDI.
- b. Alternate Energy Systems, Inc.
- c. Ely Energy, Inc.
- d. Ransome Manufacturing: a division of Meeder Equipment Company.
- e. **<Insert manufacturer's name>**.
- f. or approved equal.

- B. Fabricate base and attachment to vaporizers with reinforcement strong enough to resist vaporizer movement during a seismic event when steel base is anchored to a concrete base.

C. Casing:

1. Mineral-fiber insulation, a minimum of **2 inches (50 mm)** thick, surrounding the heat exchanger.
2. Integral one-piece skid with forklift access holes.
3. Lifting lugs on top of vaporizer.
4. Flue rain cap and bird screen.
5. Sheet metal jacket with screw-fastened closures and **[baked-enamel] [powder-coat]** protective finish.
6. Mounting base to secure boiler to concrete base.
7. Control Compartment Enclosure: NEMA 250, Type 4, enclosure housing control panels for LPG-fired vaporizers. Explosion-proof control compartment construction required for electric vaporizers.

D. LPG Liquid and Vapor Circuit Specialties:

1. Y-type strainer with drain valve at inlet.
2. Vaporizer coil safety pressure relief valve.
3. Vaporizer coil blowdown valve.

4. Vapor outlet isolation valve.
 5. Pressure gages, a minimum of 2-1/2 inches (63 mm) in diameter, at liquid inlet and vapor discharge. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.
 6. Inlet safety solenoid valve to close with off-normal operation alarm.
 7. Backflow check valve in bypass around inlet safety solenoid valve.
 8. Liquid carryover or float-type safety shutoff switch.
 9. LPG Vapor Filter: Steel shell designed and manufactured per ASME Boiler and Pressure Vessel Code, Section VIII, Division 1; factory mounted on vaporizer discharge. Shells larger than 5 inches (125 mm) shall be ASME "U" stamped. Fill with stainless-steel, woven-mesh coalescing element to remove 99 percent of particles larger than 10 microns. 250-psig (1723-kPa) minimum working pressure. Finish with corrosion-resistant coating for an exterior application. Include factory-mounted and -piped, differential pressure gage with gage cocks in and out, and minimum NPS 3/4 (DN 20) full-port, ball-type drain valve.
- E. Direct-Type, Direct-Fired Heat Exchanger:
1. Description: ASME-rated and -stamped, LPG, vaporizer coil contained in an enclosure insulated with at least 2-inch- (50-mm-) thick, mineral-fiber board enclosure with a burner.
 2. Burner Tubes and Orifices: Stainless steel.
 - a. Gas Train: Control devices and burner control sequence shall be FMG labeled. Include shutoff valve, high- and low-pressure safety switches, pressure regulator, and main- and pilot-control valves.
 - b. Pilot: Standing pilot with 100 percent main-valve and pilot safety shutoff.
 3. Burner Operating Controls:
 - a. Controls shall maintain safe operating conditions. Mechanical burner safety controls limit operation of the burner.
 - b. High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design pressure.
 - c. Operating Vapor-Pressure Control: Factory piped and mounted to control burner.
- F. Indirect-Type, Direct-Fired Heat Exchanger:
1. Description: ASME-rated and -stamped, LPG, vaporizer vessel with a replaceable, immersion-type, electric heating element.
 2. Heating Element Operating Controls:
 - a. Operating controls shall maintain safe operating conditions. Safety controls limit operation of the element.[**Microprocessor-based control system integrates safety and operating controls.**]
 - b. Operating Vapor-Pressure Control: Factory wired and mounted to control heating element.
 - c. High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design pressure.

- d. Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
- e. Control Transformer: 115-V maximum control voltage.

G. Direct-Type, Water-Bath Heat Exchanger:

1. Description: Straight, steel fire tubes welded into steel headers with ASME-rated and -stamped, helical, LPG, vaporizer coil submerged in water bath. Include the following:
 - a. Water bath filled with water/glycol solution designed to prevent freezing at [minus 30 deg F (minus 34 deg C)] <Insert temperature>.
 - b. Water-bath, high- and low-level sight glasses.
 - c. Low-water cutoff to stop burner and annunciate alarm.
 - d. Water/glycol fill and vent fitting.
 - e. Minimum NPS 3/4 (DN 20) hose-end drain valves.
 - f. Operating high- and low-limit aquastat controllers.
 - g. Water-bath temperature gage; a minimum of 2-1/2 inches (63 mm) in diameter. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.
2. Burner Tubes and Orifices: Stainless steel.
 - a. Gas Train: Control devices and burner modulation control sequence shall be FMG labeled. Include shutoff valve, high- and low-pressure safety switches, pressure regulator, and main- and pilot-control valves.
 - b. Pilot: [Intermittent-electric-spark] [Hot-surface] pilot ignition with 100 percent main-valve and pilot safety shutoff with electronic supervision of burner flame.
3. Burner Operating Controls:
 - a. Operating controls shall maintain safe operating conditions. Safety controls limit operation of the burner. [**Microprocessor-based control system integrates safety and operating controls.**]
 - b. Operating Water-Bath Temperature Control: Factory wired and mounted to control burner.
 - c. High-Temperature and High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design temperature or vapor pressure.
 - d. Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
 - e. Control Transformer: 115-V maximum control voltage.

H. Indirect-Type, Water-Bath Heat Exchanger:

1. Description: Immersion-type, electric heating element with ASME-rated and -stamped, helical, LPG, vaporizer coil submerged in water bath. Include the following:

- a. Water bath filled with water/glycol solution designed to prevent freezing at [minus 30 deg F (minus 34 deg C)] <Insert temperature>.
 - b. Water-bath, high- and low-level sight glasses.
 - c. Low-water cutoff to stop electric heater and annunciate alarm.
 - d. Water/glycol fill and vent fitting.
 - e. Minimum NPS 3/4 (DN 20) hose-end drain valves.
 - f. Operating high- and low-limit aquastat controllers.
 - g. Water-bath temperature gage; a minimum of 2-1/2 inches (63 mm) in diameter. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.
2. Electric Heater Operating Controls:
- a. Controls shall maintain safe operating conditions. Safety controls limit operation of the electric element. [**Microprocessor-based control system integrates safety and operating controls.**]
 - b. Operating Water-Bath Temperature Control: Factory wired and mounted to control burner.
 - c. High-Temperature and High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design temperature or pressure.
 - d. Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
 - e. Control Transformer: 115-V maximum control voltage.
- I. Building Management System Interface: Factory-installed hardware and software to enable building management system to monitor and control set points and display vaporizer status and alarms.
- J. Capacities and Characteristics:
1. Heating Fuel: [Propane] [Butane] [Electric].
 2. Vaporization Heat Exchanger:
 - a. Minimum Working-Pressure Rating: [250 psig (1723 kPa)] <Insert value>.
 - b. Test Pressure: [375 psig (2586 kPa)] <Insert value>.
 3. LPG Vaporization Rate: <Insert gph (mL/s)>.
 4. Entering-LPG Temperature: [Minus 30 deg F (Minus 34 deg C)] <Insert temperature>.
 5. Leaving-LPG Temperature: [80 deg F (26.7 deg C)] <Insert temperature>.
 6. Discharge-LPG Pressure: [90 psig (621 kPa)] <Insert value>.
 7. Burner Gas Input: <Insert Btu/h (kW)>.
 8. Electric Burner Input: <Insert kilowatts>.
 9. Water-Bath Shell Operating Pressure: [Atmospheric] <Insert psig (kPa)>.
 10. Water-Bath Operating Temperature: [160 deg F (71 deg C)] <Insert temperature>.
 11. Electrical Characteristics:
 - a. Volts: [120] [240] [480] <Insert value>.
 - b. Phase: [Single] [Three].

- c. Hertz: 60.
- d. Minimum Circuit Ampacity: **<Insert value>**.
- e. Maximum Overcurrent Protection: **<Insert amperage>**.

2.15 AIR MIXERS

- A. Description: Factory-fabricated, -assembled, -calibrated, and -tested[, **blower-assisted**] air mixer with surge tank, built on a steel base; including vapor supply and discharge connections, and controls. Assembly shall be FMG labeled and comply with NFPA 58 and NFPA 70.
 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. Algas-SDI.
 - b. Alternate Energy Systems, Inc.
 - c. Ely Energy, Inc.
 - d. Ransome Manufacturing; a division of Meeder Equipment Company.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
- B. Fabricate base and attachment to mixers with reinforcement strong enough to resist air mixer movement during a seismic event when steel base is anchored to a concrete base.
- C. Mounting Skid, Panels, and Surge Tank:
 1. Integral one-piece skid with forklift access holes.
 2. Lifting lugs on top of air mixer.
 3. **[Baked-enamel] [Powder-coat]** protective finish.
 4. Mounting base to secure boiler to concrete base.
 5. Control Compartment Enclosure: NEMA 250, Type 4, enclosure housing control panels.
 6. ASME-stamped surge tank with venturi, isolation valves, excess-flow safeties, and safety relief valves.
- D. Blower: Positive-displacement, rotary-lobe type.
 1. Motor: Single speed, with **[permanently lubricated] [grease-lubricated]** ball bearings. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- E. LPG Circuit Specialties:
 1. Venturi solenoid valves.
 2. Venturi nozzles, minimum of 3, for minimum of 10:1 turndown capacity.
 3. Venturi silencers.
 4. Mist filter and strainer with pressure differential gage, and blowdown ball valve.
 5. Inlet and outlet isolation valves.

6. Pressure gages, a minimum of **2-1/2 inches (63 mm)** in diameter, at inlet and discharge. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.

F. Air-Mixer Controls:

1. Controls shall maintain safe operating conditions. The following safety controls limit the operation of the air mixer. All safety controls are manual reset.
 - a. Low-inlet-vapor pressure.
 - b. High- or low-discharge pressure.
2. Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
3. Control Transformer: 115-V maximum control voltage.

G. Mount on common skid with vaporizer.

H. Capacities and Characteristics:

1. Heating Fuel: [**Propane**] [**Butane**].
2. Air Mixer:
 - a. Outlet Pressure: [**20 psig (138 kPa)**] **<Insert value>**.
 - b. Test Pressure: [**30 psig (207 kPa)**] **<Insert value>**.
3. Entering LPG:
 - a. Temperature: [**90 deg F (32 deg C)**] **<Insert temperature>**.
 - b. Inlet Pressure: [**20 psig (138 kPa)**] **<Insert value>**.
4. Mixed Gas:
 - a. Pressure: [**20 psig (138 kPa)**] **<Insert value>**.
 - b. Higher Heating Value: [**1430 Btu/cu. ft. (53 339 kJ/cu. m)**] **<Insert value>**.
 - c. Specific Gravity: [**1.3**] **<Insert value>**.
 - d. Flow Rate: **<Insert gph (mL/s)>**.
5. Electrical Characteristics:
 - a. Volts: [**120**] [**240**] [**480**] **<Insert value>**.
 - b. Phase: [**Single**] [**Three**].
 - c. Hertz: 60.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection: **<Insert amperage>**.

2.16 LABELING AND IDENTIFYING

- A. Detectable Warning Tape: Acid- and alkali-resistant PE film warning tape manufactured for marking and identifying underground utilities, a minimum of **6 inches**

(150 mm) wide and 4 mils (0.1 mm) thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches (750 mm) deep; colored yellow.

- B. Reference Section 230553 "Identification of HVAC Piping and Equipment".

2.17 CONCRETE BASES

- A. Description: Precast, reinforced concrete base, made of 3000-psi- minimum, 28-day compressive strength concrete, and measuring 4 inches thick and 4 inches larger in each dimension than supported item, unless otherwise indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for LPG piping system to verify actual locations of piping connections before equipment installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.

3.3 PREPARATION

- A. Close equipment shutoff valves before turning off LPG to premises or piping section.
- B. Perform leakage test as specified in Article 3 to determine that all equipment is turned off in affected piping section.
 - 1. Comply with ANSI Z223.1, "Prevention of Accidental Ignition" Paragraph.
- C. Inspect LPG piping according to NFPA 58 and [NFPA 54] [the International Fuel Gas Code] to determine that LPG utilization devices are turned off in piping section affected.
- D. Comply with NFPA 58 and [NFPA 54] [the International Fuel Gas Code] requirements for prevention of accidental ignition.

3.4 OUTDOOR PIPING INSTALLATION

- A. Comply with NFPA 58 and **[NFPA 54] [the International Fuel Gas Code]** requirements for installation and purging of LPG piping.
- B. Install underground, LPG piping buried at least **[36 inches (900 mm)] <Insert dimension>** below finished grade. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.
 - 1. If LPG piping is installed less than **36 inches (914 mm)** below finished grade, install it in containment conduit.
- C. Install underground, PE, LPG piping according to ASTM D 2774.
- D. Steel Piping with Protective Coating:
 - 1. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.
 - 2. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
 - 3. Replace pipe having damaged PE coating with new pipe.
- E. Copper Tubing with Protective Coating:
 - 1. Apply joint cover kits over tubing to cover, seal, and protect joints.
 - 2. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
- F. Install fittings for changes in direction and branch connections.
- G. Joints for connection to inlets and outlets on vaporizers, air mixers, regulators, and valves may be flanged or threaded to match the equipment.
- H. Install pressure gage **[downstream] [upstream and downstream]** from each service regulator. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."

3.5 SERVICE ENTRANCE PIPING

- A. Extend LPG piping and connect to fuel gas distribution for service entrance to building.
 - 1. Exterior LPG distribution system piping, service pressure regulator and service meter will be provided by gas utility.
- B. Install dielectric fitting downstream from and adjacent to each service meter unless meter is supported from service-meter bar with integral dielectric fitting. Install shutoff valve downstream from and adjacent to dielectric fitting. Refer to Section 230500 "Common Work Results for HVAC" for dielectric fittings.

3.6 INDOOR PIPING INSTALLATION

- A. Comply with **[NFPA 54] [the International Fuel Gas Code]** for installation and purging of LPG piping.
- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- C. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
- D. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- E. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- F. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- G. Locate valves for easy access.
- H. Install LPG piping at uniform grade of 2 percent down toward drip and sediment traps.
- I. Install piping free of sags and bends.
- J. Install fittings for changes in direction and branch connections.
- K. Verify final equipment locations for roughing-in.
- L. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.
- M. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where readily accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
 - 1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than **3 inches (75 mm)** long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.
- N. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.
- O. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.

- P. Concealed Location Installations: Except as specified below, install concealed LPG piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints as described in Part 2. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.
1. Above Accessible Ceilings: LPG piping, fittings, valves, and regulators may be installed in accessible spaces without containment conduit, subject to approval of authorities having jurisdiction, whether or not such spaces are used as plenums. Do not locate valves above ceilings.
 2. In Floors: Install LPG piping with welded or brazed joints and protective coating in cast-in-place concrete floors, subject to approval of authorities having jurisdiction. Cover piping to be cast in concrete slabs with minimum of 1-1/2 inches (38 mm) of concrete. Piping may not be in physical contact with other metallic structures such as reinforcing rods or electrically neutral conductors. Do not embed piping in concrete slabs containing quickset additives or cinder aggregate.
 3. In Floor Channels: Install LPG piping in floor channels, subject to approval of authorities having jurisdiction. Channels must have cover and be open to space above cover for ventilation.
 4. In Walls or Partitions: Do not install concealed piping in solid partitions. Protect tubing installed inside partitions or hollow walls from physical damage using steel striker barriers at rigid supports.
 - a. Exception: Tubing passing through partitions or walls does not require striker barriers.
 5. Prohibited Locations:
 - a. Do not install LPG piping in or through circulating air ducts, clothes, or trash chutes, chimneys, or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
 - b. Do not install LPG piping in solid walls or partitions.
- Q. Install fuel gas piping at uniform grade of 0.1% slope upward toward risers.
- R. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
- S. Connect branch piping from top or side of horizontal piping.
- T. Install unions in pipes NPS 2 (DN 50) and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.
- U. Install corrugated, stainless-steel tubing system according to manufacturer's written instructions. Include striker plates to protect tubing from puncture where tubing is restrained and cannot move.
- V. Do not use LPG piping as grounding electrode.

- W. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.
- X. Install pressure gage [**downstream**] [**upstream and downstream**] from each line regulator. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."
- Y. Install flanges on valves, specialties, and equipment having NPS 2-1/2 and larger connections.
- Z. Install vent piping for gas pressure regulators and gas trains, extend outside building, and vent to atmosphere. Terminate vents with turned-down, reducing-elbow fittings with corrosion-resistant insect screens in large end.
- AA. Install containment conduits for gas piping below slabs, within building, in gastight conduits extending minimum of 4 inches outside building, and vented to atmosphere. Terminate vents with turned-down, reducing-elbow fittings with corrosion-resistant insect screens in large end. Prepare and paint outside of conduits with coal-tar, epoxy-polyamide paint according to SSPC-Paint 16.
- BB. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- CC. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- DD. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.7 SERVICE-METER ASSEMBLY INSTALLATION

- A. Install service-meter assemblies aboveground[, **on concrete bases**].
- B. Install metal shutoff valves upstream from service regulators. Shutoff valves are not required at second regulators if two regulators are installed in series.
- C. Install strainer on inlet of service-pressure regulator and meter set.
- D. Install service regulators mounted outside with vent outlet horizontal or facing down. Install screen in vent outlet if not integral with service regulator.
- E. Install pressure gauge [**downstream**] [**upstream and downstream**] from each service pressure regulator.
- F. Install metal shutoff valves upstream from service meters. Install dielectric fittings downstream from service meters.

- G. Install service meters downstream from pressure regulators.
 - 1. Service meters with connections NPS 1 and smaller on meter bars.
 - 2. Service meters with connections larger than NPS 1 supported from piping or set on concrete bases.

- H. Install metal bollards to protect meter assemblies. Comply with requirements in Section 055000 "Metal Fabrications" for pipe bollards.

3.8 VALVE INSTALLATION

- A. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing, aluminum, or copper connector.
- B. Install underground valves with valve boxes.
- C. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.
- D. Install earthquake valves aboveground outside buildings according to listing.
- E. Install anode for metallic valves in underground PE piping.

3.9 PIPING JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded Joints:
 - 1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
 - 2. Cut threads full and clean using sharp dies.
 - 3. Ream threaded pipe ends to remove burrs and restore full ID of pipe.
 - 4. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
 - 5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. Welded Joints:
 - 1. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
 - 2. Bevel plain ends of steel pipe.
 - 3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.

- E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Ch. 22, "Pipe and Tube."
 - 1. Brazed Joints: Make with brazing alloy with melting point greater than 1000oF.
 - 2. Brazing alloys containing phosphorus are prohibited.
- F. Flanged Joints: Install gasket material, size, type, and thickness appropriate for LPG service. Install gasket concentrically positioned.
- G. Flared Joints: Cut tubing with roll cutting tool. Flare tube end with tool to result in flare dimensions complying with SAE J513. Tighten finger tight, then use wrench. Do not overtighten.
- H. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
 - 1. Plain-End Pipe and Fittings: Use butt fusion.
 - 2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.10 HANGER AND SUPPORT INSTALLATION

- A. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- C. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
 - 1. NPS 1 (DN 25) and Smaller: Maximum span, 96 inches (2438 mm); minimum rod size, 3/8 inch (10 mm).
 - 2. NPS 1-1/4 (DN 32): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
 - 3. NPS 1-1/2 and NPS 2 (DN 40 and DN 50): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
 - 4. NPS 2-1/2 to NPS 3-1/2 (DN 65 to DN 90): Maximum span, 10 feet (3 m); minimum rod size, 1/2 inch (13 mm).
 - 5. NPS 4 (DN 100) and Larger: Maximum span, 10 feet (3 m); minimum rod size, 5/8 inch (16 mm).
- D. Install hangers for horizontal, drawn-temper copper tubing with the following maximum spacing and minimum rod sizes:
 - 1. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
 - 2. NPS 1/2 and NPS 5/8 (DN 15 and DN 18): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).

3. **NPS 3/4 and NPS 7/8** (DN 20 and DN 22): Maximum span, **84 inches** (2134 mm); minimum rod size, **3/8 inch** (10 mm).
 4. **NPS 1** (DN 25): Maximum span, **96 inches** (2440 mm); minimum rod size, **3/8 inch** (10 mm).
- E. Install hangers for horizontal, corrugated stainless-steel tubing with the following maximum spacing and minimum rod sizes:
1. **NPS 3/8** (DN 10): Maximum span, **48 inches** (1220 mm); minimum rod size, **3/8 inch** (10 mm).
 2. **NPS 1/2** (DN 15): Maximum span, **72 inches** (1830 mm); minimum rod size, **3/8 inch** (10 mm).
 3. **NPS 3/4** (DN 20) and Larger: Maximum span, **96 inches** (2440 mm); minimum rod, **3/8 inch** (10 mm).

3.11 CONNECTIONS

- A. Connect to utility's gas main according to utility's procedures and requirements.
- B. Drawings indicate general arrangement of LPG piping, fittings, and specialties.
- C. Install piping adjacent to appliances to allow service and maintenance.
- D. Install LPG piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.
- E. Install piping adjacent to appliances to allow service and maintenance of appliances.
- F. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within **72 inches** (1830 mm) of each gas-fired appliances and equipment. Install union between valve and appliances or equipment.
- G. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.
- H. Ground equipment.
 1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.
 2. Do not use gas pipe as grounding electrode.

3.12 TRANSPORT TRUCK UNLOADING FACILITY

- A. Install transport truck unloading in a cast-in-place concrete base, **48 inches** (1220 mm) square by **36 inches** (914 mm) deep. Set top of concrete base at least **6 inches** (150 mm) above finished grade.

- B. Install remote emergency shutoff station with cable release in an accessible location, a minimum of **25 feet (7.6 m)** and a maximum of **100 feet (30 m)** away from transport truck unloading.
- C. Install at least two **6-inch- (150-mm-)** diameter metal bollards set in and filled with concrete on both sides of transport truck unloading. Bollard length shall be at least **48 inches (1220 mm)** above and below grade, with concrete encasement a minimum of **12 inches (305 mm)** in diameter.

3.13 STORAGE CONTAINER INSTALLATION

- A. Fill storage container to at least 80 percent capacity with [**butane**] [**propane**].
- B. Install piping connections with swing joints or flexible connectors to allow for storage container settlement and for thermal expansion and contraction.
- C. Ground containers according to NFPA 780. Grounding is specified in Section 264113 "Lightning Protection for Structures."
- D. Set storage containers in felt pads on concrete or steel saddles. Install corrosion protection at container-to-felt contact.
- E. Install tie-downs over storage containers on saddles with proper tension.
- F. Set concrete saddles on dowels set in concrete base. Anchor steel saddles to concrete base.
- G. Set storage container on concrete ballast base large enough to offset buoyancy of empty storage container immersed in water.
- H. Install tie-down straps over container anchored in ballast base and repair damaged coating.
- I. Backfill with a minimum coverage for underground or mounded storage containers according to NFPA 58.
- J. Backfill with pea gravel as required in Section 312000 "Earth Moving."
- K. Install cathodic protection for storage container. Cathodic protection is specified in Section 264200 "Cathodic Protection."

3.14 PUMP INSTALLATION

- A. Install pumps with access space for periodic maintenance including removal of motors, impellers, and accessories.
- B. Set pumps on and anchored to concrete base.
- C. Install suction piping with minimum fittings and change of direction.

- D. Connect liquid suction to container, supply to vaporizer, and return line to container.

3.15 VAPORIZER INSTALLATION

- A. Install vaporizer with access space for periodic maintenance.
- B. Set vaporizers on and anchor to concrete base.
- C. Connect liquid line from pump set, and vapor supply to distribution piping.
- D. Install backup connection from vapor space of container to inlet of pressure-regulating valve at vaporizer discharge to bypass the vaporizer during maintenance. Install shutoff valves to change source from vaporizer to storage container.

3.16 AIR MIXER WITH VAPORIZER INSTALLATION

- A. Install air mixer with vaporizer with access space for periodic maintenance.
- B. Set air mixer with vaporizer on and anchor to concrete base.
- C. Connect liquid line from pump set, and mixed gas supply to distribution piping.
- D. Install backup connection from vapor space of container to inlet of pressure-regulating valve at vaporizer discharge to bypass vaporizer during maintenance. Install shutoff valves to change source from vaporizer to storage container.
- E. Replace filters at Substantial Completion if air mixer was operated during construction.

3.17 LABELING AND IDENTIFYING

- A. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for piping and valve identification.
- B. Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplate or sign on or near each service meter, pressure regulator, and specialty valve.
 - 1. Text: In addition to name of identified unit, distinguish between multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations.
- C. Install detectable warning tape directly above gas piping, **12 inches** (305 mm) below finished grade, except **6 inches** (150 mm) below subgrade under pavements and slabs.

3.18 PAINTING

- A. Comply with requirements in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting" for painting interior and exterior LPG piping.
- B. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components with factory-applied paint or protective coating.
1. Alkyd System: MPI EXT 5.1D.
 - a. Prime Coat: Alkyd anticorrosive metal primer.
 - b. Intermediate Coat: Exterior alkyd enamel matching topcoat.
 - c. Topcoat: Exterior alkyd enamel [(flat)] [(semigloss)] [(gloss)].
 - d. Color: [Gray] <Insert color>.
- C. Paint exposed, interior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components with factory-applied paint or protective coating.
1. Latex Over Alkyd Primer System: MPI INT 5.1Q.
 - a. Prime Coat: [Alkyd anticorrosive] [Quick-drying alkyd] metal primer.
 - b. Intermediate Coat: Interior latex matching topcoat.
 - c. Topcoat: Interior latex [(flat)] [(low sheen)] [(eggshell)] [(satin)] [(semigloss)] [(gloss)].
 - d. Color: [Gray] <Insert color>.
 2. Alkyd System: MPI INT 5.1E.
 - a. Prime Coat: [Alkyd anticorrosive] [Quick-drying alkyd] metal primer.
 - b. Intermediate Coat: Interior alkyd matching topcoat.
 - c. Topcoat: Interior alkyd [(flat)] [(eggshell)] [(semigloss)] [(gloss)].
 - d. Color: [Gray] <Insert color>.
- D. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

3.19 CONCRETE BASES

- A. Concrete Bases: Anchor equipment to concrete base[**according to seismic codes at Project**].
1. Locate bases at service meters and service regulators.
 2. Excavate earth and make level beds to support bases. Set bases level with top surface projecting approximately 3 inches (75 mm) above grade.
 3. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.

4. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on [18-inch (451-mm)] <Insert dimension> centers around the full perimeter of the base.
5. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
6. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
7. Install anchor bolts to elevations required for proper attachment to supported equipment.
8. Use [3000-psig (20.7-MPa)] <Insert value>, 28-day, compressive-strength concrete and reinforcement as specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

3.20 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
 1. Test, inspect, and purge LPG according to NFPA 58 and [NFPA 54] [the International Fuel Gas Code] and requirements of authorities having jurisdiction, and as per Testing Piping Systems article below.
- C. LPG piping will be considered defective if it does not pass tests and inspections.
- D. Repair leaks and defects with new materials and retest system until satisfactory results are obtained.
- E. Report test results promptly and in writing to DEN Project Manager and authorities having jurisdiction.
- F. Verify capacities and pressure ratings of service meters, pressure regulators, valves, and specialties.
- G. Verify correct pressure settings for pressure regulators.
- H. Verify that specified piping tests are complete.
- I. Prepare test and inspection reports.

3.21 TESTING PIPING SYSTEMS

- A. Perform all tests in the presence of the authorized City representative when required. Contractor shall provide inspector 48-hour prior notice of test; also notify DEN Project Manager.
- B. No piping or joint shall be left untested. All leaks shall be repaired and the piping system shall be re-tested until satisfactory results are obtained.

C. Pneumatic Leak Test:

1. General: Pneumatic leak tests shall only be used on natural gas piping, piping with restricted access, piping exposed to freezing conditions, or where water leakage would damage critical DEN operational equipment. Contractor shall submit a written request for test in accordance with the Submittals Article of this specification section.
2. Test all natural gas piping prior to initial operation, to assure tightness. The test medium shall be air, or inert gas. Pipe joints shall be left exposed for examination during the test. A pressure test shall be maintained for a period of twelve (12) hours and precautions shall be taken to avoid excessive pressure. The test pressure to be used shall be no less than 1-1/2 times the proposed maximum working pressure, but not less than 10 psig, irrespective of design pressure. There shall be no loss of pressure during test. The piping system shall be visually examined for signs of leakage or other defects. All exposed joints shall be checked by means of a soap bubble test or other foaming agent test. In the event repairs or additions are made following the pressure test, the affected piping shall be retested. After test is completed and prior to putting piping systems into operation, completely purge system. Purging medium may be same as piping medium as long as piping medium can be introduced at a moderately rapid and continuous rate
3. Pneumatic Test Procedure:
 - a. Contractor shall submit safety plan for pneumatic testing prior to test.
 - b. General: Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations:
 - 1) The piping system does not contain cast iron pipe or plastic pipe subject to brittle failure.
 - 2) The system does not contain soldered or solvent cement joints over NPS 2.
 - 3) The test pressure does not exceed 150 psig.
 - c. Test Medium: The gas shall be nonflammable and nontoxic.
 - d. Preliminary Test: Prior to application of full pneumatic test pressure, a preliminary test of not more than 10 psig shall be applied to reveal possible major leaks. Pneumatic Test Pressure:
 - 1) Except as limited in 2) below, the test pressure shall not exceed 1.25 times the design pressure. Pressure shall be applied in several stages, allowing time for the system to reach equilibrium at each stage.
 - 2) The test pressure shall not exceed the maximum allowable pneumatic test pressure for any vessel, pump, valve, or other component in the system under test.
 - e. Examination for Leakage: After the preliminary test, pressure shall be raised in stages of not more than 25% up to full pneumatic test pressure, allowing time for equalization of strains and detection of major leaks at each

stage. Following the application of test pressure for at least 10 minutes, the pressure may be reduced to design pressure and examination shall be made for leakage of the piping. Leaks may be detected by soap bubble, halogen gas, scented gas, test gage monitoring, ultrasonic, or other suitable means. If leaks are found, pressure shall be vented, appropriate repair or replacement shall be made, and the pneumatic test repeated until no leakage is found.

- f. Contractor shall measure the surface temperature of the pipe for the duration of testing. The pneumatic test will be deemed successful only when the test pressure can be held at a constant pipe surface temperature for a period of no less than 10 continuous minutes. Record of the pipe temperatures and pressures during the duration of the test shall be submitted to the DEN Project Manager following completion of the test.

- D. Testing shall be witnessed by DEN Mechanical Inspector and DEN Project Manager or Designated Representative.
- E. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.
- F. Prepare written report of testing procedures and result. Submit in accordance with Section 23400 "Basic HVAC Requirements".

3.22 ADJUSTING

- A. Adjust controls and safety devices. Replace damaged and malfunctioning controls and safety devices.

3.23 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain LPG equipment.

3.24 OUTDOOR PIPING SCHEDULE

- A. Underground LPG liquid pipingshall be[**one of**] the following:
1. Schedule 40 steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
 2. **[Annealed]** **[Drawn]**-temper copper tube, **[Type K (Type A)]** **[Type L (Type B)]** with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
- B. Aboveground LPG liquid pipingshall be[**one of**] the following:

1. [NPS 2 (DN 50)] <Insert pipe size> and Smaller: [Schedule 40] [Schedule 80] steel pipe, malleable-iron threaded fittings and threaded [and seal welded] joints. Coat pipe and fittings with protective coating for steel piping.
 2. [NPS 2-1/2 (DN 65)] <Insert pipe size> and Larger: Schedule 40, steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
 3. [Annealed] [Drawn]-temper copper tube, Type L (Type B,) with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
- C. Underground LPG vapor piping shall be [one of] the following:
1. Schedule 40, steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
 2. [Annealed] [Drawn]-temper copper tube, Type L (Type B) with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
- D. Aboveground LPG vapor piping shall be [one of] the following:
1. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
 2. Schedule 40, steel pipe with wrought-steel fittings and welded joints, or mechanical couplings.
 3. [Annealed] [Drawn]-temper copper tube, Type L (Type B,) with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
- E. Branch Piping in Cast-in-Place Concrete to Single Appliance: Annealed-temper copper, with wrought-copper fittings and [brazed] [flared] joints. Install piping embedded in concrete with no joints in concrete.
- F. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- 3.25 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES LESS THAN 0.5 PSIG (3.45 kPa)
- A. Aboveground, branch piping [NPS 1 (DN 25)] <Insert pipe size> and smaller shall be [one of] the following:
1. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
 2. Annealed-temper, tin-lined copper tube with flared joints and fittings.
 3. Annealed-temper copper tube with wrought-copper fittings and [brazed] [flared] joints.
 4. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
- B. Aboveground, distribution piping shall be [one of] the following:

1. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
 2. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
 3. Drawn-temper copper tube, **Type L (Type B)** with wrought-copper fittings and brazed joints.
- C. Underground, below building, piping shall be **one of** the following:
1. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
 2. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
- D. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- E. Containment Conduit Vent Piping: Schedule 40, steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.
- 3.26 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES MORE THAN **0.5 PSIG** (3.45 kPa) AND LESS THAN **5 PSIG** (34.5 kPa)
- A. Aboveground, branch piping [**NPS 1 (DN 25)**] **<Insert pipe size>** and smaller shall be **one of** the following:
1. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
 2. Annealed-temper, tin-lined copper tube with flared joints and fittings.
 3. Annealed-temper copper tube, **Type L (Type B)** with wrought-copper fittings and **[brazed] [flared]** joints.
 4. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
- B. Aboveground, distribution piping shall be **one of** the following:
1. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
 2. Schedule 40, steel pipe with steel welding fittings and welded joints.
 3. Drawn-temper copper tube, [**Type L (Type B)**] [**Type G**] with wrought-copper fittings and brazed joints.
- C. Underground, below building, piping shall be **one of** the following:
1. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
 2. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
- D. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat underground pipe and fittings with protective coating for steel piping.
- E. Containment Conduit Vent Piping: Schedule 40, steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

3.27 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES MORE THAN 5 PSIG
(34.5 kPa)

- A. Aboveground Piping: Maximum operating pressure more than [5 psig (34.5 kPa)] <Insert pressure>.
- B. Aboveground, Branch Piping: Schedule 40, steel pipe with steel welding fittings and welded joints.
- C. Aboveground, distribution piping shall be [one of] the following:
 - 1. Schedule 40, steel pipe with steel welding fittings and welded joints.
 - 2. Drawn-temper copper tube, [Type L (Type B)] [Type G] with wrought-copper fittings and brazed joints.
- D. Underground, below building, piping shall be [one of] the following:
 - 1. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
 - 2. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
- E. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
- F. Containment Conduit Vent Piping: Schedule 40, steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

3.28 UNDERGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

- A. Connections to Existing Gas Piping: Use valve and fitting assemblies made for tapping utility's gas mains and listed by an NRTL.
- B. Underground Vapor Piping:
 - 1. PE valves.
 - 2. NPS 2 (DN 50) and Smaller: Bronze, [lubricated] [nonlubricated] plug valves.
 - 3. NPS 2-1/2 (DN 65) and Larger: Cast-iron, [lubricated] [nonlubricated] plug valves.

3.29 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

- A. Aboveground Liquid Piping:
 - 1. Two-piece, [full] [regular]-port, bronze ball valves with bronze trim.
- B. Valves for pipe NPS 2 (DN 50) and smaller at service meter shall be [one of] the following:
 - 1. One-piece, bronze ball valve with bronze trim.

2. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
 3. Bronze plug valve.
- C. Valves for pipe **NPS 2-1/2 (DN 65)** and larger at service meter shall be **[one of]** the following:
1. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
 2. Bronze plug valve.
 3. Cast-iron, nonlubricated plug valve.
- D. Distribution piping valves for pipe **NPS 2 (DN 50)** and smaller shall be **[one of]** the following:
1. One-piece, bronze ball valve with bronze trim.
 2. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
 3. Bronze plug valve.
- E. Distribution piping valves for pipe **NPS 2-1/2 (DN 65)** and larger shall be **[one of]** the following:
1. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
 2. Bronze plug valve.
 3. Cast-iron, **[nonlubricated]** **[lubricated]** plug valve.
- F. Valves in branch piping for single appliance shall be **[one of]** the following:
1. One-piece, bronze ball valve with bronze trim.
 2. Two-piece, **[full]** **[regular]**-port, bronze ball valves with bronze trim.
 3. Bronze plug valve.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 231126

SECTION 231213 - FACILITY FUEL-OIL PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Submersible fuel-oil storage tank pumps.
 - 2. Simplex fuel-oil pumps.
 - 3. Duplex fuel-oil pumps.
 - 4. Triplex fuel-oil pumps.
 - 5. Fuel-oil maintenance systems.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- B. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
- C. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, and dimensions of individual components and profiles.
 - 2. Include, where applicable, certified performance curves and rated capacities, operating characteristics, final impeller dimensions, electrical characteristics, and furnished specialties and accessories for each type of product indicated. Indicate pump's operating point on curves.

3. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For fuel-oil pumps.

1. Show pump layout and connections.
2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
3. Include construction details and dimensions of individual components for fuel-oil pumps.
4. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
5. Wiring Diagrams: Power, signal, and control wiring.
6. Scale: [1/4 inch per foot (1:50)] <Insert scale>.

C. Delegated-Design Submittal: For fuel-oil pumps.

1. Detail fabrication and assembly of anchors and seismic restraints.
2. Design Calculations: Calculate requirements for selecting seismic restraints.
3. Detail fabrication and assembly of hangers, supports, and attachments of the same to building structure.

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For qualified professional engineer.

B. Seismic Qualification Certificates: For fuel-oil pumps from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

C. Field quality-control reports.

D. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For fuel-oil pumps and fuel-oil maintenance systems to include in emergency, operation, and maintenance manuals.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- 1. Drive Belt: [**One**] <Insert number> for each belt-driven pump.

1.8 QUALITY ASSURANCE

- A. Source Limitations: Obtain fuel-oil pumps through one source from a single manufacturer.
- B. Product Options: Drawings indicate size, profiles, and dimensional requirements of fuel-oil pumps and are based on the specific system indicated. Refer to Division 01.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.
- B. Store pumps in dry location.
- C. Retain protective covers for flanges and protective coatings during storage.
- D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.
- E. Comply with pump manufacturer's written rigging instructions.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 Basic HVAC Requirements.

1.11 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- 1. Minimum one or 10% of quantity pumps delivered.

2. Mechanical Seals: [**One (1)**] <Insert number> mechanical seal(s) for each pump.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Statically and dynamically balance rotating parts.
- B. Construction to permit complete servicing without breaking piping or motor connections.
- C. Pump connections to be flanged.

2.2 PERFORMANCE REQUIREMENTS

- A. Maximum Operating-Pressure Ratings: **3-psig (21-kPa)** fuel-oil supply pressure at oil-fired appliances.
- B. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design restraint and anchors for fuel-oil pumps, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- C. Seismic Performance: Factory-installed support attachments for pumps shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <Insert requirement>.
 1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.

2.3 SUBMERSIBLE FUEL-OIL STORAGE TANK PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. Franklin Fueling Systems.
2. Red Jacket Pumps; a division of Veeder-Root.
3. **<Insert manufacturer's name>.**
4. or approved equal.

B. **Description:** Comply with UL 79, UL 87, and UL 343.

1. Impeller: Turbine.
2. Housing and Volute: Cast iron.
3. Bearings: Bronze, self-lubricating.
4. Seals: Mechanical.
5. Shaft: Polished steel.
6. Suspension Piping: Telescoping to accommodate tank diameter and depth of bury.
7. Base: Steel.
8. Pressure Relief: Built in.
9. Discharge Check Valve: Built in.
10. Drive: Direct, close coupled.

C. **Controls:** Pump controller panel complying with UL 353 and UL 508C and with interlock and terminals for connections to fuel-oil-burning equipment.

1. Maintain minimum manifold pressure with outdoor-air temperature less than [60 deg F (16 deg C)] **<Insert temperature>.**
2. Seven-day schedule.
3. Stage multiple pumps to maintain pressure at a common supply manifold.
4. Alternate pumps to equalize run time.
5. Alarm motor failure.
6. Manual reset dry-run protection.
7. Stop pumps if fuel level falls below pump suction.
8. De-energize and sound alarm for pump, locked-rotor condition.
9. Sound alarm for open circuit and for high and low voltage.
10. Lights shall indicate normal power on, run, and off conditions.
11. Interface with automatic control system. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" to control and indicate the following:
 - a. Start/stop pump set when required by schedule, fuel-fired appliance operation, day tank level control, or weather conditions.
 - b. Operating status.
 - c. Alarm off-normal status.

D. **Capacities and Characteristics:**

1. Number of Stages: **<Insert number>.**

2. Capacity: <Insert gph (L/s)>.
3. Discharge Pressure: <Insert psig (kPa)>.
4. Outlet Size: <Insert NPS (DN)>.
5. Motor Speed: <Insert rpm>.
6. Motor Horsepower: <Insert value>.
7. Electrical Characteristics:
 - a. Volts: [120] [208] [240] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage.>

2.4 SIMPLEX FUEL-OIL TRANSFER PUMPS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [DESMI INC./Rotan Pumps.](#)
2. [Earth Safe Systems.](#)
3. [Haight Pumps; Division of Baker Mfg.](#)
4. [Preferred Utilities Manufacturing Corporation.](#)
5. [Suntec Industries Incorporated.](#)
6. [Tuthill Corporation; Tuthill Pump Div.](#)
7. [Viking Pump Inc.; a Unit of IDEX Corporation.](#)
8. [Webster Fuel Pumps & Valves; a division of Capital City Tool, Inc.](#)
9. <Insert manufacturer's name>.
10. or approved equal.

- B. Description: Comply with UL 343 and HI 3.1-3.5.

1. Type: Positive-displacement, rotary type.
2. Impeller: [Steel gear with crescent] [Carbon vane].
3. Housing: Cast-iron foot mounted.
4. Bearings: Bronze, self-lubricating.
5. Shaft: Polished steel.
6. Seals: Mechanical.
7. Base: Steel.
8. Pressure Relief: Built in.
9. Discharge Check Valve: Built in.

- C. Drive: [V-belt with guard; gear reducer; or direct, close coupled] [V-belt with guard] [Gear reducer] [Direct, close coupled].

- D. Controls:

1. Maintain minimum manifold pressure with outdoor-air temperature less than [60 deg F (16 deg C)] <Insert temperature>.

2. Seven-day schedule.
3. Alarm motor failure.
4. Manual reset dry-run protection.
5. Stop pump if fuel level falls below pump suction.
6. De-energize and sound alarm for pump, locked-rotor condition.
7. Sound alarm for open circuit and for high and low voltage.
8. Lights shall indicate normal power on, run, and off conditions.
9. Interface with automatic control system. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" to control and indicate the following:
 - a. Start/stop pump set when required by schedule, fuel-fired appliance operation, day tank level control, or weather conditions.
 - b. Operating status.
 - c. Alarm off-normal status.

E. Capacities and Characteristics:

1. Number of Stages: **<Insert number>**.
2. Capacity: **<Insert gph (L/s)>**.
3. Inlet Vacuum: **<Insert inches Hg (kPa)>**.
4. Discharge Pressure: **<Insert psig (kPa)>**.
5. Inlet and Outlet Size: **<Insert NPS (DN)>**.
6. Motor Speed: **<Insert rpm>**.
7. Motor Horsepower: **<Insert value>**.
8. Electrical Characteristics:
 - a. Volts: **[120] [208] [240] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.5 **[DUPLEX] [TRIPLEX] FUEL-OIL TRANSFER PUMP SETS**

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Alyan Pump Company](#).
2. [Earth Safe Systems](#).
3. [Hydronic Modules Corporation](#).
4. [Preferred Utilities Manufacturing Corporation](#).
5. [Smith-Koch, Inc.; a Geiger company](#).
6. [Webster Fuel Pumps & Valves; a division of Capital City Tool, Inc.](#)
7. **<Insert manufacturer's name>**.
8. or approved equal.

B. Description: Comply with HI 3.1-3.5.

1. Type: Positive-displacement, rotary type.
 2. Impeller: [**Steel gear with crescent**] [**Carbon vane**].
 3. Housing: Cast-iron foot mounted.
 4. Bearings: Bronze, self-lubricating.
 5. Shaft: Polished steel.
 6. Seals: Mechanical.
 7. Base: Steel.
 8. Pressure Relief: Built in.
 9. Discharge Check Valve: Built in.
- C. Drive: [**V-belt with guard, gear reducer, or direct close coupled**] [**V-belt with guard**] [**Gear reducer**] [**Direct close coupled**].
- D. Controls:
1. Maintain minimum manifold pressure with outdoor-air temperature less than [**60 deg F (16 deg C)**] <Insert temperature>.
 2. Seven-day schedule.
 3. Stage multiple pumps to maintain pressure at a common supply manifold.
 4. Alternate pumps to equalize run time.
 5. Alarm motor failure.
 6. Manual reset dry-run protection.
 7. Stop pumps if fuel level falls below pump suction.
 8. De-energize and sound alarm for pump, locked-rotor condition.
 9. Sound alarm for open circuit and for high and low voltage.
 10. Lights shall indicate normal power on, run, and off conditions.
 11. Interface with automatic control system. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" to control and indicate the following:
 - a. Start/stop pump set when required by schedule, fuel-fired appliance operation, day tank level control, or weather conditions.
 - b. Operating status.
 - c. Alarm off-normal status.
- E. Piping Furnished with Pumps: Steel with ferrous fittings and threaded or welded joints.
- F. Strainers Furnished with Pumps: Duplex, basket type with corrosion-resistant-metal-screen baskets.
- G. Capacities and Characteristics:
1. Number of Stages: <Insert number>.
 2. Capacity (Each Pump): <Insert gph (L/s)>.
 3. Inlet Vacuum: <Insert inches Hg (kPa)>.
 4. Discharge Pressure: <Insert psig (kPa)>.
 5. Inlet and Outlet Size: <Insert NPS (DN)>.
 6. Motor Speed: <Insert rpm>.
 7. Motor Horsepower (Each Pump): <Insert value>.
 8. Electrical Characteristics (Pump Set):

- a. Volts: [120] [208] [240] <Insert value>.
- b. Phase: [Single] [Three].
- c. Hertz: 60.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.6 FUEL MAINTENANCE SYSTEM

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Fuel Technologies International, LLC](#).
 2. <Insert manufacturer's name>.
 3. or approved equal.
- B. **Description:** Factory-fabricated and wired fuel maintenance system for fuel-oil filtration; with enclosure, filter, fuel-oil pump, and controls.
1. System shall be FMG approved and listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 2. Enclosure: NEMA 250, Type 3R, painted steel containing pumps, filters, accessories, and controls. Hinged door on the front of enclosure.
 3. Pump: Comply with HI 3.1-3.5, steel gear with crescent, positive displacement, direct coupled, rotary type.
 4. Materials: Cast-iron housing; bronze bearings; steel shaft; mechanical seals; and built-in, pressure relief bypass valve.
 5. Piping: Steel with malleable-iron fittings and threaded joints or wrought-steel fittings and welded joints.
 6. Spin-On, Replaceable, Multistage Filters:
 - a. Stage 1: 100-mesh strainer.
 - b. Stage 2: Centrifuge to separate particulates and water from oil.
 - c. Stage 3: Coalescing water and particulate filter.
 - d. Stage 4: 30-micron particulate removal.
 - e. Stage 5: 10-micron particulate removal.
 - f. Stage 6: Minimum 99.5 percent water removal with see-through bowl and water-sensor probe.
 - g. Stage 7: [1.5] [3]-micron particulate removal.
 7. Multiple-Tank Manifolds:
 - a. Manifold fabricated of Schedule 80, black steel pipe and threaded nipples for [two] [three] [four] tanks.
 - b. Solenoid valves for supply and return piping to each tank.
 - c. Strainers for each tank supply connection.
 8. Programmable Logic Controller:

- a. Alarm on maximum **15-in. Hg** (51-kPa) vacuum at pump suction indicating plugged filter.
 - b. Alarm on high water level in filter.
 - c. Alarm leak in enclosure.
 - d. Touch screen; with minimum 2-line, 20-character, backlit, LCD display.
 - e. Controller strip heater with thermostat.
9. Interface with automatic control system is specified in Section 230900 "Instrumentation and Control for HVAC" to control and indicate the following:
- a. Start/stop system when required by schedule.
 - b. Operating status.
 - c. Alarm off-normal status.

C. Capacities and Characteristics:

1. Capacity (Each Pump): [**3 gpm** (0.19 L/s)] [**8 gpm** (0.50 L/s)] [**24 gpm** (1.5 L/s)] **<Insert value>**.
2. Maximum Suction Lift: [**15 feet** (4.6 m)] **<Insert value>**.
3. Inlet and Outlet Size: **<Insert NPS (DN)>**.
4. Motor Horsepower (Each Pump): **<Insert value>**.
5. Electrical Characteristics (Pump Set):
 - a. Volts: [**120**] [**208**] [**240**] **<Insert value>**.
 - b. Phase: [**Single**] [**Three**].
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.7 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 2. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 3. Motor Bearings: **<Insert requirements>**.
 4. Unusual Service Conditions:
 - a. Ambient Temperature: **<Insert deg C>**.
 - b. Altitude: **<Insert feet ((m))>** above sea level.
 - c. High humidity.
 - d. **<Insert conditions>**.

5. Efficiency: Premium efficient.
6. NEMA Design: **<Insert designation>**.
7. Service Factor: **<Insert value>**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for fuel-oil pumps to verify actual locations of pump connections before equipment installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.

3.3 PREPARATION

- A. Close equipment shutoff valves before turning off fuel oil to premises or piping section.
- B. Comply with NFPA 30 and NFPA 31 requirements for prevention of accidental ignition.

3.4 INSTALLATION - GENERAL

- A. Decrease from line size, with long radius reducing elbows or reducers. Support piping adjacent to pump such that no weight is carried on pump casings. Provide supports under elbows on pump suction and discharge line sizes 4 inches and over.
- B. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25 percent of midpoint of published maximum efficiency curve.
- C. Qualified millwright to check, align, and certify base mounted pumps prior to start-up.

3.5 FUEL-OIL PUMP INSTALLATION

- A. Submersible Pumps:
 1. Suspend pumps from supply piping and anchored to bottom of tank.
- B. Transfer Pumps:

1. Install pumps with access space for periodic maintenance including removal of motors, impellers, and accessories.
 2. Set pumps on and anchor to concrete base.
 3. Pump Mounting:
 - a. Install base-mounted pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete.]" [Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
 - b. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - c. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
 4. Equipment Mounting: Install in-line pumps with continuous-thread hanger rods and **[elastomeric hangers] [spring hangers] [spring hangers with vertical-limit stop]** of size required to support weight of in-line pumps.
 - a. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - b. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- C. Install two-piece, full-port ball valves at suction and discharge of pumps. Comply with requirements in Section 230523.12 "Ball Valves for HVAC Piping."
- D. Install mechanical leak-detector valves at pump discharge.
- E. Install **[Y-pattern] [basket] [T-pattern]** strainer on inlet side of simplex fuel-oil pumps.
- F. Install check valve on discharge of simplex fuel-oil pumps.
- G. Install suction piping with minimum fittings and change of direction.
- H. Install vacuum and pressure gage, upstream and downstream, respectively, at each pump to measure the differential pressure across the pump. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."
- 3.6 FUEL MAINTENANCE SYSTEM INSTALLATION
- A. Install suction line, with foot valve, at one end of storage tank, **1 inch (25 mm)** from the bottom of tank.
 - B. Install return line at the opposite end of storage tank from suction line.
- 3.7 LABELING AND IDENTIFYING
- A. Install nameplates and signs on each fuel-oil pump. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment."

3.8 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Start fuel-oil transfer pumps to verify for proper operation of pump, and check for leaks.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Fuel-oil pumps will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.9 DEMONSTRATION

- A. [**Engage a factory-authorized service representative to train**] [Train] Owner's maintenance personnel to adjust, operate, and maintain [**fuel-oil pumps**] <Insert other>.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 231213

SECTION 231313 - FACILITY UNDERGROUND FUEL-OIL STORAGE TANKS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Composite, steel, fuel-oil USTs.
 - 2. Jacketed, steel, fuel-oil USTs.
 - 3. FRP fuel-oil USTs.
 - 4. Liquid-level gage systems.
 - 5. Leak-detection systems.
 - 6. Fuel oil.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. FPM: Vinylidene fluoride-hexafluoropropylene copolymer rubber.
- B. FRP: Glass-fiber-reinforced plastic.
- C. UST: Underground storage tank.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, and dimensions of individual components and profiles.
 - 2. Tank specifications. Include, where applicable, rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Leak-detection and monitoring system.
 - 4. Tank manufacturer's installation checklist.
 - 5. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: For underground fuel-oil storage tanks.
1. Complete tank system drawings, fully dimensioned. Include plans, elevations, sections, and ballast pads and anchors, and lifting or supporting points.
 2. Complete details of tanks and piping. Include details of equipment assemblies, piping, fittings, manways, ladders, hold-down straps, and other accessories. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Shop Drawing Scale: [1/4 inch per foot (1:50)] <Insert scale>.

1.5 INFORMATIONAL SUBMITTALS

- A. Site Survey: Plans, drawn to scale, on which underground fuel-oil storage tanks are shown and coordinated with other services and utilities.
- B. Tank manufacturer's installation checklist and warranty.
- C. Bill of materials.
- D. Manufacturer shall submit certification that Equipment will comply with performance requirements as specified.
- E. Manufacturer shall submit certified test report for shop leakage test.
- F. Contractor shall submit proof of state licensing or certification to perform UST work.
- G. Contractor shall submit certification that UST system installation method is approved by the implementing regulatory agency.
- H. Contractor shall obtain, complete, and submit to DEN UST notification forms within ten (10) days of completing UST installation.
- I. Field quality-control reports.
- J. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- B. Tank strapping calibration report.

1.7 QUALITY ASSURANCE

- A. Manufacturer's Qualifications: Firms regularly engaged in the manufacture of steel underground storage tanks of the types and sizes required, whose products have been

in satisfactory use in similar service for not less than five (5) years.

- B. **Manufacturer's Certification:** The tank manufacturer shall certify that surface preparation and tank coating systems are in accordance with the specifications. Proof of **[UL 58 construction]** and STI-P3 label is required. Submit manufacturer's certification of the following:
1. Surface preparation conformance.
 2. Interior coating performance.
 3. UL label.
 4. STI-P3 label.
- C. **Installer Qualifications:**
1. Installation contractor shall have had a minimum of five (5) years experience in the installation of tanks of similar type, size, and configuration.
 2. FRP tanks; trained and certified by the tank manufacturer.
- D. **Performance Characteristics:** Tanks shall be built in strict accordance with NFPA 30 and shall be labeled by Underwriters' Laboratories (UL) [and the Steel Tank Institute (STI)].
- E. **Underground Fuel-Oil Storage Tanks:** Comply with requirements of the EPA and of state and local authorities having jurisdiction, including recording fuel-oil storage tanks.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver products to site under provisions of Section Division 01.
- B. Store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements".
- C. Lift and support fuel-oil storage tanks only at designated lifting or supporting points, as shown on Shop Drawings. Do not move or lift tanks unless empty.

1.9 WARRANTY

- A. **Special Warranty:** Manufacturer agrees to repair or replace components of fuel-oil storage tanks that fail in materials or workmanship within specified warranty period.
1. **Storage Tanks:**
 - a. Failures include, but are not limited to, the following when used for storage of fuel oil at temperatures not exceeding **[150 deg F (66 deg C)] <Insert temperature>**:
 - 1) Structural failures including cracking, breakup, and collapse.
 - 2) Corrosion failure including external and internal corrosion of steel tanks.

- b. Warranty Period: Minimum **[thirty (30)] <Insert number>** years from date of Substantial Completion.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 TANKS - GENERAL

A. Construction:

1. The Contractor shall provide the tanks with the capacities, sizes and appurtenances as shown on the drawings. Construct tank with nozzles, manways, **[and internal ladders]** as detailed on the drawings. **[No items in contact with fuel shall be fabricated of copper, copper-alloy, zinc, or galvanized materials.]** Prior to fabrication of tanks, re-confirm required sizes of nozzles and openings as required for installation of pumps or other equipment.
2. The tanks shall be installed on anti-flotation slabs and secured by hold-down straps as indicated by the drawings, and in conformity with tank manufacturer's recommendations.

B. Pipe and Fittings:

1. Steel Pipe: Steel pipe shall be Grade B, black, welded or seamless pipe ASTM A 53 or API 5L, Furnace butt-welded pipe may be used in sizes 2-inches and smaller. Sizes smaller than 2-inches shall be Schedule 80. Sizes 2-inch and larger shall be Schedule 40 for sizes up to and including 10 inches.
2. Welding Fittings: Welding fittings shall conform to ANSI B16.9 and ASTM A 234, Grade WPB for use with carbon steel pipe. Welding outlets shall be standard weight forged steel conforming to ASTM A 181, Grade 1.
3. Forged Welding Flanges: Flanges shall be carbon steel conforming to ANSI B16.5, Class 150, except as otherwise specified. Flanged facings shall correspond to the equipment to which the piping is joined. Materials shall conform to the requirements of ASTM A 181 or to ASTM A 105.
4. Bolting: Flange bolts and nuts shall conform to the requirements of ASTM A 307, Grade B, square bolt heads and hexagon nuts.
5. Threaded Steel Fittings: Threaded fittings, shall be Pressure Class 3000 conforming to ANSI B16.11. Fittings material shall be ASTM A 105.
6. Nipples: Carbon Steel pipe nipples shall be of the same material as the pipe they join and shall conform to the requirements of ASTM A 733.

C. Interior Finishes:

1. Interior surfaces shall be coated by the manufacturer.

2. Interior ferrous metal surfaces shall be protected by polyurethane coating as per requirements of Section 220505 "Coatings and Corrosion Protection".
3. Protective wood covers shall be bolted to all flange nozzles and all tank couplings shall be plugged to protect interior of tank until installation.

D. Interior Finishes:

1. Interior surfaces shall be coated by the manufacturer.
2. Interior ferrous metal surfaces shall be coated with material meeting the requirements of MIL C 4556D. Refer to Section 220505 "Coatings and Corrosion Protection".
3. Total dry film thickness shall be 6.0 mils minimum.
4. Protective wood covers shall be bolted to all flange nozzles and all tank couplings shall be plugged to protect interior of tank until installation.
5. Color shall be white.

- E. Exterior Surfaces: The exterior of the tank, including manhole cover and extensions, shall be cleaned and coated in accordance with STI-P3, and shall be protected by factory-installed [**magnesium**] [**zinc**] sacrificial anode system as required for STI-P3 certification.

2.2 STEEL, FUEL-OIL UST WITH STI-P3

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Ace Tank & Fueling Equipment, LLC.](#)
2. [Adamson Global Technology Corporation.](#)
3. [Brown Tank LLC.](#)
4. [Clawson Tank Company.](#)
5. [Hamilton Tanks.](#)
6. [Highland Tank & Manufacturing Company, Inc.](#)
7. [Kennedy Tank and Manufacturing Company, Inc.](#)
8. [Modern Welding Company, Inc.](#)
9. [Palmer Manufacturing & Tank Inc.](#)
10. [Service Welding & Machine Co., Inc.](#)
11. [Steel Tank & Fabricating Co., Inc.](#)
12. [Watco Tanks, Inc.](#)
13. [We-Mac Manufacturing, Inc.](#)
14. <Insert manufacturer's name>.
15. or approved equal.

- B. Description: UL 58 and STI P3, double-wall, horizontal, steel tank; with cathodic protection and electrical isolation.

1. Containment Method: STI-P3, [**Type I, with primary and secondary walls in contact**] [**Type II, with interstitial space**].
2. Provide interstitial space monitoring for detection of leakage. [**The interstitial monitoring system shall be capable of distinguishing between the**

presence of water and hydrocarbons].

- C. Construction: Fabricated with welded carbon steel tank plate. All shell seams shall be made by butt welding; lap joints are not acceptable. Weld joints shall be ground smooth. Suitable for operation at atmospheric pressure and for storing liquids with specific gravity up to 1.1; fabricated for the following loads:
1. Depth of Bury: **36 inches** (900 mm) from top of tank to finished surface.
 2. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.
 3. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of **32,000 lb** (14 515 kg).
- D. Corrosion-Protection System: Protect tank and factory-installed piping by engineered and installed corrosion-protection system according to STI P3, with means of monitoring cathodic protection.
- E. Capacities and Characteristics:
1. Capacity: **<Insert gal. (L)>**.
 2. Diameter: **<Insert feet (m)>**.
 3. Length: **<Insert feet (m)>**.
 4. Connection Sizes:
 - a. Fill Line: **<Insert NPS (DN)>**.
 - b. Vent Line: **<Insert NPS (DN)>**.
 - c. Outlet: **<Insert NPS (DN)>**.
 - d. Return: **<Insert NPS (DN)>**.
 - e. Gage: **<Insert NPS (DN)>**.
 5. Manholes:
 - a. Number Required: **<Insert number>**.
 - b. Diameter: **<Insert inches (mm)>**.
 6. Fuel-Oil Grade Number: **[Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>**.

2.3 COMPOSITE, STEEL, FUEL-OIL UST

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Ace Tank & Fueling Equipment, LLC.](#)
 2. [Adamson Global Technology Corporation.](#)
 3. [Brown Tank LLC.](#)
 4. [Clawson Tank Company.](#)
 5. [Hall Tank Co.](#)
 6. [Hamilton Tanks.](#)
 7. [Highland Tank & Manufacturing Company, Inc.](#)

8. [Lannon Tank Corporation](#).
 9. [Modern Welding Company, Inc.](#)
 10. [Palmer Manufacturing & Tank Inc.](#)
 11. [Service Welding & Machine Co., Inc.](#)
 12. [Watco Tanks, Inc.](#)
 13. [We-Mac Manufacturing, Inc.](#)
 14. <Insert manufacturer's name>.
 15. or approved equal.
- B. Description: UL 58, double-wall, horizontal, composite tank; with coating complying with UL 1746 and STI F894.
1. Containment Method: STI F894, [Type I, with primary and secondary walls in contact] [Type II, with interstitial space]. Provide interstitial space monitoring for detection of leakage. [**The interstitial monitoring system shall be capable of distinguishing between the presence of water and hydrocarbons**].
- C. Construction: Fabricated with welded carbon steel plate. All shell seams shall be made by butt welding; lap joints are not acceptable. Factory coating according to UL 1746 and STI F894; suitable for operation at atmospheric pressure and for storing liquids with specific gravity up to 1.1; fabricated for the following loads:
1. Depth of Bury: **36 inches** (900 mm) from top of tank to finished surface.
 2. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.
 3. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of **32,000 lb** (14 515 kg).
- D. Capacities and Characteristics:
1. Capacity: <Insert gal. (L)>.
 2. Diameter: <Insert feet (m)>.
 3. Length: <Insert feet (m)>.
 4. Connection Sizes:
 - a. Fill Line: <Insert NPS (DN)>.
 - b. Vent Line: <Insert NPS (DN)>.
 - c. Outlet: <Insert NPS (DN)>.
 - d. Return: <Insert NPS (DN)>.
 - e. Gage: <Insert NPS (DN)>.
 5. Manholes:
 - a. Number Required: <Insert number>.
 - b. Diameter: <Insert inches (mm)>.
 6. Fuel-Oil Grade Number: [**Grade No. 1**] [**Grade No. 2**] [**Diesel**] <Insert grade>.

2.4 JACKETED, STEEL, FUEL-OIL UST

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Ace Tank & Fueling Equipment, LLC.](#)
2. [Cardinal Tank Corp.](#)
3. [Clawson Tank Company.](#)
4. [Hamilton Tanks.](#)
5. [Highland Tank & Manufacturing Company, Inc.](#)
6. [Kennedy Tank and Manufacturing Company, Inc.](#)
7. [Lannon Tank Corporation.](#)
8. [Modern Welding Company, Inc.](#)
9. [Palmer Manufacturing & Tank Inc.](#)
10. [Service Welding & Machine Co., Inc.](#)
11. [Watco Tanks, Inc.](#)
12. **<Insert manufacturer's name>.**
13. or approved equal.

B. **Description:** Jacketed, horizontal, steel tank; complying with UL 58, and with plastic or fiberglass jacket and corrosion-protection system according to UL 1746[**and STI F922**].

C. **Construction:** Tank fabricated with welded carbon steel plate. All shell seams shall be made by butt welding; lap joints are not acceptable. Jacket fabricated with plastic or fiberglass and vacuum-sealed interstitial space; suitable for operation at atmospheric pressure and with integral leak-detection device. Tank fabricated for the following loads:

1. Depth of Bury: **36 inches** (900 mm) from top of tank to finished surface.
2. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.
3. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of **32,000 lb** (14 515 kg).

D. **Capacities and Characteristics:**

1. Capacity: **<Insert gal. (L)>.**
2. Diameter: **<Insert feet (m)>.**
3. Length: **<Insert feet (m)>.**
4. Connection Sizes:
 - a. Fill Line: **<Insert NPS (DN)>.**
 - b. Vent Line: **<Insert NPS (DN)>.**
 - c. Outlet: **<Insert NPS (DN)>.**
 - d. Return: **<Insert NPS (DN)>.**
 - e. Gage: **<Insert NPS (DN)>.**
5. Manholes:

- a. Number Required: **<Insert number>**.
 - b. Diameter: **<Insert inches (mm)>**.
6. Fuel-Oil Grade Number: **[Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>**.

2.5 FRP FUEL-OIL UST

- A. **Manufacturers: Subject to compliance with requirements, provide products by the following:**
1. [Containment Solutions, Inc.](#)
 2. [Palmer Manufacturing & Tank Inc.](#)
 3. [Xerxes Corporation.](#)
 4. **<Insert manufacturer's name>**.
 5. or approved equal.
- B. **Description: Horizontal, FRP UST; UL 1316, double wall, with interstitial space[and integral, hydrostatic, leak-detection and monitoring system].**
- C. **Construction: Fabricated with fiberglass-reinforced polyester resins; suitable for operation at atmospheric pressure; fabricated for the following loads:**
1. **Internal Load: Tanks shall withstand without leakage a 5 psig air pressure test (3 psig for testing 12-foot diameter tanks) with a 5 to 1 safety factor. Contractor shall individually test tanks for leakage prior to installation.**
 2. **Vacuum Test: To insure structural integrity, each tank shall be vacuum tested by the tank manufacturer at the factory to 11.5 inches of mercury. A copy of each test report shall be delivered to the DEN Project Manager within 30 days of the date of testing.**
 3. **Depth of Bury: 36 inches (900 mm) from top of tank to finished surface.**
 4. **External Hydrostatic Pressure: Tanks shall be capable of withstanding <Insert value> feet of overburden with the hole fully flooded with a 7 to 1 safety factor against general buckling.**
 5. **Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of 32,000 lb (14 515 kg).**
 6. **Tanks shall support accessory equipment such as heating coils, drop tubes, submersible pumps and ladders, when installed according to manufacturer's recommendations and limitations.**
- D. **Product Storage:**
1. **Tanks shall be capable of storing petroleum products with a specific gravity up to 1.1.**
 2. **Tanks shall be vented to atmosphere. Tanks shall not be subjected to internal pressures, except as required for use with vapor recovery or emissions control systems, provided that pressure or vacuum does not exceed 1 psig.**
 3. **Tanks shall be capable of storing gasoline or gasohol (10% ethanol and 90% gasoline mixture) 90.5% gasoline and 9.5% Oxinol-50* (4.75% methanol and 4.75% GTBA mixture), Dupont EPA waiver (gasoline with 5% methanol and a**

minimum of 2.5% cosolvent, the blend may contain a maximum concentration of up to 3.7 weight percent oxygen in the final fuel); MTBE (methyl tertiary butyl ether) - gasoline with up to 20% by volume of MTBE; gasoline/water/ethanol or methanol blend motor fuels including neat or near neat methanol or ethanol fuel at ambient temperatures jet fuel, aviation gasoline; kerosene; diesel fuel; new or used motor oil; potable water at ambient underground temperatures; or used for fuel oil at temperatures not to exceed 150 degrees F.

E. Materials:

1. Tanks shall be manufactured with 100% resin and glass fiber reinforcement with no sand fillers.

F. Interstitial Space: Tanks shall have a space between the primary and secondary shell walls to allow for the free flow and containment of all leaked product from the primary tank. Space also allows the insertion of monitoring device(s) through a monitoring fitting.

G. Capacities and Characteristics:

1. Capacity: <Insert gal. (L)>.
2. Diameter: <Insert feet (m)>.
3. Length: <Insert feet (m)>.
4. Connection Sizes:
 - a. Fill Line: <Insert NPS (DN)>.
 - b. Vent Line: <Insert NPS (DN)>.
 - c. Outlet: <Insert NPS (DN)>.
 - d. Return: <Insert NPS (DN)>.
 - e. Gage: <Insert NPS (DN)>.
5. Manholes:
 - a. Number Required: <Insert number>.
 - b. Diameter: <Insert inches (mm)>.
6. Fuel-Oil Grade Number: [Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>.

2.6 FUEL-OIL UST ACCESSORIES

- A. Tank Manholes: 22-inch- (560-mm-) minimum diameter; bolted, flanged, and gasketed, with extension collar; for access to inside of tank.
1. Except as otherwise specified or shown, manways shall be 22" internal diameter, flanged and complete with UL listed gaskets, plated bolts and covers.
 2. Locations shall be as shown on the Drawings.
 3. Where indicated or required for the project, provide manufacturer's standard manway extension tubes. **[Extension tubes shall be of FRP construction on**

FRP tanks.]

4. Manway covers shall be equipped with fittings welded in place for piping connections as shown by drawing details. Provide specially fabricated covers to accommodate installation of submersible pumps.
- B. Steel Tank Masonry Supports: Two [6-by-6-by-3/8-inch (150-by-150-by-10-mm)] <Insert dimensions> steel angles, [72 inches (1800 mm)] <Insert dimension> long, located longitudinally on tank on each side of manholes and continuously welded in place.
- C. Threaded pipe connection fittings on top of tank for fill, supply, return, vent, sounding, and gaging; in locations and of sizes indicated. Include cast-iron plugs for shipping.
- D. NPT Threaded Fittings:
1. All threaded fittings shall be constructed of a material consistent with the requirements of the UL label and located as shown on the drawings.
 2. All standard threaded fittings shall be half couplings and shall be 4-inch NPT. Provide reducers for smaller connection sizes where shown or required.
 3. NPT fittings shall withstand a minimum of 150 foot-pounds torque and 1,000 foot-pounds bending moment, both with a 2:1 safety factor.
 4. Suction lines shall be field-installed and shall terminate a minimum of 4 inches from tank bottom.
 5. Submersible pumps shall be installed as detailed on the drawings.
- E. Monitor Fittings:
1. Each monitor fitting shall consist of a 4" NPT fitting on the secondary tank.
 2. Tanks with a capacity of 3,000 gallons or greater shall have two monitor fittings, one near each end of the tank. Tanks less than 3,000 gallon capacity shall have one monitor fitting.
- F. Submersible Pump Sump Probes:
1. Probes shall be constructed of a material, which is suitable for prolonged complete immersion in any of the fluids listed in UL Standard for Safety 1316, Table 14.1, all columns.
 2. Sensors shall detect the presence of liquid in the sump when the liquid level has risen to a maximum of one inch above the bottom of the probe as located in its permanent mounting position. The permanent mounting position shall be determined by the Contractor at the time of installation.
 3. The probe shall be capable of being mounted in the sump in a manner, which allows adjustment of height. The probe must be mounted so that an increase in the liquid level does not interfere with the normal operation of the sensor.
 4. Probe mounting assemblies shall be arranged to protect the probe from damage arising from normal work activities, which may take place within the sump.
 5. Sensors shall be capable of providing reliable operation at a distance of up to 500 feet from the control panel.
- G. Operating Parameters:

1. Temperature 0 to 150 degrees F.
 2. Voltage: 110 or 120 VAC, 50/60 Hz
- H. Striker Plates: Inside tank, on bottom below fill, vent, sounding, gage, and other tube openings.
- I. Lifting Lugs: For handling and installation.
- J. Ladders: Carbon-steel ladder inside tank, anchored to top and bottom. Include reinforcement of tank at bottom of ladder.
- K. Supply Tubes: Extension of supply piping fitting into tank, terminating **6 inches (150 mm)** above tank bottom and cut at a 45-degree angle.
- L. FRP Supply Tubes:
1. Fill tubes shall be manufacturer's standard FRP product or, at Contractor's option, aluminum fabrications, located as shown on the drawings.
 2. FRP tubes shall be 4" diameter with 6" x 4" double tapped reduced bushing and include a 6" NPT fitting on the tank. Aluminum tubes shall be 4" diameter and fit directly into a 4" NPT fitting. Tube ends shall be cut at a 45-degree angle, and tubes shall terminate a minimum of 4" from bottom of tank.
- M. Sounding and Gage Tubes: Extension of fitting into tank, terminating **6 inches (150 mm)** above tank bottom and cut at a 45-degree angle.
- N. Containment Sumps: **[Fiberglass] [PE]** with sump base, add-on extension pieces as required, sump top, lid, and gasket-seal joints. Include sump entry boots for pipe penetrations through sidewalls.
- O. Sump Entry Boots: Two-part pipe fitting for field assembly and of size required to fit over pipe. Include gaskets shaped to fit sump sidewall, sleeves, seals, and clamps as required for liquid-tight pipe penetrations.
- P. Anchor Straps: Storage tank manufacturer's standard anchoring system, with straps, strap-insulating material, cables, and turnbuckles; of strength at least one and one-half times maximum uplift force of empty tank without backfill in place.
- Q. Filter Mat: Geotextile woven or spun filter fabric, in 1 or more layers, for minimum total weight of **[3 oz./sq. yd. (101.7 g/sq. m)] <Insert dimension>**.
- R. Overfill Prevention Valves: Factory fabricated or shop or field assembled from manufacturer's standard components. Include drop tube, cap, fill nozzle adaptor, check valve mechanism or other devices, and vent if required to restrict flow at 95 percent of tank capacity and to provide complete shutoff of filling at **[98] [99] <Insert other>** percent of tank capacity.
- S. Heating Coils:
1. Heating coils shall be installed in a separate manway and shall be standard items supplied by tank manufacturer.

2. Coil locations shall be as shown on drawings.

2.7 LIQUID-LEVEL GAGE SYSTEM

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Caldwell Systems Corporation.](#)
 2. [Clawson Tank Company.](#)
 3. [Franklin Fueling Systems.](#)
 4. [Highland Tank & Manufacturing Company, Inc.](#)
 5. [INCON.](#)
 6. [King Engineering Corp.](#)
 7. [Krueger Sentry Gauge.](#)
 8. [Pneumercator Inc.](#)
 9. [Preferred Utilities Manufacturing Corporation.](#)
 10. [Rochester Gauges, Inc.](#)
 11. [Tuthill Corporation; Tuthill Transfer Systems; Sotera Systems.](#)
 12. [Uehling Instrument Company.](#)
 13. [Venture Measurement Company, LLC.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Description: Calibrated, liquid-level gage system complying with [**UL 180 with floats**] [**UL 1238 with probes**] or other sensors and remote annunciator panel.
- C. Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms, fuel indicator with registration in **gallons** (liters), and overfill alarm. Include gage volume range that covers fuel-oil storage capacity.
- D. Controls: Electrical, operating on [**120**] **<Insert voltage>**-V ac.

2.8 LEAK-DETECTION AND MONITORING SYSTEM

- A. Cable and Sensor System: Comply with UL 1238.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Caldwell Systems Corporation.](#)
 - b. [Containment Solutions, Inc.](#)
 - c. [Franklin Fueling Systems.](#)
 - d. [Gems Sensors & Controls Inc.](#)
 - e. [Highland Tank & Manufacturing Company, Inc.](#)
 - f. [INCON, Inc.](#)
 - g. [In-Situ, Inc.](#)
 - h. [MSA; Instrument Div.](#)
 - i. [Perma-Pipe, Inc.](#)

- j. [Pentair Thermal Management](#).
 - k. [Pneumercator Inc.](#)
 - l. [Raychem Corp; Tyco Electronics Corporation](#).
 - m. [Tuthill Corporation; Tuthill Transfer Systems; Sotera Systems](#).
 - n. [Veeder-Root; a Danaher Corporation company](#).
 - o. <Insert manufacturer's name>.
 - p. or approved equal.
2. Calibrated, leak-detection and monitoring system with probes and other sensors and remote alarm panel for fuel-oil storage tanks and fuel-oil piping.
 3. Include fittings and devices required for testing.
 4. Controls: Electrical, operating on [120] <Insert voltage>-V ac.
 5. Calibrated, liquid-level gage complying with [UL 180 with floats] [UL 1238 with probes] or other sensors and remote annunciator panel.
 6. Remote Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms, fuel indicator with registration in gallons (liters), and overflow alarm. Include gage volume range that covers fuel-oil storage capacity.
 7. Controls: Electrical, operating on [120] <Insert voltage>-V ac.
- B. Hydrostatic System: Comply with UL 1238.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Caldwell Systems Corporation](#).
 - b. [Containment Solutions, Inc.](#)
 - c. [Franklin Fueling Systems](#).
 - d. [Gems Sensors & Controls Inc.](#)
 - e. [Highland Tank & Manufacturing Company, Inc.](#)
 - f. [INCON, Inc.](#)
 - g. [In-Situ, Inc.](#)
 - h. [MSA; Instrument Div.](#)
 - i. [Pentair Thermal Management](#).
 - j. [Perma-Pipe, Inc.](#)
 - k. [Pneumercator Inc.](#)
 - l. [Raychem Corp; Tyco Electronics Corporation](#).
 - m. [Tuthill Corporation; Tuthill Transfer Systems; Sotera Systems](#).
 - n. [Veeder-Root; a Danaher Corporation company](#).
 - o. <Insert manufacturer's name>.
 - p. or approved equal.
 2. Calibrated, leak-detection and monitoring system with brine antifreeze solution, reservoir sensor, and electronic control panel to monitor leaks in inner and outer tank walls.
 3. Include fittings and devices required for testing.
 4. Controls: Electrical, operating on [120] <Insert voltage>-V ac.
 5. Calibrated, liquid-level gage complying with [UL 180 with floats] [UL 1238 with probes] or other sensors and remote annunciator panel.
 6. Remote Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms; fuel indicator with registration in gallons ((liters)); and

- overfill alarm. Include gage volume range that covers fuel-oil storage capacity.
7. Controls: Electrical, operating on [120] <Insert voltage>-V ac.

2.9 FUEL OIL

- A. Fuel Oil: ASTM D 396, [Grade No. 1] [Grade No. 2].
- B. Diesel Fuel Oil: ASTM D 975, [Grade Low Sulfur] [Grade No. 1-D, special purpose] [Grade No. 2-D, general purpose], high volatility.

2.10 CONCRETE MANHOLES

- A. Precast Concrete Manhole Sections: ASTM C 478 (ASTM C 478M), base and concentric-cone sections with integral ladder or steps.
- B. Cast-Iron Frame and Cover: Heavy-duty, water-resistant, cast-iron manhole frame, gasket, and bolted cover; [24-inch- (609-mm-)] <Insert dimension> diameter, inside opening dimension; [8-inch (203-mm)] <Insert dimension> frame riser height.

2.11 LABELING AND IDENTIFYING

- A. Detectable Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches (152 mm) wide and 4 mils (0.1 mm) thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches (762 mm) deep; colored yellow.

2.12 SOURCE QUALITY CONTROL

- A. Pressure test and inspect fuel-oil storage tanks, after fabrication and before shipment, according to ASME and the following:
1. Horizontal, Steel USTs with the STI-P3 Corrosion-Protection System: UL 58 and STI P3.
 2. [Composite] [Composite and Jacketed] [Jacketed], Steel USTs: UL 58.
 3. FRP USTs: UL 1316.
- B. Affix standards organization's code stamp.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Unloading and Handling: Before unloading tanks, ensure that equipment used to lift

tanks has adequate rating for handling the load. Prepare the unloading and storage area by removing all rocks and debris, and arrange for supply of sandbags or tires to be used as chocks.

1. Factory-installed lifting lugs shall be used for lifting tanks; chain, cable, or other sling methods shall not be used. Use guy ropes to guide tanks as needed; do not move tanks by rolling them.
2. Whenever tanks are stored at site, they shall be chocked in place to prevent rolling. Tie-downs may be required under high wind conditions.

- B. Inspection: After delivery and before pre-installation testing, visually inspect the entire surface area for indications of damage, such as holes, cracks, or deep scrapes. If damage is detected, do not attempt repairs; contact tank manufacturer for evaluation and determination of appropriate action.

3.2 EXAMINATION

- A. Examine roughing-in for underground fuel-oil storage tanks to verify actual locations.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.
- B. Excavate to sufficient depth for a minimum of **36 inches (900 mm)** of earth cover from top of tank to finished grade. Allow for cast-in-place, concrete-ballast base plus **6 inches (150 mm)** of sand or pea gravel between ballast base and tank. Extend excavation at least **12 inches (300 mm)** around perimeter of tank.
- C. Backfill excavation with clean sand or pea gravel in **12-inch (305-mm)** lifts and tamp backfill lift to consolidate.
- D. Install filter mat between top of backfill material and earth fill.

3.4 PRE-INSTALLATION TESTING

- A. Before lowering tanks into final position, Contractor shall conduct a pre-installation test for each tank. Test pressure and test manifolds shall conform to manufacturer's recommendations. Contractor shall exercise caution to minimize the possibility of physical injuries or property damage, which could be caused by failure of any tank components under air-pressurized conditions.
1. Should any tank fail its test, Contractor shall not attempt repairs. Notify DEN Project Manager in writing. Contact tank manufacturer and comply with manufacturer's recommendations.

- B. Test Procedure: Comply with Field Quality Control article of this Section.

3.5 FUEL-OIL UST INSTALLATION

- A. Set tie-down eyelets for hold-down straps in concrete-ballast base and tie to reinforcing steel.
- B. Place 6 inches (152 mm) of clean sand or pea gravel (rounded particles, size between 1/8" and 3/4") on top of concrete-ballast base, evenly graded and thoroughly compacted, prior to tank placement.
- C. Tanks shall be unloaded and placed on the sand bed using crane and the rigging procedures required by the manufacturer. Use the tank lifting lugs for lifting into place. The use of slings around the tank is not permitted, nor is the use of chock blocks of any sort. During handling, carefully inspect the tank for coating damage and repair any damage whatsoever before proceeding.
- D. After placement, check tank to insure proper, uniform slope. The elevation shall be confirmed. Place the tank as required for the nozzles to be level in all directions.
- E. Before proceeding with backfill, install the hold down straps and tighten the turnbuckles securely and evenly throughout the length of the tank. The bottom and sides of tanks shall be fully and evenly supported by hand shoveling and tamping. Use clean sand to backfill up to 12" above the top of tank. Hand-guided power equipment can be used to place fill in 6" layers, compacted to a minimum of 95% maximum dry density, after the bottom quadrant is filled. A minimum of four density tests per tank to be performed. Clean, noncorrosive, well tamped gravel shall be used for backfill from a point 12" above the tank to subgrade for concrete slab.
- F.
- G.
- H. Install tank leak-detection and monitoring devices.
 - 1. Coordinate installation of the leak detection monitoring systems as specified with Division 26 and controls and instrumentation work.
- I. Install containment sumps.
- J. Install steel USTs with the STI-P3 corrosion-protection system according to STI R821 and STI R891. Protect anodes during tank placement and backfilling operations.
- K. Install composite, steel USTs according to STI R913 and STI R891.
- L. Install jacketed, steel USTs according to STI R923 and STI R891.
- M. Install FRP USTs with FRP hold-down straps, manhole extensions, and manhole risers.

- N. Do not fill the tank, even partially, before the bottom quadrant is backfilled. The level of product shall not exceed the level of compacted backfill at any time.
- O. Do not fill tanks until initial cleaning [**and tank strapping**] are performed, as outlined in articles below.
- P. Do not fill tank until approved to do so in writing by DEN Project Manager.
- Q. Test tanks in accordance with UL 142 standards and submit written test report.

3.6 BACKFILLING UST

- A. Backfill material shall be washed and free flowing, conforming to requirements of ASTM C 33, sizes 6 through 8. No more than 5 percent, by weight, of the material may pass through a #8 sieve. Backfill material shall not be mixed with sand or native soil.
- B. Tanks subject to traffic loads shall have a cover depth of at least 18 [**36**] inches of backfill plus 9 inches of asphaltic concrete pavement (or 6 inches of reinforced concrete pavement cover). Where both traffic loading and high water table conditions exist, cover depth of backfill shall be 30 [**36**] inches.
- C. Tanks shall be bedded on a smooth and uniform 12-inch (minimum) layer of approved backfill material, adjusted to provide tank pitch if required by drawing details. After tanks have been placed and leveled, the first diameter reading shall be taken, followed by anchoring tanks securely to anti-flotation slabs or deadman anchors as required by drawing details.
 - 1. Place one 12-inch lift of backfill material, and work material (by hand) completely beneath the tank body and domes to provide full support, using a probe long enough to reach under the tank to push backfill into place. Repeat this step for a second 12-inch lift.
 - 2. Install remainder of backfill in lifts not exceeding 12 inches, ensuring that no voids will exist adjacent to tanks. For all backfilling, exercise care to prevent damage to tanks from use of tamping bars or other tools.
- D. When backfill is flush with top of tank, an intermediate diameter reading shall be taken as an in-process check, and pre-installation air pressure tests, including soap solution testing of accessible areas, shall be repeated.

3.7 LIQUID-LEVEL GAGE SYSTEM INSTALLATION

- A. Install liquid-level gage system. Install panel inside building where indicated.

3.8 LEAK-DETECTION AND MONITORING SYSTEM INSTALLATION

- A. Install leak-detection and monitoring system. Install alarm panel inside building where indicated.

1. Double-Wall, Fuel-Oil Storage Tanks: **[Install probes] [Install probes or use factory-installed integral probes] [Use factory-installed integral probes]** in interstitial space.
2. Single-Wall, Fuel-Oil Storage Tanks: Install probes as indicated.
3. Double-Containment, Fuel-Oil Piping: Install leak-detection sensor **[probes in fuel-oil storage tank containment sumps and at low points in piping] [cable probes in interstitial space of double-containment piping]**.
4. Install liquid-level gage.

3.9 LABELING AND IDENTIFYING

- A. Nameplates, pipe identification, and signs are specified in Section 230553 "Identification for HVAC Piping and Equipment."
- B. Install detectable warning tape directly above UST, **[12 inches (304 mm)] <Insert dimension>** below finished grade, except **[6 inches (152 mm)] <Insert dimension>** below subgrade under pavements and slabs.
 1. Terminate tracer wire in an accessible area, and identify as "tracer wire" for future use with plastic-laminate sign.
 2. Install over edges of each UST.

3.10 INITIAL CLEANING

- A. The tanks shall be left in a completely clean and dry state. Close all uncovered openings with plywood covers fastened in a manner suitable for a permanent connection. Damage caused to the tank by the entry of foreign substances prior to coatings application shall be remedied by the Contractor at no additional cost to the Owner.

3.11 TANK STRAPPING

- A. After all installation work is complete, prepare a calibration table for the tanks showing the volume of fuel in gallons in the tank to the nearest tenth of a gallon at any height of liquid in hundredths of a foot units when measured by a steel tape lowered through the manual gauge well. Calibrate the tank in accordance with API 2550 for critical measurement. Calibration table shall be prepared by precisely metering integrated flow into each tank, simultaneously taking accurate depth measurements; calculation method of preparing the table is not acceptable. Furnish a certified record of the calibration for each tank to the DEN Project Manager.

3.12 FIELD QUALITY CONTROL

- A. Submit detailed procedures for testing methods for approval before starting tank installation. This includes all radiographing, pressure testing, and holiday testing.
- B. Upon request by DEN Project Manager, tank manufacturer shall have a representative

on Site during installation and testing of tank and representative shall remain until installation and testing are complete.

- C. Tests may be witnessed by DEN Project Manager.
1. Notify DEN Project Manager seven (7) days in advance of testing.
- D. Tanks shall be field tested for leakage immediately prior to installation.
- E. Tank tightness testing procedure after tank has been lowered into place and anchored, but before piping joints are concealed with backfill or other construction:
1. Tighten all tank connection fittings.
 2. Soap entire tank and fittings.
 3. Pressurize the tank with air to no more than 5 psig and visually inspect for leaks.
 - a. Use an air gauge with one-pound increments so that changes in pressure can be easily observed.
 - b. Retighten all leaking fittings until such leakage is stopped.
 - c. All damaged areas on the tank, which are found to be leaking shall be brought to the attention of the manufacturer's installation representative. The manufacturer's representative shall submit the proposed repair method to DEN Project Manager for review and acceptance.
 - d. Test shall not be considered complete until pressure has been maintained for two hours during which no leaks are detected.
 4. Tanks which have been repaired and those, which have been dropped or impacted after test shall be retested. Tanks shall continue to be retested until a successful leakage test is obtained.
- F. At least five (5) days' written notice shall be given to Engineer and DEN Project Manager for acceptance test to provide time to arrange for immediate fill of buried tanks with fuel after testing is complete. No liquid shall be put into the tank until sufficient backfill material has been placed outside to support it. Under no circumstances shall liquid be put into the tank to a level above the backfill height at any time during the installation.
- G. Tank Coating Testing Procedure:
1. Contractor shall make a detailed inspection with an appropriate voltage holiday tester of all tank coatings and joint coatings preceding the lowering of the tank.
 2. Holiday tester voltage shall not be higher than the manufacturer's recommended voltage for the coating tested. Testing shall be for holidays only and not to test the dielectric strength of the coating materials.
 3. All holidays and damaged or broken places in the coating shall be repaired in a workmanlike manner at Contractor's expense using the methods specified for field-applied external protective pipe coating and procedure in Section 220505 "Coatings and Corrosion Protection" and as recommended by manufacturer.
- H. Electrically test all insulating flanges and joints.

- I. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. Tanks: Minimum hydrostatic or compressed-air test pressures for fuel-oil storage tanks that have not been factory tested and do not bear the ASME code stamp or a listing mark acceptable to authorities having jurisdiction:
 - a. Double-Wall Tanks:
 - 1) Inner Tanks: Minimum **3 psig** (20.7 kPa) and maximum **5 psig** (34.5 kPa).
 - 2) Interstitial Space: Minimum **3 psig** (20.7 kPa) and maximum **5 psig** (34.5 kPa), or **5.3-in. Hg** (18-kPa) vacuum.
 - b. Where vertical height of fill and vent pipes is such that the static head imposed on the bottom of the tank is greater than **10 psig** (69 kPa), hydrostatically test the tank and fill and vent pipes to a pressure equal to the static head thus imposed.
 - c. Maintain the test pressure for one hour.
- J. USTs will be considered defective if they do not pass tests and inspections.
- K. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 231313

SECTION 231323 - FACILITY ABOVEGROUND FUEL-OIL STORAGE TANKS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Vertical, steel, fuel-oil ASTs.
 - 2. Horizontal, steel, fuel-oil ASTs.
 - 3. Containment-dike, steel, fuel-oil ASTs.
 - 4. Insulated, steel, fuel-oil ASTs.
 - 5. Concrete-vaulted, steel, fuel-oil ASTs.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. AST: Aboveground storage tank.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include manufacturer's installation and testing instructions.
 - 2. Include construction details, material descriptions, and dimensions of individual components and profiles.
 - 3. Tank specifications. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 4. Fuel-oil storage tank accessories.
 - 5. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Complete tank system drawings, fully dimensioned. Include plans, elevations, sections, and ballast pads and anchors, and lifting or supporting points.
 - 2. Indicate dimensions, components, and location and size of each field connection.
 - 3. Shop Drawing Scale: [1/4 inch per foot (1:50)] <Insert scale>.

1.5 INFORMATIONAL SUBMITTALS

- A. Site Survey: Plans, drawn to scale, on which fuel-oil storage tanks are shown and coordinated with other services and utilities.
- B. Qualification Data: For qualified professional engineer.
- C. Submit tank erector name and prior experience listing of projects.
- D. Seismic Qualification Certificates: For ASTs, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- E. Brazing certificates.
- F. Welding certificates.
- G. Field quality-control reports.
- H. Submit tank strapping charts after tanks are erected and field measurements have been made.
- I. Provide calculations for buoyancy of floating suction swingline.
- J. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fuel-oil equipment and accessories to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Contractor shall also provide a complete set of fabrication and erection drawings of the tanks at the Site which are to be kept up to date as as-constructed drawings during erection. At completion of erection, erection drawings shall be provided to DEN Project Manager.

1.7 QUALITY ASSURANCE

- A. EPA Compliance: Comply with EPA and state and local authorities having jurisdiction. Include recording of fuel-oil storage tanks and monitoring of tanks.
- B. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

1.8 DELIVERY, STORAGE AND HANDLING

- A. Comply with manufacturer's rigging and installation instructions.
- B. Special Precautions:
 - 1. The tank erector shall give special consideration to, and include adequate provisions for, prevention of tank shell damage during erection, due to high winds. Suitable structural bracing of the shell, both internally and externally, shall be provided and used at all times to prevent damage from winds.
 - 2. If damage from winds does occur, such as shell buckling or collapse, repairs shall be expedited to ensure minimal or no negative impact to the construction schedule. All additional materials required shall be provided and repair work performed at no cost to DEN. Any construction schedule time extensions resulting from wind damage shall result in no additional cost to DEN Project Manager.
 - 3. Any necessary repairs shall be performed in accordance with API 650 and API 653 as a minimum. Additionally, all damaged plates shall be replaced at the discretion of DEN. Final acceptance of any required repairs shall be by DEN. Note that visible defects, resulting from wind damage and allowed by the API standards may not be acceptable to DEN, potentially requiring repair or replacement of shell or bottom plates at no cost to DEN.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of fuel-oil storage tanks that fail in materials or workmanship within specified warranty period.
 - 1. Storage Tanks:
 - a. Failures include, but are not limited to, the following when used for storage of fuel oil at temperatures not exceeding [150 deg F (66 deg C)] **<Insert temperature>**:
 - 1) Structural failures including cracking, breakup, and collapse.
 - 2) Corrosion failure including external and internal corrosion of steel tanks.
 - b. Warranty Period: [30] **<Insert number>** years from date of Substantial Completion.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design restraint and anchors for fuel-oil ASTs, and equipment, including comprehensive engineering analysis, using performance requirements and design criteria indicated.
- B. Seismic Performance: Factory-installed support attachments for AST shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified **[and the unit will be fully operational after the seismic event].**"

2.2 STEEL **[FUEL]** STORAGE TANKS - GENERAL

- A. Tank: Closed type, conforming to UL 142 requirements **[and bearing UL stamp]**, of heavy gage welded steel (0.25 inch minimum thickness), with shop applied exterior prime coat.
1. All shell seams shall be made by buttwelding; lap joints are not acceptable. Weld joints shall be ground smooth.
- B. Construct tank with nozzles, manways, **[floating suction,]** **[and internal ladders]** as detailed on the drawings. **[No items in contact with fuel shall be fabricated of copper, copper-alloy, zinc, or galvanized materials.] [Include railed top access platforms as detailed, along with tappings for installation of accessories. Manufacturer shall include railed catwalks and access stairway as specified and shown on the drawings, with fabrication and assembly of all exterior access appurtenances in conformance with Division 05 requirements.]**
1. All manways shall be furnished complete with **[UL listed]** gaskets, bolts and covers. **[At least one manway cover for each tank shall be fitted with emergency pressure release feature conforming to requirements of NFPA 30.]**
- C. Provide fill, pump-out, **[drainable sump,]** and vent provisions as detailed. Include hold-down straps and turnbuckles as required for anchorage to supporting construction shown on the drawings.

- D. Provide grounding lug for each tank (1-1/2" x 1-1/2" x 1/4" steel, with 1/2" drilled hole), welded to bottom of tank adjacent to supporting pier for connection to grounding system under Division 26 work as indicated. Grounding lug shall not be painted.
- E. Interior Finishes:
1. Interior surfaces shall be coated by the manufacturer.
 2. Interior ferrous metal surfaces shall be protected by polyurethane coating as specified in Section 220505 "Coatings and Corrosion Protection".
 3. Protective wood covers shall be bolted to all flange nozzles and all tank couplings shall be plugged to protect interior of tank until installation.
- F. Interior Finishes:
1. Interior surfaces shall be coated by the manufacturer.
 2. Interior ferrous metal surfaces shall be coated with material meeting the requirements of MIL C 4556D. Refer to Section 220505 "Coatings and Corrosion Protection".
 3. Total dry film thickness shall be 6.0 mils minimum.
 4. Protective wood covers shall be bolted to all flange nozzles and all tank couplings shall be plugged to protect interior of tank until installation.
 5. Color shall be white.
- G. Exterior Surfaces:
1. The exterior of the tank, including manhole cover and extensions, shall be cleaned and coated in accordance with Division 09 requirements
- H. Fittings -Threaded - NPT:
1. All threaded fittings on UL-labeled tanks for storage of petroleum products shall be of a material and construction consistent with the requirements of the UL label. All fittings to be supplied with threaded plugs.
 2. All standard threaded fittings of 4-inch or smaller diameter shall be 4-inch half couplings. Reducers shall be used for smaller final connections.
 3. Thread Standards: All threaded fittings shall have machine tolerances in accordance with the ANSI standard for each fitting size.
 4. Inlet/Outlet connections: Note requirement that flanged inlet and outlet flanged connections must be of nominal pipe size 4 inches larger than the nominal sizes (6 inch and 8 inch, respectively) of the fire safety valves to be provided for inlets and outlets under Section 335243.13 "Aviation Fuel Piping, Valves and Fittings". Inlet and outlet nozzles shall be dual-flange type, with internal flange concentrically installed with, and of same size as, external flange. Coordinate for overall nozzle length with installation of fire safety valves.
 5. Provide, in accordance with UL 142 standards, tank shell reinforcing rings or plates for nozzles and openings for which size and/or imposed strains make shell reinforcement necessary.
- I. Ladders: Shall be standard carbon steel or stainless steel and shall be supplied by the tank manufacturer. Refer to drawings for location.

- J. Lifting Lugs: Provide lifting lugs on all tanks. Lugs shall be capable of withstanding weight of tank with a safety factor of 3 to 1.
- K. Floating Suction Swingline Assembly:
1. Provide flanged swing joints, Staytite or approved equivalent, with bronze bushings pressed into yoke mounted to the inside flange, same size as suction nozzle. Locate as indicated on drawings.
 2. Swing line pipe shall be fabricated of type 6048 aluminum or Schedule 10 steel conforming to ASTM A 53 or API 5L seamless or electric resistance welded. Pipe size to be same as suction nozzle. Steel pipe shall be coated inside before installation with two coat epoxy system conforming with MIL-C-4556-E.
 3. Design the swing pipe inlets for maximum velocity of 5 feet per second with flow rate of [1,600] <Insert value> gallons per minute.
 4. Provide pipe supports, with appropriate pipe support cradles, to support the swing line assembly a minimum of 12 inches above the bottom of the tank.
 5. Provide floats as necessary to ensure flotation of swing line, and position floats to ensure that fluid inlet is always at least 1'-0" below the surface of the liquid. Provide buoyancy calculations as specified under submittals requirements of this section.
 6. Provide stainless steel rope tether (ASTM A 492-82), secured to bottom of tank, to prevent swing line from contacting top of tank.
 7. Pneumatically test floats for leaks. Floats shall be equipped with suitable plugs for testing.
 8. Provide, for each tank, external target-type indicator to indicate operating height of floating suction assembly.

2.3 MATERIALS

- A. Material shall be carbon steel tank plate in conformance with standards referenced above, and suitable for the minimum design temperature of minus 25 degrees F [in accordance with API-650].
- B. Pipe and fittings:
1. Steel Pipe: Steel pipe shall be Grade B, black, welded or seamless pipe ASTM A 53; or API 5L, Furnace butt-welded pipe may be used in sizes 2-inches and smaller. Sizes smaller than 2-inches shall be Schedule 80. Sizes 2-inch and larger shall be Schedule 40 for sizes up to and including 10 inches.
 2. Welding Fittings: Welding fittings shall conform to ANSI B16.9 and ASTM A 234, Grade WPB for use with carbon steel pipe. Welding outlets shall be standard weight forged steel conforming to ASTM A 181, Grade 1.
 3. Forged Welding Flanges: Flanges shall be carbon steel conforming to ANSI B16.5, Class 150, except as otherwise specified. Flanged facings shall correspond to the equipment to which the piping is joined. Materials shall conform to the requirements of ASTM A 181 or to ASTM A 105.
 4. Bolting: Flange bolts and nuts shall conform to the requirements of ASTM A 307, Grade B, square bolt heads and hexagon nuts.
 5. Threaded Steel Fittings: Threaded fittings, shall be Pressure Class 3000 conforming to ANSI B16.11. Fittings material shall be ASTM A 105.

6. Nipples: Carbon Steel pipe nipples shall be of the same material as the pipe they join and shall conform to the requirements of ASTM A 733.
7. Gaskets: Gaskets for use with flanged connections shall be 1/8 inch thick and shall conform to the requirements of Section 335243.13 "Aviation Fuel Piping, Valves and Fittings".

2.4 VERTICAL, STEEL, FUEL-OIL AST

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Ace Tank & Fueling Equipment, LLC.](#)
 2. [Adamson Global Technology Corporation.](#)
 3. [Brown Tank LLC.](#)
 4. [Buffalo Tank Company, Inc.](#)
 5. [Cardinal Tank Corp.](#)
 6. [Clawson Tank Company.](#)
 7. [Hall Tank Co.](#)
 8. [Highland Tank & Manufacturing Company, Inc.](#)
 9. [Modern Welding Company, Inc.](#)
 10. [Palmer Manufacturing & Tank Inc.](#)
 11. [Steel Tank & Fabricating Co., Inc.](#)
 12. [Watco Tanks, Inc.](#)
 13. [We-Mac Manufacturing, Inc.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Description: UL 142, single-wall, vertical, steel tank.
- C. Description: UL 142[**and STI F921**], double-wall, vertical, steel tank; with primary- and secondary-containment walls and interstitial space.
- D. Construction: Fabricated with welded, carbon steel suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and maintained temperature up to **150 deg F** (66 deg C).
- E. Capacities and Characteristics:
1. Capacity: **<Insert gal. (L)>.**
 2. Diameter: **<Insert feet (m)>.**
 3. Length: **<Insert feet (m)>.**
 4. Connection Sizes:
 - a. Fill Line: **<Insert NPS (DN)>.**
 - b. Vent Line: **<Insert NPS (DN)>.**
 - c. Outlet: **<Insert NPS (DN)>.**
 - d. Return: **<Insert NPS (DN)>.**
 - e. Gage: **<Insert NPS (DN)>.**

5. Manholes:
 - a. Number Required: **<Insert number>**.
 - b. Diameter: **<Insert inches (mm)>**.
6. Fuel-Oil Grade Number: **[Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>**.

2.5 HORIZONTAL, STEEL, FUEL-OIL AST

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Ace Tank & Fueling Equipment, LLC.](#)
 2. [Adamson Global Technology Corporation.](#)
 3. [Brown Tank LLC.](#)
 4. [Buffalo Tank Company, Inc.](#)
 5. [Cardinal Tank Corp.](#)
 6. [Clawson Tank Company.](#)
 7. [Hall Tank Co.](#)
 8. [Highland Tank & Manufacturing Company, Inc.](#)
 9. [Modern Welding Company, Inc.](#)
 10. [Palmer Manufacturing & Tank Inc.](#)
 11. [Safe-T-Tank Corp.](#)
 12. [Steel Tank & Fabricating Co., Inc.](#)
 13. [Watco Tanks, Inc.](#)
 14. [We-Mac Manufacturing, Inc.](#)
 15. **<Insert manufacturer's name>**.
 16. or approved equal.
- B. Description: UL 142, single-wall, horizontal, steel tank.
- C. Description: UL 142[**and STI F921**], double-wall, horizontal, steel tank; with primary- and secondary-containment walls and interstitial space.
- D. Construction: Fabricated with welded, carbon steel; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with maintained temperature up to **150 deg F** (66 deg C).
- E. Supports: Manufacturer's standard structural steel welded to tank.
- F. Supports: Manufacturer's standard type[**and number**], steel or cast-iron cradles, for field installation.
 1. Number of Supports: **<Insert number>**.
- G. Capacities and Characteristics:
 1. Capacity: **<Insert gal. (L)>**.
 2. Diameter: **<Insert feet (m)>**.
 3. Length: **<Insert feet (m)>**.

4. Connection Sizes:
 - a. Fill Line: <Insert NPS (DN)>.
 - b. Vent Line: <Insert NPS (DN)>.
 - c. Outlet: <Insert NPS (DN)>.
 - d. Return: <Insert NPS (DN)>.
 - e. Gage: <Insert NPS (DN)>.
5. Manholes:
 - a. Number Required: <Insert number>.
 - b. Diameter: <Insert inches (mm)>.
6. Fuel-Oil Grade Number: [Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>.

2.6 CONTAINMENT-DIKE, STEEL, FUEL-OIL AST

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Areo Power Unitized Fueler Inc.](#)
 2. [Buffalo Tank Company, Inc.](#)
 3. [Cardinal Tank Corp.](#)
 4. [Hall Tank Co.](#)
 5. [Highland Tank & Manufacturing Company, Inc.](#)
 6. [Modern Welding Company, Inc.](#)
 7. [Palmer Manufacturing & Tank Inc.](#)
 8. [Safe-T-Tank Corp.](#)
 9. [Watco Tanks, Inc.](#)
 10. [We-Mac Manufacturing, Inc.](#)
 11. <Insert manufacturer's name>.
 12. or approved equal.
- B. Description: UL 142 and STI F911, single-wall, horizontal, steel tank; with [**open or enclosed**] [**enclosed**], secondary-containment dike with capacity greater than tank capacity.
- C. Construction: Fabricated with welded, carbon steel; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with maintained temperature up to **150 deg F** (66 deg C).
- D. Capacities and Characteristics:
 1. Capacity: <Insert gal. (L)>.
 2. Diameter: <Insert feet (m)>.
 3. Length: <Insert feet (m)>.
 4. Connection Sizes:
 - a. Fill Line: <Insert NPS (DN)>.

- b. Vent Line: **<Insert NPS (DN)>**.
 - c. Outlet: **<Insert NPS (DN)>**.
 - d. Return: **<Insert NPS (DN)>**.
 - e. Gage: **<Insert NPS (DN)>**.
5. Manholes:
- a. Number Required: **<Insert number>**.
 - b. Diameter: **<Insert inches (mm)>**.
6. Fuel-Oil Grade Number: **[Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>**.

2.7 INSULATED, STEEL, FUEL-OIL AST

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Ace Tank & Fueling Equipment, LLC.](#)
 2. [Adamson Global Technology Corporation.](#)
 3. [Areo Power Unitized Fueler Inc.](#)
 4. [Brown Tank LLC.](#)
 5. [ConVault, Inc.](#)
 6. [Hamilton Tanks.](#)
 7. [Highland Tank & Manufacturing Company, Inc.](#)
 8. [Modern Welding Company, Inc.](#)
 9. [Palmer Manufacturing & Tank Inc.](#)
 10. [Steel Tank & Fabricating Co., Inc.](#)
 11. [We-Mac Manufacturing, Inc.](#)
 12. **<Insert manufacturer's name>**.
 13. or approved equal.
- B. Description: **[UL 142 and UL 2085] [UL 142, UL 2085, and STI F941]**, thermally insulated and fire-resistant, double-wall, horizontal, steel tank; with primary- and secondary-containment walls and insulation and with interstitial space.
- C. Construction: Fabricated with welded, carbon steel and insulation; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with test temperature according to UL 2085.
- D. Capacities and Characteristics:
1. Capacity: **<Insert gal. (L)>**.
 2. Diameter: **<Insert feet (m)>**.
 3. Length: **<Insert feet (m)>**.
 4. Connection Sizes:
 - a. Fill Line: **<Insert NPS (DN)>**.
 - b. Vent Line: **<Insert NPS (DN)>**.
 - c. Outlet: **<Insert NPS (DN)>**.

- d. Return: <Insert NPS (DN)>.
 - e. Gage: <Insert NPS (DN)>.
5. Manholes:
- a. Number Required: <Insert number>.
 - b. Diameter: <Insert inches (mm)>.
6. Fuel-Oil Grade Number: [Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>.

2.8 CONCRETE-VAULTED, STEEL, FUEL-OIL AST

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Cardinal Tank Corp.](#)
2. [ConVault, Inc.](#)
3. [EcoVault, Inc.](#)
4. <Insert manufacturer's name>.
5. or approved equal.

B. Description: [UL 142 and UL 2085] [UL 142, UL 2085, and STI F941]; thermally insulated, fire-resistant and protected, double-wall, horizontal, steel tank; with primary- and secondary-containment walls and insulation and with interstitial space.

C. Construction: Fabricated with welded, carbon steel and insulation and encased in concrete that will protect from bullets; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with test temperature according to UL 2085.

D. Capacities and Characteristics:

1. Capacity: <Insert gal. (L)>.
2. Diameter: <Insert feet (m)>.
3. Length: <Insert feet (m)>.
4. Connection Sizes:
 - a. Fill Line: <Insert NPS (DN)>.
 - b. Vent Line: <Insert NPS (DN)>.
 - c. Outlet: <Insert NPS (DN)>.
 - d. Return: <Insert NPS (DN)>.
 - e. Gage: <Insert NPS (DN)>.
5. Manholes:
 - a. Number Required: <Insert number>.
 - b. Diameter: <Insert inches (mm)>.
6. Fuel-Oil Grade Number: [Grade No. 1] [Grade No. 2] [Diesel] <Insert grade>.

2.9 SHOP PAINTING OF AST

- A. Apply manufacturer's standard prime coat to exterior steel surface of AST[**and supports**].
- B. Prepare exterior steel surface of AST[**and tank supports**].
- C. Shop Cleaning: After fabrication, blast clean according to [SSPC-SP 6/NACE No. 3] [SSPC-SP 10/NACE No. 2].
- D. After cleaning, remove dust or residue from cleaned surfaces.
- E. If surface develops rust before prime coat is applied, repeat surface preparation.
- F. Apply manufacturer's standard prime coat to shop-cleaned, dry surface same day as surface preparation.
- G. Apply manufacturer's standard two-component, epoxy finish coats.

2.10 FUEL-OIL AST ACCESSORIES

- A. Tank Manholes: **22-inch-** (560-mm-) minimum diameter; bolted, flanged, and gasketed; centered on top of tank.
- B. Tank Manholes: **22-inch-** (560-mm-) minimum diameter; bolted, flanged, and gasketed; on top and at side of tank.
- C. Threaded pipe connection fittings on top of tank, for fill, supply, return, vent, sounding, and gaging. Include cast-iron plugs for shipping.
- D. Threaded pipe connection fittings on top or sides of tank as indicated, for fill, supply, return, vent, sounding, and gaging. Include cast-iron plugs for shipping.
- E. Striker Plates: Inside tank, on bottom below fill, vent, sounding, gage, and other tube openings.
- F. Lifting Lugs: For handling and installation.
- G. Ladders: Carbon-steel ladder inside tank, anchored to top and bottom, and located as indicated. Include reinforcement of tank at bottom of ladder.
- H. Ladders: Carbon-steel ladder outside tank, anchored to top and side wall. Comply with requirements in Section 055000 "Metal Fabrications" for exterior steel ladder.
 - 1. Cage: Include welded steel cage around ladders for tanks [20 feet (6 m)] <Insert dimension> high or higher.
- I. Supply Tube: Extension of supply piping fitting into tank, terminating **6 inches** (150 mm) above tank bottom and cut at a **45-degree angle** (1:1 slope).

- J. Sounding and Gage Tubes: Extension of fitting into tank, terminating **6 inches** (150 mm) above tank bottom and cut at a **45-degree angle** (1:1 slope).

2.11 LIQUID-LEVEL GAGE SYSTEM

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Caldwell Systems Corporation.](#)
2. [Clawson Tank Company.](#)
3. [Franklin Fueling Systems.](#)
4. [Highland Tank & Manufacturing Company, Inc.](#)
5. [INCON.](#)
6. [King Engineering Corp.](#)
7. [Krueger Sentry Gauge.](#)
8. [Pneumercator Inc.](#)
9. [Preferred Utilities Manufacturing Corporation.](#)
10. [Rochester Gauges, Inc.](#)
11. [Tuthill Corporation; Tuthill Transfer Systems; Sotera Systems.](#)
12. [Uehling Instrument Company.](#)
13. [Venture Measurement Company, LLC.](#)
14. **<Insert manufacturer's name>.**
15. or approved equal.

- B. Description: Calibrated liquid-level gage system complying with [**UL 180 with floats**] [**UL 1238 with probes**] or other sensors and remote annunciator panel.

- C. Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms; fuel indicator with registration in **gallons** (liters); and overfill alarm. Include gage volume range that covers fuel-oil storage capacity.

- D. Controls: Electrical, operating on [**120**] **<Insert voltage>**-V ac.

2.12 LEAK-DETECTION AND MONITORING SYSTEM

- A. Cable and Sensor System: Comply with UL 1238.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Caldwell Systems Corporation.](#)
- b. [Containment Solutions, Inc.](#)
- c. [Franklin Fueling Systems.](#)
- d. [Gems Sensors & Controls Inc.](#)
- e. [Highland Tank & Manufacturing Company, Inc.](#)
- f. [INCON.](#)
- g. [In-Situ, Inc.](#)
- h. [MSA; Instrument Div.](#)

- i. [Pentair Thermal Management](#).
 - j. [Perma-Pipe, Inc.](#)
 - k. [Pneumercator Inc.](#)
 - l. [Raychem Corp; Tyco Electronics Corporation](#).
 - m. [Tuthill Corporation; Tuthill Transfer Systems; Sotera Systems](#).
 - n. [Veeder-Root; a Danaher Corporation company](#).
 - o. **<Insert manufacturer's name>**.
 - p. or approved equal.
 2. Calibrated leak-detection and monitoring system with probes and other sensors and remote alarm panel for fuel-oil storage tanks and fuel-oil piping.
 3. Include fittings and devices required for testing.
 4. Controls: Electrical, operating on [120] **<Insert voltage>**-V ac.
 5. Calibrated liquid-level gage complying with [UL 180 with floats] [UL 1238 with probes] or other sensors and remote annunciator panel.
 6. Remote Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms; fuel indicator with registration in gallons ((liters);) and overfill alarm. Include gage volume range that covers fuel-oil storage capacity.
 7. Controls: Electrical, operating on [120] **<Insert voltage>**-V ac.
- B. Hydrostatic System: Comply with UL 1238.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Caldwell Systems Corporation](#).
 - b. [Containment Solutions, Inc.](#)
 - c. [Franklin Fueling Systems](#).
 - d. [Gems Sensors & Controls Inc.](#)
 - e. [Highland Tank & Manufacturing Company, Inc.](#)
 - f. [INCON](#).
 - g. [In-Situ, Inc.](#)
 - h. [MSA; Instrument Div.](#)
 - i. [Pentair Thermal Management](#).
 - j. [Perma-Pipe, Inc.](#)
 - k. [Pneumercator Inc.](#)
 - l. [Raychem Corp; Tyco Electronics Corporation](#).
 - m. [Tuthill Corporation; Tuthill Transfer Systems; Sotera Systems](#).
 - n. [Veeder-Root; a Danaher Corporation company](#).
 - o. **<Insert manufacturer's name>**.
 - p. or approved equal.
 2. Calibrated leak-detection and monitoring system with brine antifreeze solution, reservoir sensor, and electronic control panel to monitor leaks in inner and outer tank walls.
 3. Include fittings and devices required for testing.
 4. Controls: Electrical, operating on [120] **<Insert voltage>**-V ac.
 5. Calibrated liquid-level gage complying with [UL 180 with floats] [UL 1238 with probes] or other sensors and remote annunciator panel.
 6. Remote Annunciator Panel: With visual and audible, high-tank-level and

- low-tank-level alarms; fuel indicator with registration in gallons (liters); and overflow alarm. Include gage volume range that covers fuel-oil storage capacity.
7. Controls: Electrical, operating on [120] <Insert voltage>-V ac.

2.13 FUEL OIL

- A. Fuel Oil: ASTM D 396, [Grade No. 1] [Grade No. 2].
- B. Diesel Fuel Oil: ASTM D 975, [Grade Low Sulfur] [Grade No. 1-D, special purpose] [Grade No. 2-D, general purpose], high volatility.

2.14 SOURCE QUALITY CONTROL

- A. Pressure test and inspect fuel-oil storage tanks, after fabrication and before shipment, according to ASME and the following:
1. [Vertical] [Vertical or Horizontal] [Horizontal], Single-Wall Steel ASTs: UL 142.
 2. [Vertical] [Vertical or Horizontal] [Horizontal], Double-Wall Steel ASTs: UL 142, STI F921, and STI R931.
 3. Horizontal, Containment-Dike, Steel ASTs: UL 142 and STI F911.
 4. Horizontal, [Concrete-Vaulted] [Concrete-Vaulted and Insulated] [Insulated], Steel ASTs: UL 142 and UL 2085.
- B. Affix standards organization's code stamp.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for aboveground fuel-oil storage tanks to verify actual locations.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.
- B. Allow for cast-in-place, concrete base.

3.3 INSTALLATION - GENERAL

- A. Install tanks in strict conformity with manufacturer's instructions. [Install hold-down straps, secured to anchor bolts provided as Division 03 work.]

- B. Test tanks in accordance with UL 142 standards and submit written test report.

3.4 FUEL-OIL AST INSTALLATION

- A. Install tank bases and supports.
- B. Concrete Bases: Anchor AST to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project.
 1. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.
 2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on [18-inch (457-mm)] <Insert dimension> centers around the full perimeter of the base.
 3. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
 4. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 5. Install anchor bolts to elevations required for proper attachment to supported equipment.
 6. Use [3000-psi (20.7-MPa)] <Insert dimension>, 28-day, compressive-strength concrete and reinforcement as specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
- C. Connect piping and vent fittings.
- D. Install ground connections.
- E. Install tank leak-detection and monitoring devices.
- F. Install steel ASTs according to STI R912.
- G. Install insulated and concrete-vaulted, steel ASTs according to STI R942.
- H. Fill storage tanks with fuel oil.

3.5 LIQUID-LEVEL GAGE SYSTEM INSTALLATION

- A. Install liquid-level gage system. Install panel inside building where indicated.

3.6 LEAK-DETECTION AND MONITORING SYSTEM INSTALLATION

- A. Install leak-detection and monitoring system. Install alarm panel inside building where indicated.

1. Double-Wall, Fuel-Oil Storage Tanks: **[Install probes] [Install probes or use factory-installed integral probes] [Use factory-installed integral probes]** in interstitial space.
2. Single-Wall, Fuel-Oil Storage Tanks: Install probes as indicated.
3. Double-Containment, Fuel-Oil Piping: Install leak-detection sensor **[probes in fuel-oil storage tank containment sumps and at low points in piping] [cable probes in interstitial space of double-containment piping]**.
4. Install liquid-level gage.

3.7 LABELING AND IDENTIFYING

- A. Nameplates, pipe identification, and signs are specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.8 FIELD PAINTING OF AST

- A. Prepare and touch up damaged exterior surface of AST **[and supports]** as specified in "Shop Painting of AST" Article.
- B. Prepare exterior steel surface of AST **[and tank supports]**.
- C. Field Cleaning: After fabrication, blast clean according to **[SSPC-SP 6/NACE No. 3] [SSPC-SP 10/NACE No. 2]**.
- D. After cleaning, remove dust or residue from cleaned surfaces.
- E. If surfaces develop rust before prime coat is applied, repeat surface preparation.
- F. Prepare surface of AST **[and supports]** and apply painting systems according to specifications in Section 099600 "High-Performance Coatings" for **[severe] [moderate] [mild]** environment **[high-gloss] [semigloss]** finish for ferrous metal.

3.9 LIGHTING SYSTEMS

- A. Lighting system shall be installed as indicated on electrical Drawings and as specified in Division 26 and coordinated with Work of this Section.

3.10 LIGHTNING PROTECTION SYSTEMS

- A. Lightning protection system shall be installed as indicated on electrical Drawings and as specified in Division 26 and coordinated with the Work of this Section.

3.11 FIRE PROTECTION

- A. Fire protection equipment shall be provided as specified in Division 21 and coordinated with the Work of this Section.

3.12 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Tanks: Minimum hydrostatic or compressed-air test pressures for fuel-oil storage tanks that have not been factory tested and do not bear the ASME code stamp or a listing mark acceptable to authorities having jurisdiction:
 - a. Single-Wall Tanks: Minimum **3 psig** (20.7 kPa) and maximum **5 psig** (34.5 kPa).
 - b. Double-Wall Tanks:
 - 1) Inner Tanks: Minimum **3 psig** (20.7 kPa) and maximum **5 psig** (34.5 kPa).
 - 2) Interstitial Space: Minimum **3 psig** (20.7 kPa) and maximum **5 psig** (34.5 kPa), or **5.3-in. Hg** (18-kPa) vacuum.
 - c. Where vertical height of fill and vent pipes is such that the static head imposed on the bottom of the tank is greater than **10 psig** (69 kPa), hydrostatically test the tank and fill and vent pipes to a pressure equal to the static head thus imposed.
 - d. Maintain the test pressure for one hour.
- C. ASTs will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.13 INITIAL CLEANING

- A. The tanks shall be left in a completely clean and dry state. Close all uncovered openings with plywood covers fastened in a manner suitable for a permanent connection. Damage caused to the tank by the entry of foreign substances prior to coatings application shall be remedied by the Contractor at no additional cost to the Owner.

3.14 TANK STRAPPING

- A. After all installation work is complete, prepare a calibration table for the tanks showing the volume of fuel in gallons in the tank to the nearest tenth of a gallon at any height of liquid in hundredths of a foot units when measured by a steel tape lowered through the manual gauge well. Calibrate the tank in accordance with API 2550 for critical measurement. Calibration table shall be prepared by precisely metering integrated flow into each tank, simultaneously taking accurate depth measurements; calculation method of preparing the table is not acceptable. Furnish a certified record of the

calibration for each tank to the DEN Project Manager.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 231323

SECTION 232113 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes pipe and fitting materials and joining methods for the following:
 - 1. Hot-water heating piping.
 - 2. Chilled-water piping.
 - 3. Dual-temperature heating and cooling water piping.
 - 4. Condenser-water piping.
 - 5. Glycol cooling-water piping.
 - 6. Makeup-water piping.
 - 7. Condensate-drain piping.
 - 8. Blowdown-drain piping.
 - 9. Air-vent piping.
 - 10. Safety-valve-inlet and -outlet piping.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: Include data on pipe materials, pipe fittings, and accessories. Provide manufacturers catalogue information. Include flow and pressure drop curves based on manufacturer's testing for diverting fittings, calibrated balancing valves, and automatic flow-control valves. Include the following:
 - 1. Plastic pipe and fittings with solvent cement.
 - 2. RTRP and RTRF with adhesive.
 - 3. Pressure-seal fittings.
 - 4. Chemical treatment.
 - 5. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.
 - 2. Laboratory Test Reports for Credit IEQ 4.1: For solvent cements and adhesive

primers, documentation indicating that products comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

- C. Shop Drawings: For buried runs of insulated piping [**and <Insert other>**], submit drawings accurately showing piping layout, indicating:
1. Lengths of each straight section of piping run and calculated amount of expansion or contraction applicable for each straight section of run based on design temperature range of piping system contents.
 2. Details of provisions, which will be applied (where needed, based on manufacturer's recommendations and subject to the DEN Project Manager's approval) to accommodate expansion and contraction in a manner acceptably protecting the installation and adequately maintaining effectiveness of insulation.
- D. Shop Drawings: Detail fabrication of pipe anchors, hangers, special pipe support assemblies, alignment guides, expansion joints and loops, and their attachment to the building structure. Detail location of anchors, alignment guides, and expansion joints and loops.
- E. Delegated-Design Submittal:
1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
 2. Locations of pipe anchors and alignment guides and expansion joints and loops.
 3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
 4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Suspended ceiling components.
 2. Other building services.
 3. Structural members.
- B. Qualification Data: For Installer.
- C. Welding certificates. Include welders certification of compliance with [**ASME SEC 9**] [**AWS D1.1.**] **<Insert requirement>**.
- D. Pneumatic Leak Test:

1. Contractor shall submit drawings and procedures of the pneumatic leak test to the DEN Project Manager no later than two (2) weeks prior to testing. Contractor may not proceed with tests unless approved in writing by the DEN Project Manager.
- E. Field Quality Control Test Reports: Written reports of tests specified in Part 3 of this Section. Include the following:
1. Test procedures used.
 2. Test results that comply with requirements.
 3. Failed test results and corrective action taken to achieve requirements.
- F. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For hydronic specialties and special-duty valves to include in maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
1. Record actual locations of valves, piping and anchors.
- C. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Drawings to be submitted in current DEN approved format as per requirements of Division 01. Other file formats will not be accepted.

1.6 EXTRA STOCK

- A. Provide [**two (2)**] <Insert number> repacking kits for each size and valve type.

1.7 QUALITY ASSURANCE

- A. Manufacture: Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.
- B. Manufacturer's Qualifications:
1. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum [**three (3)**] <Insert number> years documented experience.
- C. Installer Qualifications:

1. Installer: Company specializing in performing the Work of this Section [**with minimum five (5)**] <Insert requirements> years documented experience].
 2. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.
 3. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.
- D. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- E. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.
1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
 2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.
 3. Provide certificate of compliance from [**authority having jurisdiction**] <Insert authority> indicating approval of welders.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" Division 01 requirements.
- B. Accept components on site in shipping containers with labeling in place. Inspect for damage. Collect and save installation instructions for DEN Project Manager's use.
- C. Provide temporary end caps and closures on piping and fittings. Maintain in place until installation.
- D. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:
1. Hot-Water Heating Piping: <Insert psig (kPa)> at [200 deg F (121 deg C)] <Insert temperature>.
 2. Chilled-Water Piping: <Insert psig (kPa)> at [200 deg F (93 deg C)] <Insert temperature>.
 3. Dual-Temperature Heating and Cooling Water Piping: <Insert psig (kPa)> at [200 deg F (93 deg C)] <Insert temperature>.
 4. Condenser-Water Piping: <Insert psig (kPa)> at [150 deg F (66 deg C)] <Insert temperature>.
 5. Glycol Cooling-Water Piping: <Insert psig (kPa)> at [150 deg F (66 deg C)] <Insert temperature>.
 6. Makeup-Water Piping: [80 psig (552 kPa)] <Insert value> at [150 deg F (66 deg C)] <Insert temperature>.
 7. Condensate-Drain Piping: [150 deg F (66 deg C)] <Insert temperature>.
 8. Blowdown-Drain Piping: [200 deg F (93 deg C)] <Insert temperature>.
 9. Air-Vent Piping: [200 deg F (93 deg C)] <Insert temperature>.
 10. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 COPPER TUBE AND FITTINGS

- A. Drawn-Temper Copper Tubing: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M, Type C)].
- B. Annealed-Temper Copper Tubing: ASTM B 88, Type K (ASTM B 88M, Type A).
- C. DWV Copper Tubing: ASTM B 306, Type DWV.
- D. Copper or Bronze Pressure-Seal Fittings:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. NIBCO INC.
 - b. Viega.
 - c. <Insert manufacturer's name>.
 - d. or approved equal.
 2. Housing: Copper.
 3. O-Rings and Pipe Stops: EPDM.
 4. Tools: Manufacturer's special tools.
 5. Minimum 200-psig (1379-kPa) working-pressure rating at 250 deg F (121 deg C).

E. Copper, Mechanically Formed Tee Option: For forming T-branch on copper water tube.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [T-DRILL Industries Inc.](#)
- b. **<Insert manufacturer's name>.**
- c. or approved equal.

F. Wrought-Copper Unions: ASME B16.22.

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

H. Steel Pressure-Seal Fittings:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. [Victaulic Company.](#)
- b. **<Insert manufacturer's name>.**
- c. or approved equal.

2. Housing: Steel.
3. O-Rings and Pipe Stop: EPDM.

4. Tools: Manufacturer's special tool.
5. Minimum 300-psig (2070-kPa) working-pressure rating at 230 deg F (110 deg C).

- I. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.4 PLASTIC PIPE AND FITTINGS

- A. CPVC Plastic Pipe: ASTM F 441/F 441M, with wall thickness as indicated in "Piping Applications" Article.
 1. CPVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM F 438 for Schedule 40 pipe; ASTM F 439 for Schedule 80 pipe.
- B. PVC Plastic Pipe: ASTM D 1785, with wall thickness as indicated in "Piping Applications" Article.
 1. PVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM D 2466 for Schedule 40 pipe; ASTM D 2467 for Schedule 80 pipe.

2.5 FIBERGLASS PIPE AND FITTINGS

- A. RTRP: ASTM D 2996, filament-wound pipe with tapered bell and spigot ends for adhesive joints.
- B. RTRF: Compression or spray-up/contact molded of same material, pressure class, and joining method as pipe.
- C. Flanges: ASTM D 4024. Full-face gaskets suitable for the service, minimum 1/8-inch (3.2-mm) thick, 60-70 durometer. ASTM A 307, Grade B, hex head bolts with washers.

2.6 JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
 1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch (3.2-mm) maximum thickness unless otherwise indicated.
 - a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
- B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.
- D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux

according to ASTM B 813.

- E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.
- F. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- G. Solvent Cements for Joining Plastic Piping:
 - 1. CPVC Piping: ASTM F 493.
 - a. CPVC solvent cement shall have a VOC content of 490 g/L or less.
 - b. Adhesive primer shall have a VOC content of 550 g/L or less.
 - c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
 - 2. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.
 - a. PVC solvent cement shall have a VOC content of 510 g/L or less.
 - b. Adhesive primer shall have a VOC content of 550 g/L or less.
 - c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
- H. Fiberglass Pipe Adhesive: As furnished or recommended by pipe manufacturer.
 - 1. Fiberglass adhesive shall have a VOC content of 80 g/L or less.
 - 2. Adhesive shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
- I. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.7 TRANSITION FITTINGS

- A. Plastic-to-Metal Transition Fittings:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Charlotte Pipe and Foundry Company.

- b. [IPEX Inc.](#)
 - c. [KBI \(King Bros. Industries\).](#)
 - d. **<Insert manufacturer's name>.**
 - e. or approved equal.
2. One-piece fitting with one threaded brass or copper insert and one solvent-cement-joint end of material and wall thickness to match plastic pipe material.

B. Plastic-to-Metal Transition Unions:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Charlotte Pipe and Foundry Company.](#)
 - b. [IPEX Inc.](#)
 - c. [KBI \(King Bros. Industries\).](#)
 - d. [NIBCO INC;](#) Model #T/S-1710.
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
2. Brass or copper end, solvent-cement-joint end of material and wall thickness to match plastic pipe material, rubber gasket, and threaded union.

2.8 DIELECTRIC FITTINGS

- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [A.Y. McDonald Mfg. Co.](#)
 - b. [Capitol Manufacturing Company.](#)
 - c. [Central Plastics Company.](#)
 - d. [Hart Industries International, Inc.](#)
 - e. [Jomar International, Ltd.](#)
 - f. [Matco-Norca.](#)
 - g. [Watts Regulator Co.](#)
 - h. [Zurn Industries, LLC; AquaSpec Commercial Faucet Products.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
2. Description:
 - a. Standard: ASSE 1079.
 - b. Pressure Rating: **[125 psig (860 kPa) minimum at 180 deg F (82 deg C)]**

- [150 psig (1035 kPa)] [250 psig (1725 kPa)] <Insert value>.
- c. End Connections: Solder-joint copper alloy and threaded ferrous.

C. Dielectric Flanges:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
- a. [Capitol Manufacturing Company.](#)
 - b. [Central Plastics Company.](#)
 - c. [Matco-Norca.](#)
 - d. [Watts Regulator Co.](#)
 - e. [Zurn Industries, LLC; AquaSpec Commercial Faucet Products.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
2. Description:
- a. Standard: ASSE 1079.
 - b. Factory-fabricated, bolted, companion-flange assembly.
 - c. Pressure Rating: [125 psig (860 kPa) **minimum at 180 deg F (82 deg C)**] [150 psig (1035 kPa)] [175 psig (1200 kPa)] [300 psig (2070 kPa)] <Insert value>.
 - d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
- a. [Advance Products & Systems, Inc.](#)
 - b. [Calpico, Inc.](#)
 - c. [Central Plastics Company.](#)
 - d. [Pipeline Seal and Insulator, Inc.](#)
 - e. <Insert manufacturer's name>.
 - f. or approved equal.
2. Description:
- a. Nonconducting materials for field assembly of companion flanges.
 - b. Pressure Rating: [150 psig (1035 kPa)] <Insert value>.
 - c. Gasket: Neoprene or phenolic.
 - d. Bolt Sleeves: Phenolic or polyethylene.
 - e. Washers: Phenolic with steel backing washers.

E. Dielectric Nipples:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Elster Perfection.](#)
- b. [Grinnell Mechanical Products.](#)
- c. [Matco-Norca.](#)
- d. [Precision Plumbing Products, Inc.](#)
- e. [Victaulic Company.](#)
- f. <Insert manufacturer's name>.
- g. or approved equal.

2. Description:

- a. Standard: IAPMO PS 66.
- b. Electroplated steel nipple, complying with ASTM F 1545.
- c. Pressure Rating: [300 psig (2070 kPa) at 225 deg F (107 deg C)] <Insert value and temperature>.
- d. End Connections: Male threaded.
- e. Lining: Inert and noncorrosive, propylene.

2.9 BYPASS CHEMICAL FEEDER

- A. Description: Welded steel construction; 125-psig (860-kPa) working pressure; 5-gal. (19-L) capacity; with fill funnel and inlet, outlet, and drain valves.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

PART 3 - EXECUTION

3.1 ENVIRONMENTAL REQUIREMENTS

- A. Do not install underground piping when bedding is wet or frozen.

3.2 GENERAL

- A. Where more than one piping system material is specified, ensure system components are compatible and joined to ensure the integrity of the system is not jeopardized. Provide necessary joining fittings. Ensure flanges, union, and couplings for servicing are consistently provided.
- B. Use unions, flanges, and couplings downstream of valves and at equipment or apparatus connections. Do not use direct welded connections to valves, equipment, or other apparatus.
- C. Use non-conducting dielectric waterway fittings or insulating flanges whenever jointing dissimilar metals in piping systems. Dielectric fittings shall have end connections that match the adjoining pipe.
- D. Provide pipe hangers and supports in accordance with [ASTM B31.9] [MSS SP69]

unless indicated otherwise.

- E. Use **[gate] [ball] [or] [butterfly]** valves for shut off and to isolate equipment, part of systems, or vertical risers.
- F. Use **[globe] [ball] [or] [butterfly]** valves for throttling, bypass, or manual flow control services.
- G. Use spring loaded check valves on discharge of **[condenser water] <Insert type>** pumps where more than one pump supplies water to a common header.
- H. Use plug cocks for throttling service. Use non lubricated plug cocks only when shut off or isolating valves are also provided.
- I. Use butterfly valves **[in heating water systems] [in chilled and condenser water systems] [in heating, chilled and condenser water systems]** interchangeably with gate and globe valves.
- J. Use only butterfly valves in chilled and condenser water systems for throttling and isolation service.
- K. Butterfly valves shall be lug type.
- L. Use 3/4 inch ball valves with cap for drains at main shut off valves, low points of piping, bases of vertical risers, and at equipment. **[Pipe to nearest floor drain.]**

3.3 PIPING APPLICATIONS

- A. Hot-water heating piping, aboveground, **[NPS 2 (DN 50) and smaller] <Insert pipe size range>**, shall be **[any of]** the following:
 - 1. **[Type L (Type B)] [Type M (Type C)]**, drawn-temper copper tubing, wrought-copper fittings, and **[soldered] [brazed]** joints.
 - 2. **[Schedule 40]**, Grade B, Type 96 steel pipe fittings; cast-iron flanges and flange fittings; and threaded joints.
- B. Hot-water heating piping, aboveground, **[NPS 2-1/2 (DN 65) and larger] <Insert pipe size range>**, shall be **[any of]** the following:
 - 1. Schedule 40 or STD Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
- C. Hot-water heating piping installed belowground and within slabs shall be **[either of]** the following:
- D. Steel Pipe: ASTM A 53, Schedule 40, **[0.375 inch wall for sizes 12 inch and over,] black [with ASME C105 polyethylene jacket, or double layer, half-lapped 10 mil polyethylene tape]**.
- E. Fittings: ASTM A 234 forged steel welding type. **[With double layer, half-lapped 10 mil polyethylene tape.]**

- F. Joints: AWS D1.1, welded.
- G. Casing: **[Closed glass cell insulation.] [Polyurethane insulation with high density polyethylene jacket and heat shrink sleeves.] <Insert type>**
- H. Chilled-water piping, aboveground, **[NPS 2 (DN 50) and smaller] <Insert pipe size range>**, shall be **[any of]** the following:
1. **[Type L (Type B)] [Type M (Type C)]**, drawn-temper copper tubing, wrought-copper fittings, and **[soldered] [brazed] [pressure-seal]** joints.
 2. **[Schedule 40] [Schedule 80]** steel pipe, fittings; cast-iron flanges and flange fittings; and threaded joints.
- I. Chilled-water piping, aboveground, **[NPS 2-1/2 (DN 65) and larger] <Insert pipe size range>**, shall be **[any of]** the following:
1. **[Type L (Type B)] [Type M (Type C)]**, drawn-temper copper tubing, wrought-copper fittings, and **[soldered] [brazed]** joints.
 2. Schedule 40 or STD Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
- J. Chilled-water piping installed belowground and within slabs shall be **[either of]** the following:
1. Steel Pipe: ASTM A 53, Schedule 40, **[0.375 inch wall for sizes 12 inch and over,] black [with AWWA C105 polyethylene jacket, or double layer, half-lapped 10 mil polyethylene tape].**
 - a. Fittings: ASTM A 234, forged steel welding type.
 - b. Joints: AWS D1.1, welded.
 - c. Casing: **[Closed glass cell insulation.] [Polyurethane insulation with high density polyethylene jacket and heat shrink sleeves.] <Insert type>**.
 2. Ductile Iron Pipe: AWWA C151 **[with AWWA C105 polyethylene jacket, or double layer, half-lapped 10 mil polyethylene tape].**
 - a. Fittings: AWWA C110, ductile iron, standard thickness.
 - b. Joints: AWWA C111, rubber gasket with mechanical joint restraint.
 3. PVC Pipe: ASTM D 1785, Schedule 40, **[and Schedule 80 for sizes 8 inch and larger,]** or ASTM D 2241, SDR 21 or 26.
 - a. Fittings: ASTM D 2466, or ASTM D 2467, PVC.
 - b. Joints: ASTM D 2855, solvent weld.
 4. FRP Pipe: ASTM D 2310, fiberglass reinforced thermosetting resin plastic.
 - a. Fittings: Fiberglass reinforced epoxy.
 - b. Joints: **[Hub and spigot with rubber gasket.] [Non threaded, union or flanged coupling.]**

- K. Dual-temperature heating and cooling water piping, aboveground, [NPS 2 (DN 50) and smaller] <Insert pipe size range>, shall be [any of] the following:
1. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] joints.
 2. Schedule 40 steel pipe fittings, flange fittings, and threaded joints.
- L. Dual-temperature heating and cooling water piping, aboveground, [NPS 2-1/2 (DN 65) and larger] <Insert pipe size range>, shall be [any of] the following:
1. Schedule 40 or STD Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
- M. Condenser-water piping, aboveground, [NPS 2 (DN 50) and smaller] <Insert pipe size range>, shall be [any of] the following:
1. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] joints.
 2. [Schedule 80] [Schedule 40] steel pipe; fittings, flange fittings, and threaded joints.
- N. Condenser-water piping, aboveground, [NPS 2-1/2 (DN 65) and larger] <Insert pipe size range>, shall be [any of] the following:
1. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] joints.
 2. [Schedule 80] [Schedule 40] [Schedule 30] [Schedule 20] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 3. [Schedule 80] [Schedule 40] [Schedule 30] [Schedule 20] steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
 4. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 5. RTRP and RTRF with adhesive or flanged joints.
- O. Condenser-water piping installed belowground and within slabs shall be [either of] the following:
1. Steel Pipe: ASTM A 53, Schedule 40, [0.375 inch wall for sizes 12 inch and over,] black[.] [with AWWA C105 polyethylene jacket, or double layer, half-lapped 10 mil polyethylene tape.]
 - a. Fittings: ASTM A 234, forged steel welding type[.] [with double layer, half-lapped 10 mil polyethylene tape.]
 - b. Joints: Screwed for pipe 2 inch and under; AWS D1.1, welded for pipe over 2 inch.
 2. Ductile Iron Pipe: AWWA C151.
 - a. Fittings: AWWA C110, ductile iron, standard thickness.
 - b. Joints: AWWA C111, rubber gasket with mechanical joint restraint.

3. PVC Pipe: ASTM D 1785, Schedule 40, [**and Schedule 80 for sizes 8 inch and larger,**] or ASTM D 2241, SDR 21 or 26.
 - a. Fittings: ASTM D 2466 or ASTM D 2467, PVC.
 - b. Joints: ASTM D 2855, solvent weld.

- P. Glycol piping, aboveground, [**NPS 2 (DN 50) and smaller**] <Insert pipe size range>, shall be [**any of**] the following:
 1. [**Type L (Type B)**] [**Type M (Type C)**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
 2. Schedule 40 fittings, flange fittings, and threaded joints.

- Q. Glycol piping, aboveground, [**NPS 2-1/2 (DN 65) and larger**] <Insert pipe size range>, shall be [**any of**] the following:
 1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

- R. Glycol piping installed belowground and within slabs shall be [**either of**] the following:
 1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 2. [**Schedule 40**] [**Schedule 80**] PVC or CPVC plastic pipe and fittings, and solvent-welded joints.

- S. Makeup-water piping installed aboveground shall be [**either of**] the following:
 1. [**Type L (Type B)**] [**Type M (Type C)**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
 2. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

- T. Makeup-Water Piping Installed Belowground and within Slabs:
 1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

- U. Condensate-Drain Piping: [**Type M (Type C)**] [**Type DWV**], drawn-temper copper tubing, wrought-copper fittings, and soldered joints [**or Schedule 40 PVC plastic pipe and fittings and solvent-welded joints**].

- V. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

- W. Air-Vent Piping:
 1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
 2. Outlet: **Type L or M**, annealed-temper copper tubing with soldered or flared joints.

- X. Safety-Valve-Inlet and -Outlet Piping for Hot-Water Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
- Y. Medium Temperature Pre-Insulated Underground Piping System:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ferro-Therm as manufactured by Thermacor Process, L.P., of Fort Worth, Texas.
 - b. **<Insert manufacturer>**
 - c. or approved equal.
 2. Carrier pipe shall be steel ASTM A-53, Grade B., ERW (Type E) or seamless (Type 5), Schedule 40 for sizes 2" and larger, and shall be ASTM A-106/A-53, seamless, Schedule 40 for sizes 1-1/2" and smaller. Condensate return piping shall be Schedule 80. When practical, piping shall be provided in 40-foot double-random lengths. All carbon steel pipe shall have ends cut square and beveled for butt-welding. Straight sections of factory insulated pipe shall have 6" of exposed pipe at each end for field joint fabrication.
 3. Insulation shall be polyurethane foam either spray applied or high pressure injected with one shot into the annular space between carrier pipe and jacket. Insulation shall be rigid, 90-95% closed cell polyurethane with a 2.0 to 3.0 pounds per cubic foot density and k-factor of 0.14 and shall conform to ASTM C-591. Maximum operating temperature shall not exceed 250 degrees F. Insulation thickness shall be as defined by the following table for the piping sizes required:

Pipe Size (inches)	Jacket Size (inches)	Insulation Thickness (inches)
0.75	5.4	2.0
1	5.4	1.9
1.5	5.4	1.7
2	5.4	1.4
2.5	6.68	1.7
3	6.68	1.4
4	8.68	1.9
5	8.68	1.4
6	10.85	2.0
8	12.85	1.9
10	14.125	1.5
12	16.144	1.5

4. Jacketing material shall be extruded, black, high density polyethylene (HDPE), having a wall thickness not less than 125 mils for pipe sizes less than or equal to 12", 150 mils for jacket sizes larger than 12" to 24", and 175 mils for jacket sizes greater than 24". No FRP, HDUP, or tape jacket allowed.

5. Moisture barrier end seals shall be factory applied, sealed to the jacket and carrier pipe. End seals shall be certified as having passed a 20-foot head pressure test. End seals shall be high temperature mastic completely sealing the exposed end of the insulation. Field applied end seals shall be installed at any field cut to the piping before continuing with the installation.
6. Straight run joints shall be field-insulated per the manufacturer's instructions, using polyurethane foam poured in an HDPE sleeve and sealed with a heat shrink sleeve. All joint closures and insulation shall occur at straight sections of pipe. All insulation and jacketing materials shall be furnished by the piping system manufacturer.
7. Fittings shall be the manufacturer's standard components, factory prefabricated and preinsulated fittings with polyurethane foam to the thickness specified and jacketed with a one piece seamless molded HDPE fitting cover, a butt fusion welded, or an extrusion welded and mitered HDPE jacket. Carrier pipe fittings shall be butt-welded, except sizes smaller than 2" shall be socket-welded. Fittings include expansion loops, elbows, tees, reducers and anchors. Elbows, loops, offsets, or any other direction changes shall conform to the standards set by ANSI B31.1, Code for Power Piping.
8. Expansion/contraction compensation will be accomplished utilizing factory prefabricated and preinsulated expansion elbows, Z-bends, expansion loops and anchors specifically designed for the intended application. External expansion compensation utilizing flexible expansion pads (minimum one inch thickness), extending on either side, both inside and outside the radius of the fittings shall be used with all fittings having expansion in excess of 1/2".

Z. High Temperature Pre-Insulated Underground Piping System:

1. Preinsulated Piping: Furnish a complete HDPE jacketed system of factory preinsulated steel piping for the **[Steam] [Condensate Return] [High Temperature Heating Water]** piping system. All preinsulated pipe, fittings, insulating materials, and technical support shall be provided by the Preinsulated Piping System manufacturer.
2. A complete layout of the system, showing anchors, expansion provisions, and building entrance details, shall be provided by the preinsulated pipe manufacturer. Means for expansion must be made in pipe offsets or loops.
3. The system shall be HT-406 as manufactured by Thermacor Process, L.P., of Fort Worth, Texas, or approved substitute.
4. Carrier pipe shall be steel ASTM A-53, Grade B., ERW (Type E) or seamless (Type 5), Schedule 40 for sizes 2" and larger, and shall be ASTM A-106, Grade B, Schedule 40 for sizes 1-1/2" and smaller. Condensate return piping shall be Schedule 80. When practical, piping shall be provided in 40-foot double-random lengths. All carbon steel pipe shall have ends cut square and beveled for butt-welding.
 - a. Straight sections of factory insulated pipe shall have 6" of exposed pipe at each end for field joint fabrication.
5. Insulation shall be polyisocyanurate insulation bonded to both the jacketing and carrier pipe and either spray applied or high pressure injected with one shot into

- the annular space between carrier pipe and jacket with a minimum thickness of 2.5" for systems operating below 366 degrees F. Insulation shall be rigid, 90% - 95% closed cell at 70 degrees F with not less than 2.4 pounds per cubic foot density, having a compressive strength of not less than 30 psi and a k-Factor of 0.14 at 70 degrees F and 0.24 at 366 degrees F. Maximum operating temperature of the polyisocyanurate system shall not exceed 366 degrees F.
6. Jacketing material shall be extruded, black, high density polyethylene (HDPE), having a minimum wall thickness of 175 mils for jacket sizes less than or equal to 12", 200 mils for jacket sizes greater than 12" to 24", and 225 mils for jacket sizes greater than 24". The jacket throughout the entire system shall incorporate electric fusion, butt fusion, or extrusion welding at all fittings, joint closures, or other points of connection. This shall create a jacket that is seamless throughout the entire system with the exception of anchors, whose water shed rings shall be sealed with a Raychem Dirax or Canusa GTS-65 wrap prohibiting the ingress of water.
 7. Moisture barrier end seals shall be factory applied, sealed to the jacket and carrier pipe. End seals shall be certified as having passed a 20-foot head pressure test. End seals shall be high temperature mastic completely sealing the exposed end of the insulation. Field applied end seals shall be installed at any field cut to the piping before continuing with the installation.
 8. Straight run joints shall be insulated using high temperature sectional foam to the thickness specified and jacketed with a pressure testable joint closure, either an electro-fusion welded split sleeve HDPE joint closure, Canusa Supercase, or Raychem Rayjoint. The joint will be pressure tested at 5 psi for 5 minutes while simultaneously soap tested at the joint closure's seams for possible leaks. After passing the pressure test, a closure patch is welded (as per specified joint closure instructions) over the test hole. All joint closures and insulation shall occur at straight sections of pipe.
 9. Fittings shall be factory prefabricated and preinsulated with polyisocyanurate to the thickness specified and jacketed with a one piece seamless molded HDPE fitting cover, a butt fusion welded, or an extrusion welded and mitered HDPE jacket. No taping or hot air welding will be allowed. All fitting jackets/covers shall be connected to the straight lengths of pipe by electrofusion, butt fusion, or extrusion welding. Carrier pipe fittings shall be butt-welded, except for sizes smaller than 2", which shall be socket-welded. Fittings include expansion loops, elbows, tees, reducers, and anchors. Elbows, loops, offsets, or any other direction changes shall conform to the standards set by ANSI B31 .1, Code for Power Piping.
 10. Expansion/contraction compensation will be accomplished utilizing factory prefabricated and preinsulated expansion elbows, Z-bends, expansion loops and anchors specifically designed for the intended application. Flexible expansion pads shall be utilized for external expansion compensation on all fittings having expansion in excess of 1/2". Expansion pads shall be a minimum one inch thick and shall extend to cover both the inside and outside radius of the fittings. Anchors shall be 1/2-inch thick steel plates welded to the carrier pipe and shall incorporate a steel water shed ring, sized to allow the jacket to slide underneath, that shall be sealed to the HDPE jacket with a Raychem Dirax or Canusa GTS-65 wrap. Anchors shall be located per manufacturers recommendations.

AA. Radiant Heating Piping:

1. Copper Tubing: ASTM B 88, Type [K,] [L,] annealed.
 - a. Fittings: ASME B16.22, wrought copper.
 - b. Joints: **[Solder, lead free,] [ASTM B 32,] [95-5 tin-antimony, or tin and silver, with melting range 430 to 535 degrees F.] [Braze, AWS A5.8 BCuP silver/phosphorus/copper alloy with melting range 1190 - 1480 degrees F.]**
 2. Polybutylene Pipe: ASTM 3309, 100 psig at 180 degrees F and 200 psig at 73 degrees F, **[gray] [black]** color.
 - a. Fittings: ASTM F 845 PB, or brass or copper.
 - b. Joints: Mechanical compression fittings or insert fittings with copper compression rings.
 3. Polyethylene Pipe: ASTM F 876 and ASTM F 877, cross-linked polyethylene, 100 psig operating pressure at 180 degrees F.
 - a. Fittings: Brass and copper.
 - b. Joints: Mechanical compression fittings.
 4. Composite Polyethylene Pipe: Aluminum tube laminated between two layers of **[high density] [cross-linked]** polyethylene, **[150] [125] <Insert number>** psig operating pressure at maximum **[140] [180] <Insert number>** degrees F.
 - a. Fittings: Brass flared compression.
 - b. Joints: Fittings adapt to copper tubing or copper tube fittings, threaded pipe and fittings, and copper compression fittings.
 5. Hose: Composite hose with nitrile liner, braided fiber reinforcing, neoprene cover, 150 psig operating pressure at 205 degrees F.
 - a. Fittings: Copper.
 - b. Joints: Nipple with stainless steel clamp.
- BB. Equipment Drains and Overflows:
1. Steel Pipe: ASTM A 53, Schedule 40 galvanized.
 - a. Fittings: Galvanized cast iron, or ASTM B 16.3 malleable iron.
 - b. Joints: Threaded.
 2. Copper Tubing: ASTM B 88, Type **[M and DWV,] [M,] [L,]** hard drawn.
 - a. Fittings: ASME B16.18, cast brass, or ASME B16.22 solder wrought copper.
 - b. Joints: Solder, lead free, **[ASTM B 32,]** 95-5 tin-antimony, or tin and silver, with melting range 430 to 535 degrees F.

3.4 PIPING INSTALLATIONS

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- E. Install piping to permit valve servicing.
- F. Install piping at indicated slopes.
- G. Install piping free of sags and bends.
- H. Install fittings for changes in direction and branch connections.
- I. Install piping to allow application of insulation.
- J. Select system components with pressure rating equal to or greater than system operating pressure.
- K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.
- L. Install drains, consisting of a tee fitting, NPS 3/4 (DN 20) ball valve, and short NPS 3/4 (DN 20) threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.
- M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.
- N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.
- O. Install branch connections to mains using [**mechanically formed**] tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.
- P. Install valves according to Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," Section 230523.14 "Check Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- Q. Install unions in piping, [NPS 2 (DN 50)] <Insert pipe size> and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

- R. Install flanges in piping, [NPS 2-1/2 (DN 65)] <Insert pipe size> and larger, at final connections of equipment and elsewhere as indicated.
- S. Install shutoff valve immediately upstream of each dielectric fitting.
- T. Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.
- U. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.
- V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.5 DIELECTRIC FITTING INSTALLATION

- A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.
- B. Dielectric Fittings for [NPS 2 (DN 50)] <Insert pipe size> and Smaller: Use dielectric [nipples] [unions].
- C. Dielectric Fittings for [NPS 2-1/2 to NPS 4 (DN 65 to DN 100)] <Insert pipe size range>: Use dielectric [flanges] [flange kits] [nipples].
- D. Dielectric Fittings for [NPS 5 (DN 125)] <Insert pipe size> and Larger: Use dielectric flange kits.

3.6 HANGERS AND SUPPORTS

- A. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.
- B. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet (6 m) long.
 2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet (6 m) or longer.
 3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet (6 m) or longer, supported on a trapeze.
 4. Spring hangers to support vertical runs.
 5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
 6. On plastic pipe, install pads or cushions on bearing surfaces to prevent hanger from scratching pipe.
- D. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:
1. NPS 3/4 (DN 20): Maximum span, 7 feet (2.1 m).
 2. NPS 1 (DN 25): Maximum span, 7 feet (2.1 m).
 3. NPS 1-1/2 (DN 40): Maximum span, 9 feet (2.7 m).
 4. NPS 2 (DN 50): Maximum span, 10 feet (3 m).
 5. NPS 2-1/2 (DN 65): Maximum span, 11 feet (3.4 m).
 6. NPS 3 (DN 80) and Larger: Maximum span, 12 feet (3.7 m).
- E. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:
1. NPS 3/4 (DN 20): Maximum span, 5 feet (1.5 m); minimum rod size, 1/4 inch (6.4 mm).
 2. NPS 1 (DN 25): Maximum span, 6 feet (1.8 m); minimum rod size, 1/4 inch (6.4 mm).
 3. NPS 1-1/4 ((DN 32):)Maximum span, 7 feet (2.1 m); minimum rod size, 3/8 inch (10 mm).
 4. NPS 1-1/2 (DN 40): Maximum span, 8 feet (2.4 m); minimum rod size, 3/8 inch (10 mm).
 5. NPS 2 (DN 50): Maximum span, 8 feet (2.4 m); minimum rod size, 3/8 inch (10 mm).
 6. NPS 2-1/2 (DN 65): Maximum span, 9 feet (2.7 m); minimum rod size, 3/8 inch (10 mm).
 7. NPS 3 (DN 80) and Larger: Maximum span, 10 feet (3 m); minimum rod size, 3/8 inch (10 mm).
- F. Plastic Piping Hanger Spacing: Space hangers according to pipe manufacturer's written instructions for service conditions. Avoid point loading. Space and install hangers with the fewest practical rigid anchor points.
- G. Fiberglass Piping Hanger Spacing: Space hangers according to pipe manufacturer's written instructions for service conditions. Avoid point loading. Space and install hangers with the fewest practical rigid anchor points.
- H. Support vertical runs at roof, at each floor, and at 10-foot (3-m) intervals between floors.

3.7 PIPE JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
- D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.
- E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.
- G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.
- H. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
 - 1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
 - 2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
 - 3. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D 2855.
 - 4. PVC Nonpressure Piping: Join according to ASTM D 2855.
- I. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.
- J. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer-recommended tool and procedure, and brazed joints.
- K. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

3.8 FLANGES, UNIONS, COUPLINGS, AND MECHANICAL JOINT RESTRAINTS

A. Unions for Pipe 2 Inches and Under:

1. Ferrous Piping: 150 psig malleable iron, threaded.
2. Copper Pipe: Bronze, soldered joints.

B. Flanges for Pipe Over 2 Inches:

1. Ferrous Piping: 150 psig forged steel, slip on.
2. Copper Piping: Bronze.
3. Gaskets: 1/16 inch thick non-asbestos preformed gaskets, aramid fibers with nitrile (NBR) binder; Durlon "8500 Green", Garlock "IFG 5500", or approved equal.

C. Dielectric Waterway Fittings: Dielectric fittings designed to effectively separate dissimilar metals exposed to water or other electrolytes, conforming to NSF and ASTM F492 standards for continuous use at temperatures up to 225 degrees F and pressures up to 300 psi. Fittings to have electro-zinc-plated steel casings providing for maintained exterior electrical continuity, threaded ends as applicable, and inert linings. Provide "ClearFlow" units as manufactured by Perfection Corporation or approved substitute.

D. Mechanical Joint Restraints for Ductile Iron Pipe: Mechanical joint restraint shall be incorporated in the design of the follower gland and shall include a restraining mechanism which, when actuated, imparts multiple wedging action against the pipe, increasing its resistance as the pressure increases. Flexibility of the joint shall be maintained after burial. Glands shall be manufactured of ductile iron conforming to ASTM A 536-80. Restraining devices shall be of ductile iron heat treated to a minimum hardness of 370 BHN. Dimensions of the gland shall be such that it can be used with the standardized mechanical joint bell and tee-head bolts conforming to AWWA A21.11 and AWWA C153/A21.53 of latest revision. Twist-off nuts, sized same as tee-head bolts, shall be used to insure proper actuating of restraining devices. The mechanical joint restraint device shall have a working pressure of at least 250 psi with a minimum safety factor of 2:1 and shall be EBAA Iron, Inc. SERIES 1100 MEGALUG or equal.

3.9 INSULATING JOINTS

A. Except as otherwise specifically indicated, insulating joint assemblies shall be provided at all riser locations where buried metallic piping **[(other than copper piping 2 inches or smaller in size)]** transitions to above-ground extensions. Assemblies shall consist of dielectric fittings or insulating flange assemblies as appropriate for the application.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. LineBacker Type "E" as manufactured by Pipeline Seal and Insulator, Inc.
 - b. or approved equal.

- B. Insulating joint assemblies shall conform to the following requirements:
1. Flanged joints shall include full face insulating gaskets, insulating bolt sleeves and double quantity of insulating washers and stainless steel washers.
 2. Insulating materials shall be as follows:
 - a. Gasket: NEMA Grade G10 retainer conforming to ASTM D 229 with Teflon ring seal on each side of the retainer. Minimum dielectric strength shall be 500 volts per mil (VPM). Compressive strength shall be 50,000 psi. Water absorption shall be 0.05 percent (max.)
 - b. Sleeves: Shall be 1/32-inch wall thickness, length to suit two class 150 lb. weld neck flanges, insulating gaskets and valve body thickness. Sleeve shall provide "full" insulation of studs; minimum dielectric strength shall be 500 VPM. Material shall be NEMA Grade G10.
 - c. Insulating washers: NEMA Grade G10, 1/8-inch thick (minimum).
- C. Install insulating joints at the locations indicated on the drawings. Where not shown on the drawings, they shall be installed within 24 inches of the location at which underground piping transitions to above-ground or within-structure extension.
- D. Insulating assemblies shall provide a minimum resistance of 500,000 ohms when tested in the dry condition.

3.10 TERMINAL EQUIPMENT CONNECTIONS

- A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.
- B. Install control valves in accessible locations close to connected equipment.
- C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.
- D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.11 CLEANING, FLUSHING, AND INSPECTING

- A. Clean and flush system, with clear water, of all dirt, metal chips, sand, and foreign matter. After flushing, remove, clean, and replace all strainer baskets or screens. Inspect each run of each system for completion of joints, supports, accessory items, and obvious leaks.
- B. Examine and inspect piping in accordance with ANSI B31.1, Chapter VI.

3.12 FIELD QUALITY CONTROL

- A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Leak Testing:

1. Provide temporary equipment for testing, including pump and gages. Test piping system before insulation is installed, wherever feasible, and remove control devices before testing. Subject entire piping systems to leak tests, either as a whole, or in sections; but leave no part untested.
2. Test gauges shall have a range that provide for the test pressure to be in the middle third of the gauge scale.
3. Contractor shall provide written notification to the DEN Project Manager and DEN Inspector at least 48 hours before performing leak test. Perform all tests in the presence of the authorized City representative.
4. Hydrostatic Leak Test:
 - a. Perform hydrostatic leak test on all piping systems.
 - b. Hydrostatic Leak Test Procedure:

- 1) Leak test procedures shall comply with ASME B31.9.
 - 2) Fill piping systems with clear water, vent all air, and pressurize at 110% of operating pressure, (but not less than 100 psi) for 1 hour. Test fails if leakage is observed, or pressure drop exceeds 5% of test pressure.
5. Pneumatic Leak Test:
- a. General: Pneumatic leak tests shall only be used on piping with restricted access, under freezing conditions, or where water leakage would damage critical DEN operational equipment. Contractor shall submit a written request for test in accordance with the Submittals paragraphs of this specification Section.
 - b. Pneumatic Test Procedure:
 - 1) Contractor shall submit safety plan for pneumatic testing prior to test.
 - 2) General: Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations:
 - a) The piping system does not contain cast iron pipe or plastic pipe subject to brittle failure.
 - b) The system does not contain soldered or solvent cement joints over NPS 2.
 - c) The test pressure does not exceed 150 psig.
 - 3) Test Medium: The gas shall be nonflammable and nontoxic.
 - 4) Preliminary Test: Prior to application of full pneumatic test pressure, a preliminary test of not more than 10 psig shall be applied to reveal possible major leaks. Pneumatic Test Pressure:
 - a) Except as limited in 2) below, the test pressure shall not exceed 1.25 times the design pressure. Pressure shall be applied in several stages, allowing time for the system to reach equilibrium at each stage.
 - b) The test pressure shall not exceed the maximum allowable pneumatic test pressure for any vessel, pump, valve, or other component in the system under test.
 - 5) Examination for Leakage: After the preliminary test, pressure shall be raised in stages of not more than 25% up to full pneumatic test pressure, allowing time for equalization of strains and detection of major leaks at each stage. Following the application of test pressure for at least 10 minutes, the pressure may be reduced to design pressure and examination shall be made for leakage of the piping. Leaks may be detected by soap bubble, halogen gas, scented gas, test gage monitoring, ultrasonic, or other suitable means. If leaks are found, pressure shall be vented, appropriate repair or replacement shall be made, and the pneumatic test repeated until no leakage is found.

- 6) Contractor shall measure the surface temperature of the pipe for the duration of testing. The pneumatic test will be deemed successful only when the test pressure can be held at a constant pipe surface temperature for a period of no less than 10 continuous minutes. Record of the pipe temperatures and pressures during the duration of the test shall be submitted to the DEN Project Manager following completion of the test.
6. Testing shall be witnessed by DEN Mechanical Inspector and DEN Project Manager or Designated Representative.
 7. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.
 8. Drain test water from piping systems after testing and repair work that has been completed.
 9. Prepare written report of testing procedures and result.
- D. Perform the following before operating the system:
1. Open manual valves fully.
 2. Inspect pumps for proper rotation.
 3. Set makeup pressure-reducing valves for required system pressure.
 4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
 5. Set temperature controls so all coils are calling for full flow.
 6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
 7. Verify lubrication of motors and bearings.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232113

SECTION 232113.13 - UNDERGROUND HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Copper tube and fittings.
 - 2. Steel pipes and fittings.
 - 3. Ductile-iron pipe and fittings.
 - 4. Plastic pipe and fittings.
 - 5. Fiberglass pipe and fittings.
 - 6. Transition fittings.
 - 7. Conduit piping system.
 - 8. Cased piping system.
 - 9. Loose-fill insulation.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. The following are industry abbreviations for plastic and rubber piping materials:
 - 1. CPVC: Chlorinated polyvinyl chloride plastic.
 - 2. EPDM: Ethylene-propylene-diene terpolymer rubber.
 - 3. NBR: Acrylonitrile-butadiene rubber.
 - 4. PTFE: Polytetrafluoroethylene plastic.
 - 5. PVC: Polyvinyl chloride plastic.
 - 6. RTRP: Fiberglass, reinforced-thermosetting-resin pipe.
- B. Thermal Conductivity and Apparent Thermal Conductivity (k-Value): As defined in ASTM C 168. In this Section, these values are the result of the formula $Btu \times in./h \times sq. ft. \times deg F$ or $W/m \times K$ at the temperature differences specified. Values are expressed as Btu or W.
 - 1. Example: Apparent Thermal Conductivity (k-Value): 0.26 or 0.037.

1.4 PERFORMANCE REQUIREMENTS

- A. Provide components and installation capable of producing hydronic piping systems with the following minimum working-pressure ratings:
1. Hot-Water Piping: [100 psig (690 kPa)] [150 psig (1035 kPa)] <Insert value> at [200 deg F (93 deg C)] <Insert temperature>.
 2. Chilled-Water Piping: [100 psig (690 kPa)] [150 psig (1035 kPa)] <Insert value> at [200 deg F (93 deg C)] <Insert temperature>.
 3. Condenser-Water Piping: [100 psig (690 kPa)] [150 psig (1035 kPa)] <Insert value> at [150 deg F (66 deg C)] <Insert temperature>.

1.5 ACTION SUBMITTALS

- A. Product Data: For the following:
1. Conduit piping. Include carrier piping, insulation type and k-value, casing, and major components for each conduit piping system.
 2. Cased piping. Include carrier piping, insulation type and k-value, jacket, end seals, and major components for each cased piping system.
 3. Loose-fill insulation.
 4. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
1. Product Data for Credit EQ 4.1: For adhesives, documentation including printed statement of VOC content and chemical components.
- C. Shop Drawings: For underground hydronic piping. Signed and sealed by a professional engineer.
1. Calculate requirements for expansion compensation for underground piping.
 2. Show expansion compensators, offsets, and loops with appropriate materials to allow piping movement in the required locations. Show anchors and guides that restrain piping movement with calculated loads, and show concrete thrust block dimensions.
 3. Show pipe sizes, locations, and elevations. Show piping in trench, conduit, and cased pipe with details showing clearances between piping, and show insulation thickness.

1.6 INFORMATIONAL SUBMITTALS

- A. Profile Drawings: Show system piping in elevation. Draw profiles at horizontal scale of not less than 1 inch equals 50 feet (1:500) and at vertical scale of not less than 1 inch equals 5 feet (1:50). Indicate manholes and piping. Show types, sizes, materials, and elevations of other utilities crossing hydronic piping.
- B. Qualification Data: For qualified Installer.

- C. Welding certificates.
 - 1. Welders' certificates for welding processes and operators.
- D. Material Test Reports: For **[conduit] [cased]** piping.
- E. Source quality-control reports.
- F. Field Quality Control Test Reports: Written reports of tests specified in Part 3 of this Section. Include the following:
 - 1. Test procedures used.
 - 2. Test results that comply with requirements.
 - 3. Failed test results and corrective action taken to achieve requirements.
- G. Warranties: Special warranties specified in this Section.

1.7 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For hydronic specialties and special-duty valves to include in maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of valves, piping and anchors.
- C. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Drawings to be submitted in current DEN approved format as per requirements of Division 01. Other file formats will not be accepted.

1.8 EXTRA STOCK

- A. Provide **[two (2)] <Insert number>** repacking kits for each size and valve type.

1.9 QUALITY ASSURANCE

- A. Manufacture: Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.
- B. Manufacturer's Qualifications:
 - 1. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum **[three (3)] <Insert number>** years documented experience.

C. Installer Qualifications:

1. Installer: Company specializing in performing the Work of this Section [**with minimum five (5)**] <Insert requirements> years documented experience].

D. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.

E. Welding Qualifications: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with provisions in ASME B31.9, "Building Services Piping", for materials, products, and installation.
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

F. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

1.10 COORDINATION

- A. Coordinate pipe-fitting pressure classes with products specified in related Sections to allow matching of flange boltholes.

1.11 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" Division 01 requirements.
- B. Accept components on site in shipping containers with labeling in place. Inspect for damage. Collect and save installation instructions for DEN Project Manager's use.
- C. Provide temporary end caps and closures on piping and fittings. Maintain in place until installation.
- D. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

1.12 WARRANTY

- A. General Warranty: The special warranty specified in this Article shall not deprive the Owner of other rights the Owner may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by the Contractor under requirements of the Contract Documents.
- B. Special Warranty: Submit a written warranty, executed by Contractor, to repair dry, testable, conduit systems and replace components damaged by failure.

- C. Warranty Period: Manufacturer's standard, but not less than five (5) <Insert number> years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS

- A. Drawn-Temper Copper Tubing: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M, Type C)].
- B. DWV Copper Tube: ASTM B 306, drainage tube.
- C. Wrought-Copper Fittings: ASME B16.22.
- D. Wrought-Copper Unions: ASME B16.22.
- E. Cast-Copper Fittings: ASME B16.18.
- F. Bronze Flanges: ASME B16.24, Class 150 cast bronze with solder-joint end. Furnish Class 300 if required to match system, operating pressure, or companion flanges.
- G. Copper, Grooved-End Fittings: ASTM B 75, copper tube or ASTM B 584 bronze casting with dimensions matching piping.
- H. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.
- I. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

2.2 STEEL PIPES AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, [black] [galvanized] with plain ends; type, grade, and wall thickness as indicated in "Piping Application" Article.
- B. Cast-Iron, Threaded Fittings: ASME B16.4; [Class 125] [and] [Class 250].
- C. Malleable-Iron, Threaded Fittings: ASME B16.3, [Class 150] [and] [Class 300].
- D. Malleable-Iron Unions: ASME B16.39; [Class 150] [Class 250] [and] [Class 300].

- E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, **[Class 125] [and] [Class 250]**; raised ground face, and bolt holes spot faced.
- F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.
- G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - 1. Material Group: 1.1.
 - 2. End Connections: Butt welding.
 - 3. Facings: Raised face.
- H. Steel Welding Fittings: **[ASME B16.9] [and] [ASTM A 234/A 234M]**, seamless or welded.
 - 1. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- I. Grooved-End-Pipe Couplings for Galvanized-Steel Piping: AWWA C606 for steel-pipe dimensions. Include ferrous housing sections, EPDM-rubber gaskets suitable for hot and cold water, and bolts and nuts.
- J. Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.
- K. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
 - 1. ASME B16.21, nonmetallic, flat, asbestos free, **1/8-inch (3.2-mm)** maximum thickness unless thickness or specific material is indicated.
 - a. Full-Face Type: For flat-face, Class 125, cast-iron and -bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
- L. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

2.3 DUCTILE-IRON PIPE AND FITTINGS

- A. Mechanical-Joint, Ductile-Iron Pipe: AWWA C151/A21.51, with mechanical-joint bell and plain spigot end.
 - 1. Standard-Pattern, Mechanical-Joint Fittings: AWWA C110/A21.10, ductile or gray iron.
 - 2. Compact-Pattern, Mechanical-Joint Fittings: AWWA C153/A21.53, ductile iron.
 - a. Glands, Gaskets, and Bolts: AWWA C111/A21.11, ductile- or gray-iron glands, rubber gaskets, and steel bolts.

2.4 PLASTIC PIPE AND FITTINGS

A. CPVC Plastic:

1. Pipe: ASTM F 441/F 441M, Schedules 40 and 80, plain ends as indicated in "Piping Application" Article.
2. Pipe Fittings: Socket-type pipe fittings, ASTM F 438 for Schedule 40 pipe; ASTM F 439 for Schedule 80 pipe.
3. Solvent Cements: ASTM F 493.
 - a. Use CPVC solvent cement that has a VOC content of 490 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. PVC Plastic:

1. Pipe: ASTM D 1785, Schedules 40 and 80, plain ends as indicated in "Piping Application" Article.
2. Pipe Fittings: Socket-type pipe fittings, ASTM D 2466 for Schedule 40 pipe; ASTM D 2467 for Schedule 80 pipe.
3. Solvent Cements: ASTM D 2564. Include primer according to ASTM F 656.
 - a. Use PVC solvent cement that has a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.

2.5 FIBERGLASS PIPE AND FITTINGS

A. RTRP: ASTM D 2996, filament-wound pipe with tapered bell and spigot ends for adhesive joints.

B. RTRF: Compression or spray up/contact molded of same material, pressure class, and joining method as pipe.

C. Fiberglass Pipe Adhesive: As furnished or recommended by pipe manufacturer.

1. Use fiberglass adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

D. Flanges: ASTM D 4024. Full-face gaskets suitable for the service, minimum 1/8-inch- (3.2-mm-) thick, 60-70 durometer. ASTM A 307, Grade B, hex-head bolts with washers.

2.6 TRANSITION FITTINGS

- A. Plastic-to-Metal Transition Fittings: **[CPVC]** **[and]** **[PVC]** one-piece fitting with one threaded brass or copper insert and one Schedule 80 solvent-cemented-joint end.

2.7 CONDUIT PIPING SYSTEM

- A. Description: Factory-fabricated and -assembled, airtight and watertight, drainable, pressure-tested piping with conduit, inner pipe supports, and insulated carrier piping. Fabricate so insulation can be dried in place by forcing dry air through conduit.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Insul-Tek Piping Systems, Inc.](#)
- b. [Perma-Pipe, Inc.](#)
- c. [Rovanco Piping Systems, Inc.](#)
- d. [Thermacor Process, L.P.](#)
- e. **<Insert manufacturer's name>**.
- f. or approved equal.

- B. Carrier Pipe: **[Copper tube and fittings]** **[Standard-weight, steel pipe and fittings]** **[Schedule 40, steel pipe and fittings]** **[Schedule 80, steel pipe and fittings]** **[Ductile-iron pipe and fittings]** **[Plastic pipe and fittings]** **[Fiberglass pipe and fittings]**.

- C. Carrier Pipe Insulation:

1. Mineral-Wool Pipe Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, **[Type I 850 deg F (454 deg C)]** **[Type II, 1200 deg F (649 deg C)]**, Grade A.
 - a. Bands: ASTM A 666, Type 304, stainless steel, **3/4 inch (19 mm)** wide, **0.020 inch (0.5 mm)** thick.
2. Calcium Silicate Pipe Insulation: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
 - a. Bands: ASTM A 666, Type 304, stainless steel, **3/4 inch (19 mm)** wide, **0.020 inch (0.5 mm)** thick.
3. Polyisocyanurate Foam Pipe Insulation: Unfaced, preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation.
 - a. Comply with ASTM C 591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed **0.19 Btu x in./h x sq. ft. x deg F (0.027 W/m x K)** at **75 deg F (24 deg C)** after 180 days of aging.

- b. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thickness up to **1-1/2 inches (38 mm)** as tested by ASTM E 84.
 - c. Fabricate shapes according to ASTM C 450 and ASTM C 585.
 4. Polyurethane Foam Pipe Insulation: Unfaced, preformed, rigid cellular polyurethane material intended for use as thermal insulation.
 - a. Comply with ASTM C 591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed **0.19 Btu x in./h x sq. ft. x deg F (0.027 W/m x K)** at **75 deg F (24 deg C)** after 180 days of aging.
 - b. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thickness up to **1-1/2 inches (38 mm)** as tested by ASTM E 84.
 - c. Fabricate shapes according to ASTM C 450 and ASTM C 585.
- D. Minimum Clearance:
 1. Between Carrier Pipe Insulation and Conduit: **1 inch (25 mm)**.
 2. Between Insulation of Multiple Carrier Pipes: **3/16 inch (4.75 mm)**.
 3. Between Bottom of Carrier Pipe Insulation and Conduit: **1 inch (25 mm)**.
 4. Between Bottom of Bare, Carrier Pipe and Casing: **1-3/8 inches (35 mm)**.
- E. Conduit: Spiral wound, steel.
 1. Finish: With two coats of fusion-bonded epoxy, minimum 20 mils (0.50 mm) thick.
 2. Cover: With polyurethane foam insulation with an HDPE jacket; thickness indicated in "Piping Application" Article.
- F. Conduit: Galvanized Steel:
 1. Galvanized steel, 0.138 inch thick, hot-dip galvanized on interior and exterior after manufacture.
 2. Finish: Finish exterior of conduit with 3/16-inch- thick coating of high-melting-point asphalt with interposed layer of fiberglass screen and one outer wrap of asphalt-impregnated, fiberglass-reinforced pipeline felt applied spirally under tension.
- G. Conduit: Steel:
 1. Steel, 0.1345 inch thick. Finish interior of conduit with one coat of oven-cured epoxy, 6 mils thick.
 2. Finish: Finish exterior of conduit with 3/16-inch- thick coating of high-melting-point asphalt with interposed layer of fiberglass screen and one outer wrap of asphalt-impregnated, fiberglass-reinforced pipeline felt applied spirally under tension.
- H. Piping Supports within Conduit: Corrugated galvanized steel with a maximum spacing

of 10 feet (3 m).

- I. Fittings: Factory-fabricated and -insulated elbows and tees. Elbows may be bent pipe equal to carrier pipe. Tees shall be factory fabricated and insulated, and shall be compatible with the carrier pipe.
- J. Expansion Offsets and Loops: Size casing to contain piping expansion.
- K. Accessories include the following:
 - 1. Water Shed: Terminal end protector for carrier pipes entering building through floor, 3 inches (75 mm) deep and 2 inches (50 mm) larger than casing; terminate casing 20 inches (500 mm) above the floor level.
 - 2. Guides and Anchors: Steel plate welded to carrier pipes and to casing, complete with vent and drainage openings inside casing.
 - 3. End Seals: Steel plate welded to carrier pipes and to casing, complete with drain and vent openings on vertical centerline.
 - 4. Gland Seals: Packed stuffing box and gland follower mounted on steel plate, welded to end of casing, permitting axial movement of carrier piping, with drain and vent connections on vertical centerline.
 - 5. Leak Plates: Steel plate flange, 4 inches larger than casing and welded to casing only.
 - 6. Joint Kit: Half-shell, pourable or split insulation and shrink-wrap sleeve.
- L. Manholes: Black steel with lifting eyes.
 - 1. Finish: Spray-applied urethane, minimum 30 mils (0.75 mm) thick.
 - 2. Access: 30-inch- (750-mm-) diameter waterproof cover with gasket, ladder, and two 6-inch (150-mm) vents, one high and one low, extending above grade with rain caps.
 - 3. Conduit Stub-Outs and Seals: Welded steel with drain and vent openings.
 - 4. Sump: 12 inches (300 mm) in diameter, 12 inches (300 mm) deep.
 - 5. Floatation Anchor: Oversized bottom keyed into concrete base.
- M. Source Quality Control: Factory test conduit to 15 psig (105 kPa) for a minimum of two minutes with no change in pressure. Factory test carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

2.8 CASED PIPING SYSTEM

- A. Description: Factory-fabricated piping with carrier pipe, insulation, and casing.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Insul-Tek Piping Systems, Inc.
 - b. Perma-Pipe, Inc.
 - c. Rovanco Piping Systems, Inc.
 - d. Thermacor Process, L.P.

- e. [Thermal Pipe Systems](#).
 - f. [Urecon Ltd.](#)
 - g. <Insert manufacturer's name>.
 - h. or approved equal.
- B. Carrier Pipe: [**Copper tube and fittings**] [**Standard-weight, steel pipe and fittings**] [**Schedule 40, steel pipe and fittings**] [**Schedule 80, steel pipe and fittings**] [**Ductile-iron pipe and fittings**] [**Plastic pipe and fittings**] [**Fiberglass pipe and fittings**].
- C. Carrier Pipe Insulation:
- 1. Polyurethane Foam Pipe Insulation: Rigid, cellular, high-pressure injected between carrier pipe and jacket.
 - a. Comply with ASTM C 591; thermal conductivity (k-value) shall not exceed **0.14 Btu x in./h x sq. ft. x deg F (0.020 W/m x K) at 75 deg F (24 deg C)** after 180 days of aging.
- D. Casing: [**HDPE**] [**Filament-wound, fiberglass-reinforced polyester resin**] [**PVC**] [**0.034-inch- (0.85-mm-) thick, spiral-wound, lock-seam galvanized steel**] [**0.032-inch- (0.80-mm-) thick, spiral-wound, lock-seam aluminum**] [**0.025-inch- (0.65-mm-) thick, spiral-wound, lock-seam stainless steel**].
- E. Casing accessories include the following:
- 1. Joint Kit: Half-shell, pourable or split insulation, casing sleeve, and shrink-wrap sleeve.
 - 2. Expansion Blanket: Elastomeric foam, formed to fit over piping.
 - 3. End Seals: Shrink wrap the casing material to seal watertight around casing and carrier pipe.
- F. Manholes: Black steel with lifting eyes.
- 1. Finish: Spray-applied urethane, minimum **30 mils (0.75 mm)** thick.
 - 2. Access: **30-inch- (750-mm-)** diameter waterproof cover with gasket, ladder, and two **6-inch (150-mm)** vents, one high and one low, extending above grade with rain caps.
 - 3. Conduit Stub-Outs and Seals: Welded steel with drain and vent openings.
 - 4. Sump: **12 inches (300 mm)** in diameter, **12 inches (300 mm)** deep.
 - 5. Floatation Anchor: Oversized bottom keyed into concrete base.
- G. Source Quality Control: Factory test the carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

2.9 LOOSE-FILL INSULATION

A. Granular, Loose-Fill Insulation: Inorganic, nontoxic, nonflammable, sodium potassium aluminum silicate with calcium carbonate filler. Include chemical treatment that renders insulation hydrophobic.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Gilsulate International, Inc.](#)
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
2. Thermal Conductivity (k-Value): **0.60 at 175 deg F** (0.087 at 79 deg C) and **0.65 at 300 deg F** (0.094 at 149 deg C).
3. Application Temperature Range: **35 to 800 deg F** (2 to 426 deg C).
4. Dry Density: **40 to 42 lb/cu. ft.** (640 to 672 kg/cu. m).
5. Strength: **12,000 lb/sq. ft.** (58 600 kg/sq. m).

B. Powder, Loose-Fill Insulation: Inert, nontoxic, nonflammable, calcium carbonate particles. Include chemical treatment that renders insulation hydrophobic.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [DriTherm International Inc.](#)
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
2. Thermal Conductivity (k-Value): ASTM C 177, **0.58 at 100 deg F** (0.084 at 37 deg C) and **0.68 at 300 deg F** (0.098 at 149 deg C).
3. Application Temperature Range: **Minus 273 to plus 480 deg F** (Minus 169 to plus 250 deg C).
4. Dry Density: Approximately **60 lb/cu. ft.** (960 kg/cu. m).
5. Strength: **12,000 lb/sq. ft.** (58 600 kg/sq. m).

2.10 EXPANSION JOINTS

A. Single, Metal-Bellows, Packless Expansion Joints: Stainless-steel bellows type, complying with EJMA standards and the following:

1. Pressure Rating: 150 psig minimum.
2. Temperature Rating: 400 deg F minimum.
3. End Connections: Flanged, unless otherwise indicated.
4. Limit Rods: Include if indicated.

B. Double, Metal-Bellows, Packless Expansion Joints: Stainless-steel double-bellows type with integral base, complying with EJMA standards and the following:

1. Pressure Rating: 150 psig minimum.

2. Temperature Rating: 400 deg F minimum.
 3. End Connections: Flanged, unless otherwise indicated.
 4. Limit Rods: Include if indicated.
- C. Single, Slip-Type, Packed Expansion Joints: Carbon-steel or steel-pipe body with steel-pipe sliding sleeve and limit stop, stuffing box with packing, and the following:
1. Pressure Rating: 150 psig minimum.
 2. Temperature Rating: 600 deg F minimum.
 3. End Connections: Flanged, unless otherwise indicated.
 4. Base: Include integral base for units to be mounted on supports.
 5. Drain: Include tapped and plugged drain outlet in body, unless otherwise indicated.
 6. Vent: Include tapped and plugged vent in body if indicated.
- D. Double, Slip-Type, Packed Expansion Joints: Carbon-steel or steel-pipe body with integral base, with two steel-pipe sliding sleeves and limit stops, two stuffing boxes with packing, and the following:
1. Pressure Rating: 150 psig minimum.
 2. Temperature Rating: 600 deg F minimum.
 3. End Connections: Flanged, unless otherwise indicated.
 4. Drain: Include tapped and plugged drain outlets in body, unless otherwise indicated.
 5. Vent: Include tapped and plugged vent in body if indicated.

PART 3 - EXECUTION

3.1 EARTHWORK

- A. See Section 312000 "Earth Moving" for excavating, trenching, and backfilling.

3.2 ENVIRONMENTAL REQUIREMENTS

- A. Do not install underground piping when bedding is wet or frozen.

3.3 GENERAL

- A. Where more than one piping system material is specified, ensure system components are compatible and joined to ensure the integrity of the system is not jeopardized. Provide necessary joining fittings. Ensure flanges, union, and couplings for servicing are consistently provided.
- B. Use unions, flanges, and couplings downstream of valves and at equipment or apparatus connections. Do not use direct welded connections to valves, equipment, or other apparatus.

- C. Use non-conducting dielectric waterway fittings or insulating flanges whenever jointing dissimilar metals in piping systems. Dielectric fittings shall have end connections that match the adjoining pipe.

3.4 PIPING APPLICATION

A. Hot-Water Heating Piping:

1. [NPS 2 (DN 50) and smaller] <Insert pipe size range> shall be [any of] the following:
 - a. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] [pressure-seal] joints.
 - b. [Schedule 40] [Schedule 30] [Schedule 20] steel pipe; [Class 125, cast-iron] [Class 150, malleable-iron] [Class 250, cast-iron] [Class 300, malleable-iron] fittings; cast-iron flanges and flange fittings; and threaded joints.
 - c. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.
 - d. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 - e. Loose-Fill Insulation: [Granular] [Powder].
2. [NPS 2-1/2 (DN 65) and larger] <Insert pipe size range> shall be [any of] the following:
 - a. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] joints.
 - b. [Schedule 40] [Schedule 30] [Schedule 20] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 - c. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 - d. RTRP and RTRF with adhesive or flanged joints.
 - e. Loose-Fill Insulation: [Granular] [Powder].
3. Conduit piping with [mineral-wool] [calcium silicate] [polyisocyanurate] [polyurethane] carrier-pipe insulation and with [coated] [coated and insulated] conduit.
 - a. Carrier Pipe Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
 - b. Conduit Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
4. Cased piping with polyurethane carrier-pipe insulation.
 - a. Piping Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.

B. Chilled-Water Piping:

1. [NPS 2 (DN 50) and smaller] <Insert pipe size range> shall be [any of] the following:
 - a. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] [pressure-seal] joints.
 - b. [Schedule 40] [Schedule 30] [Schedule 20] steel pipe; [Class 125, cast-iron] [Class 150, malleable-iron] [Class 250, cast-iron] [Class 300, malleable-iron] fittings; cast-iron flanges and flange fittings; and threaded joints.
 - c. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.
 - d. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 - e. Loose-Fill Insulation: [Granular] [Powder].
2. [NPS 2-1/2 (DN 65) and larger] <Insert pipe size range> shall be [any of] the following:
 - a. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] joints.
 - b. [Schedule 40] [Schedule 30] [Schedule 20] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 - c. Mechanical-joint, ductile-iron pipe; [standard-] [or] [compact-] pattern mechanical-joint fittings; and mechanical joints.
 - d. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 - e. RTRP and RTRF with adhesive or flanged joints.
 - f. Loose-Fill Insulation: [Granular] [Powder].
3. Conduit piping with [mineral-wool] [calcium silicate] [polyisocyanurate] [polyurethane] carrier-pipe insulation and with [coated] [coated and insulated] conduit.
 - a. Piping Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
 - b. Conduit Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
4. Cased piping with polyurethane carrier-pipe insulation.
 - a. Piping Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.

C. Condenser-Water Piping:

1. [NPS 2 (DN 50) and smaller] <Insert pipe size range> shall be [any of] the following:

- a. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] [pressure-seal] joints.
 - b. [Schedule 40] [Schedule 30] [Schedule 20] steel pipe; [Class 125, cast-iron] [Class 150, malleable-iron] [Class 250, cast-iron] [Class 300, malleable-iron] fittings; cast-iron flanges and flange fittings; and threaded joints.
 - c. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.
 - d. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 - e. Loose-Fill Insulation: [Granular] [Powder].
2. [NPS 2-1/2 (DN 65) and larger] <Insert pipe size range> shall be[any of] the following:
- a. [Type L (Type B)] [Type M (Type C)], drawn-temper copper tubing, wrought-copper fittings, and [soldered] [brazed] joints.
 - b. [Schedule 40] [Schedule 30] [Schedule 20] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 - c. Mechanical-joint, ductile-iron pipe; [standard-] [or] [compact-] pattern mechanical-joint fittings; and mechanical joints.
 - d. [Schedule 40] [Schedule 80] CPVC plastic pipe and fittings and solvent-welded joints.
 - e. RTRP and RTRF with adhesive or flanged joints.
 - f. Loose-Fill Insulation: [Granular] [Powder].
3. Conduit piping with [mineral-wool] [calcium silicate] [polyisocyanurate] [polyurethane] carrier-pipe insulation and with [coated] [coated and insulated] conduit.
- a. Piping Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
 - b. Conduit Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
4. Cased piping with polyurethane carrier-pipe insulation.
- a. Piping Insulation Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.

3.5 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicate piping locations and arrangements if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

- B. Remove standing water in the bottom of trench.
- C. Do not backfill piping trench until field quality-control testing has been completed and results approved.
- D. Install piping at uniform grade of 0.2 percent. Install drains, consisting of a tee fitting, NPS 3/4 (D 20) ball valve, and short NPS 3/4 (DN 20) threaded nipple with cap, at low points and elsewhere as required for system drainage. Install manual air vents at high points.
- E. In conduits, install drain valves at low points consisting of tee fitting, 3/4-inch NPS ball valve, and short 3/4-inch NPS threaded nipple and cap, and manual air vents at high points.
- F. Locate groups of pipes parallel to each other, spaced to permit valve servicing. Install piping to allow application of insulation plus 1-inch clearance around insulation.
- G. Make reductions in pipe sizes using eccentric reducer fitting installed with level side up.
- H. Install couplings according to manufacturer's written instructions.
- I. Install components with pressure rating equal to or greater than system operating pressure.
- J. Install piping free of sags and bends.
- K. Install fittings for changes in direction and branch connections. Install branch connections to mains using tee fittings with takeoff out bottom of main.
- L. See Section 230517 "Sleeves and Sleeve Seals for HVAC Piping" for sleeves and mechanical sleeve seals through exterior building walls.
- M. Secure anchors with concrete thrust blocks. Concrete is specified in Section 033000 "Cast-in-Place Concrete."
- N. See Section 264200 "Cathodic Protection" for cathodic devices and connections to piping and conduit systems.

3.6 LOOSE-FILL INSULATION INSTALLATION

- A. Do not disturb the bottom of trench; otherwise, compact and stabilize it to ensure proper support.
- B. Remove standing water in the bottom of trench.
- C. Bed the pipe on a minimum 6-inch (150-mm) layer of granular fill material with a minimum 6-inch (150-mm) clearance between the pipes.

- D. Form insulation trench by excavation or by installing drywall side forms to establish required height and width of the insulation.
- E. Support piping with proper pitch, separation, and clearance to backfill or side forms using temporary supporting devices that can be removed after back filling with insulation.
- F. Place insulation and backfill after field quality-control testing has been completed and results approved.
- G. Apply bitumastic coating to carbon-steel anchors and guides. Pour concrete thrust blocks and anchors. See Section 033000 "Cast-in-Place Concrete" for concrete and reinforcement.
- H. Wrap piping at expansion loops and offsets with mineral-wool insulation of thickness appropriate for calculated expansion amount.
- I. Pour loose-fill insulation to required dimension agitating insulation to eliminate voids around piping.
- J. Remove temporary hangers and supports.
- K. Cover loose-fill insulation with polyethylene sheet a minimum of 4 mils (0.10 mm) thick, and empty loose-fill insulation bags on top.
- L. Manually backfill 6 inches (150 mm) of clean backfill. If mechanical compaction is required, manually backfill to 12 inches (300 mm) before using mechanical-compaction equipment.

3.7 JOINT CONSTRUCTION

- A. See Section 330500 "Common Work Results for Utilities" for basic piping joint construction.
- B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- D. Piping Connections: Unless otherwise indicated, make piping connections as specified below:
 - 1. Install unions in piping 2-inch NPS and smaller adjacent to each valve and at final connection to each piece of equipment with 2-inch NPS or smaller threaded pipe connection.
 - 2. Install flanges in piping 2-1/2-inch NPS and larger adjacent to flanged valves and at final connection to each piece of equipment with flanged pipe connection.
- E. Install pipe expansion joints according to manufacturer's written instructions.

1. Align expansion joints to avoid end loading and torsional stress.
 2. Underground align expansion-joint guide and secure with concrete thrust blocks.
- F. Install pipe alignment guides on piping that adjoins pipe expansion joints. Anchor underground piping with concrete thrust blocks.
- G. Install pipe anchors to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.
1. Fabricate and install anchors by welding steel shapes, plates, and bars to piping and to structure. Comply with ASME B31.9 and AWS D1.1.
 2. Where pipe expansion joints are indicated, install pipe anchors and alignment guides according to expansion joint manufacturer's written instructions to control movement.
- H. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
- I. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Ch. 35, "Pipe and Tubing," using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.
- J. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- K. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.
- L. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.
- M. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
 2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
 3. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D 2855.

- N. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.
- O. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.
- P. Conduit and Cased Piping Joints: Assemble sections and finish joints with pourable or split insulation and exterior jacket sleeve, and apply shrink-wrap seals.

3.8 IDENTIFICATION

- A. Install continuous plastic underground warning tapes during back filling of trenches for underground hydronic piping. Locate tapes **6 to 8 inches** (150 to 200 mm) below finished grade, directly over piping. See Section 312000 "Earth Moving" for warning-tape materials and devices and their installation.

3.9 CLEANING

- A. Inspect finish of exposed, hydronic piping, including outlets, valves, specialties, and devices, after installation is complete. Remove burrs, dirt, and debris. Repair damaged finishes including chips, scratches, and abrasions.
- B. Clean and flush hydronic piping. Remove, clean, and replace strainer screens. Remove disposable fine-mesh strainers in pump suction diffusers after cleaning and flushing piping but before balancing.

3.10 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Tests and Inspections:
 - 1. Prepare hydronic piping for testing according to ASME B31.9 and as follows:
 - a. Leave joints, including welds, uninsulated and exposed for examination during test.

- b. Fill system with water. Where there is risk of freezing, air or a safe, compatible liquid may be used.
 - c. Isolate equipment. Do not subject equipment to test pressure.
 - d. Install relief valve set at pressure no more than one-third higher than test pressure.
 - e. Use vents installed at high points to release trapped air while filling system.
2. Test hydronic piping as follows:
- a. Subject hydronic piping to hydrostatic test pressure that is not less than 1.5 times the design pressure.
 - b. After hydrostatic test pressure has been applied for 10 minutes, examine joints for leakage. Eliminate leaks by tightening, repairing, or replacing components as appropriate, and repeat hydrostatic test until no leaks exist.
3. Test conduit as follows:
- a. Seal vents and drains and subject conduit to **15 psig (105 kPa)** for four hours with no loss of pressure. Repair leaks and retest as required.
- E. Prepare test and inspection reports.

3.11 COMMISSIONING

- A. Fill systems.
- B. Open valves to fully open position.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232113.13

SECTION 232113.33 - GROUND-LOOP HEAT-PUMP PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes piping for [**horizontal**] [**vertical**], direct-buried, ground-loop, heat-pump systems.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Pipe and fittings.
 - 2. Joining method and equipment.
 - 3. Propylene glycol solution.
 - 4. Include data substantiating that materials comply with requirements.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
- B. Borehole backfilling and drilling operations reports.
- C. Dimensioned site layout.
- D. Startup performance results.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of valves, piping and anchors.

1.6 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PIPES AND FITTINGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Centennial Plastics, LLC.](#)
 2. [Chevron-Phillips Chemical Company; Performance Pipe Division.](#)
 3. [Lamson Pipe Company.](#)
 4. **<Insert manufacturer's name>.**
 5. or approved equal.
- B. HDPE Pipe: ASTM D 3035.
- C. Molded PE Fittings: ASTM D 2683 or ASTM D 3261, ASTM F 1055 PE resin, socket, butt-fusion or electro-fusion type, made to match PE pipe dimensions and class.
- D. U-Bend Assembly: Factory fabricated with embossed depth stamp every [24 inches (600 mm)] [36 inches (900 mm)] **<Insert dimension>** from U-bend.
- E. Ground-Loop, Heat-Pump Piping Minimum Working Pressure: [160 psig (1100 kPa)] [200 psig (1380 kPa)] **<Insert value>.**
- F. Ground-Loop, Heat-Pump Piping Operating Temperature: Between 23 and 104 deg F (minus 5 and plus 40 deg C).

2.2 BOREHOLE BACKFILL

- A. Seal Material: Bentonite clay with thermal conductivity greater than 1.07 Btu/h x sq. ft. x deg F (0.7 W/sq. m x K) according to ASTM D 5334.
- B. Permeability: Not more than 1 nm/s according to ASTM D 5084

2.3 ANTIFREEZE SOLUTION

- A. Propylene Glycol: Minimum 99 percent propylene glycol with corrosion inhibitors and environmental stabilizer additives to be mixed with water to protect piping circuit and connected equipment from physical damage caused by freezing or corrosion.

- B. Quantity: Sufficient solution for initial system startup and for preventive maintenance for one year from date of Substantial Completion.
- C. Dilution Water: Chloride content shall be less than 25 ppm, sulfate content less than 25 ppm, and hardness less than 100 ppm.

PART 3 - EXECUTION

3.1 EARTHWORK

- A. Excavating, trenching, warning tape, and backfilling are specified in Section 312000 "Earth Moving."

3.2 HORIZONTAL PIPING INSTALLATION

- A. Separate trenches by 10 feet (3 m) minimum unless otherwise indicated. Remove rocks in trenches that could contact pipe.
- B. Backfill.
- C. Extend pipe from trench onto bottom of body of water at an elevation that is at least 12 inches (300 mm) below frost line. Seal membrane or impervious liner under body of water after installing piping.
- D. Install HDPE piping in trenches according to ASTM D 2774 or ASTM F 645.
 - 1. Clean HDPE pipe and fittings and make heat-fusion joints according to ASTM D 2657. Minimize number of joints.
- E. Purge, flush, and pressure test piping before backfilling trenches.
- F. Install continuous detectable warning tape for underground piping. Locate tape a minimum of [24 inches (600 mm)] <Insert dimension> below finished grade, directly over piping. Underground warning tapes are specified in Section 312000 "Earth Moving."

3.3 VERTICAL PIPING INSTALLATION

- A. Install HDPE piping in boreholes according to ASTM D 2774 or ASTM F 645.
 - 1. Clean HDPE pipe and fittings and make heat-fusion joints according to ASTM D 2657. Minimize number of joints.
- B. Purge, flush, and pressure test piping before backfilling boreholes.
- C. Completely fill the borehole from bottom to top with backfill material.

- D. Install the header piping **4 to 6 inches** (100 to 150 mm) deep and install the horizontal piping from the header to the boreholes.
- E. Extend the horizontal piping and connect to ground-loop heat-pump piping systems at outside face of building wall in locations and pipe sizes indicated.
 - 1. Terminate water-service piping at building wall until building ground-loop heat-pump piping systems are installed. Terminate piping with caps. Make connections to building ground-loop heat-pump piping systems when those systems are installed.
- F. Backfill the horizontal piping and header trenches.
- G. Fill the entire piping loop with water or antifreeze solution.
- H. Maintain records of backfilling on-site.
- I. Mark borehole locations, header pipes, and horizontal runs with metallic locator tape as specified in Section 230553 "Identification for HVAC Piping and Equipment."
- J. Seal penetrations through building walls.
- K. Wall sleeves are specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- L. Mechanical sleeve seals are specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

3.4 ANTIFREEZE SOLUTION FILL

- A. Fill system with required quantity of propylene glycol and water to provide [**minus 10 deg F** (minus 23 deg C)] **<Insert temperature>** freezing temperature.
- B. Test dilute solution using gas chromatography to verify concentration of propylene glycol, and forward report to DEN Project Manager.

3.5 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.

3.6 FIELD QUALITY CONTROL

- A. Piping Tests: Fill piping 24 hours before testing and apply test pressure to stabilize piping. Use potable water only.
- B. Hydrostatic Tests: Test at not less than 1-1/2 times the pipe working-pressure rating or 300 percent of system design pressure, whichever is more[, **allowing for static pressure of borehole depth**].

1. Increase pressure in 50-psig (345-kPa) increments and inspect each joint between increments. Hold at test pressure for 30 minutes. Slowly increase to next test pressure increment and hold for 30 minutes. After testing at maximum test pressure, reduce pressure to 30 psig (207 kPa). Hold for 90 minutes, and measure pressure at 30-minute intervals. Repair leaks and retest until no leaks exist.
 2. Maintain a minimum pipe velocity of 24 in./s (610 mm/s) for a minimum of 15 minutes to remove all air.
- C. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232113.33

SECTION 232116 - HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes special-duty valves and specialties for the following:
 1. Hot-water heating piping.
 2. Chilled-water piping.
 3. Dual-temperature heating and cooling water piping.
 4. Condenser-water piping.
 5. Glycol cooling-water piping.
 6. Makeup-water piping.
 7. Condensate-drain piping.
 8. Blowdown-drain piping.
 9. Air-vent piping.
 10. Safety-valve-inlet and -outlet piping.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
 1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
 2. Air-control devices.
 3. Hydronic specialties.
 4. Provide product data for manufactured products and assemblies required for this project. Include component rough in requirements, service sizes, and finishes. Include product description, model, dimensions, and weight.
 5. Include data substantiating that materials comply with requirements.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.
 1. Include installation instructions, assembly views, lubrication instructions, and replacement parts list.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

- 1. Record actual locations of expansion tanks and air separators.

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.
- B. Provide one (1) extra 10 gallon drum of propylene glycol.

1.6 MAINTENANCE SERVICE FOR GLYCOL-PROTECTED SYSTEMS

- A. Perform project visit, 30 days after system startup, to make glycol fluid concentration analysis on site with refractive index measurement instrument. Provide written report of findings to maintenance personnel, covering corrective actions needed including analysis and amounts of glycol or water added as part of Contract work. Include pH analysis of system contents and perform work required to adjust pH to a level of 8.0 or higher, and add inhibitors needed to maintain pH.

1.7 QUALITY ASSURANCE

- A. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.
 - 1. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect and handle products under provisions of Division 1.
- B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- C. Provide temporary protective coating on cast iron and steel valves.
- D. Provide temporary end caps and closures on piping and fittings. Maintain in place until installation.
- E. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:
1. Hot-Water Heating Piping: <Insert psig (kPa)> at [250 deg F (121 deg C)] <Insert temperature>.
 2. Chilled-Water Piping: <Insert psig (kPa)> at [200 deg F (93 deg C)] <Insert temperature>.
 3. Dual-Temperature Heating and Cooling Water Piping: <Insert psig (kPa)> at [200 deg F (93 deg C)] <Insert temperature>.
 4. Condenser-Water Piping: <Insert psig (kPa)> at [150 deg F (66 deg C)] <Insert temperature>.
 5. Glycol Cooling-Water Piping: <Insert psig (kPa)> at [150 deg F (66 deg C)] <Insert temperature>.
 6. Makeup-Water Piping: [80 psig (552 kPa)] <Insert value> at [150 deg F (66 deg C)] <Insert temperature>.
 7. Condensate-Drain Piping: [150 deg F (66 deg C)] <Insert temperature>.
 8. Blowdown-Drain Piping: [200 deg F (93 deg C)] <Insert temperature>.
 9. Air-Vent Piping: [200 deg F (93 deg C)] <Insert temperature>.
 10. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 VALVES

- A. Gate, Globe, Check, Ball, and Butterfly Valves: Comply with requirements specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," Section 230523.14 "Check Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Section 230923.11 "Control Valves."
- C. Plastic Ball Valves:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [American Valve, Inc.](#)

- b. [Asahi/America.](#)
 - c. [Charlotte Pipe and Foundry Company.](#)
 - d. [Colonial Engineering.](#)
 - e. [George Fischer Inc.](#)
 - f. [Hayward Industrial Products, Inc.](#)
 - g. [IPEX Inc.](#)
 - h. [Jomar International, Ltd.](#)
 - i. [KBI \(King Bros. Industries\).](#)
 - j. [Legend Valve.](#)
 - k. [NIBCO INC.](#)
 - l. [Plast-O-Matic Valves, Inc.](#)
 - m. [SMC The Specialty Mfg. Co.](#)
 - n. [Thermoplastic Valves Inc.](#)
 - o. [Watts Regulator Co.](#)
 - p. **<Insert manufacturer's name>.**
 - q. or approved equal.
2. Body: One-, two-, or three-piece CPVC or PVC to match piping.
 3. Ball: Full-port CPVC or PVC to match piping.
 4. Seats: PTFE.
 5. Seals: EPDM.
 6. End Connections: Socket, union, or flanged.
 7. Handle Style: Tee shape.
 8. CWP Rating: Equal to piping service.
 9. Maximum Operating Temperature: Equal to piping service.
 10. Comply with MSS SP-122.

D. Plastic Butterfly Valves:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [American Valve, Inc.](#)
 - b. [Asahi/America.](#)
 - c. [Colonial Engineering.](#)
 - d. [George Fischer Inc.](#)
 - e. [Hayward Industrial Products, Inc.](#)
 - f. [IPEX Inc.](#)
 - g. [Legend Valve.](#)
 - h. [NIBCO INC.](#)
 - i. [Plast-O-Matic Valves, Inc.](#)
 - j. [SMC The Specialty Mfg. Co.](#)
 - k. [Thermoplastic Valves Inc.](#)
 - l. [Watts Regulator Co.](#)
 - m. **<Insert manufacturer's name>.**
 - n. or approved equal.
2. Body: PVC or CPVC to match piping wafer type for installation between flanges.
3. Disc: EPDM-coated steel.
4. Seats: PTFE.

5. Handle Style: Locking lever.
6. CWP Rating: Equal to piping service.
7. Maximum Operating Temperature: Equal to piping service.

E. Plastic Check Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [American Valve, Inc.](#)
 - b. [Asahi/America.](#)
 - c. [Colonial Engineering.](#)
 - d. [George Fischer Inc.](#)
 - e. [Hayward Industrial Products, Inc.](#)
 - f. [IPEX Inc.](#)
 - g. [KBI \(King Bros. Industries\).](#)
 - h. [Legend Valve.](#)
 - i. [NIBCO INC.](#)
 - j. [Plast-O-Matic Valves, Inc.](#)
 - k. [SMC The Specialty Mfg. Co.](#)
 - l. [Thermoplastic Valves Inc.](#)
 - m. [Watts Regulator Co.](#)
 - n. **<Insert manufacturer's name>.**
 - o. or approved equal.
2. Body: One-, two-, or three-piece PVC or CPVC to match piping.
3. Ends: Socket or flanged.
4. Seats: PTFE.
5. Check Style: Swing or ball type.
6. CWP Rating: Equal to piping service.
7. Maximum Operating Temperature: Equal to piping service.

F. Bronze, Calibrated-Orifice, Balancing Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Armstrong Pumps, Inc.](#)
 - b. [Bell & Gossett Domestic Pump.](#)
 - c. [Flow Design Inc.](#)
 - d. [Gerand Engineering Co.](#)
 - e. [Griswold Controls.](#)
 - f. [Nexus Valve, Inc.](#)
 - g. [Taco.](#)
 - h. [Tour & Andersson](#); available through Victaulic Company.
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
2. Pre-set Balance Feature: Valves to be designed to allow installing contractor to pre-set balance schedule.

3. Body: Bronze, ball or plug type with calibrated orifice or venturi.
4. Ball: Brass or stainless steel.
5. Plug: Resin.
6. Seat: PTFE.
7. End Connections: Threaded or socket.
8. Pressure Gage Connections: Integral seals for portable differential pressure meter.
9. Handle Style: Lever, with memory stop to retain set position.
10. CWP Rating: Minimum 125 psig (860 kPa).
11. Maximum Operating Temperature: 250 deg F (121 deg C).
12. Valves to have differential pressure read-out ports across valve seat area, with read-out ports be fitted with internal EPT insert and check valve.
13. Valve bodies to have 1/4" NPT tapped drain/purge port.
14. Valves to have memory stop feature to allow valve to be closed for service and then reopened to set point without disturbing balance position.
15. All valves to have calibrated nameplate to assure specific valve setting.
16. Valves to be leak-tight at full rated working pressure.

G. Steel, Calibrated-Orifice, Balancing Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Armstrong Pumps, Inc.](#)
 - b. [Bell & Gossett Domestic Pump.](#)
 - c. [Flow Design Inc.](#)
 - d. [Gerand Engineering Co.](#)
 - e. [Griswold Controls.](#)
 - f. [Nexus Valve, Inc.](#)
 - g. [Taco.](#)
 - h. [Tour & Andersson.](#)
 - i. **<Insert manufacturer's name>.**
 - j. or approved equal.
2. Pre-set Balance Feature: Valves to be designed to allow installing contractor to pre-set balance schedule.
3. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
4. Ball: Brass or stainless steel.
5. Stem Seals: EPDM O-rings.
6. Disc: Glass and carbon-filled PTFE.
7. Seat: PTFE.
8. End Connections: Flanged.
9. Pressure Gage Connections: Integral seals for portable differential pressure meter.
10. Handle Style: Lever, with memory stop to retain set position.
11. CWP Rating: Minimum 125 psig (860 kPa).
12. Maximum Operating Temperature: 250 deg F (121 deg C).
13. Valves to have differential pressure read-out ports across valve seat area, with read-out ports be fitted with internal EPT insert and check valve.

14. Valves 4"-8" shall be fitted with a bronze seat, replaceable bronze disc with EPDM seal insert and stainless steel stem.
 15. Valves to have memory stop feature to allow valve to be closed for service and then reopened to set point without disturbing balance position.
 16. All valves to have calibrated nameplate to assure specific valve setting.
 17. Valves to be leak-tight at full rated working pressure.
- ?. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.
18. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Conbraco Industries, Inc.](#)
 - e. [Spence Engineering Company, Inc.](#)
 - f. [Watts Regulator Co.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
 19. Body: Bronze or brass.
 20. Disc: Glass and carbon-filled PTFE.
 21. Seat: Brass.
 22. Stem Seals: EPDM O-rings.
 23. Diaphragm: EPT.
 24. Low inlet-pressure check valve.
 25. Inlet Strainer: **<Insert materials>**, removable without system shutdown.
 26. Valve Seat and Stem: Noncorrosive.
 27. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.
- H. Diaphragm-Operated Safety Valves: ASME labeled.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Conbraco Industries, Inc.](#)
 - e. [Spence Engineering Company, Inc.](#)
 - f. [Watts Regulator Co.](#)
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
 2. Body: Bronze or brass.
 3. Disc: Glass and carbon-filled PTFE.
 4. Seat: Brass.
 5. Stem Seals: EPDM O-rings.

6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: **<Insert materials>**, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

I. Automatic Flow-Control Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Flow Design Inc.](#)
 - b. [Griswold Controls.](#)
 - c. [Nexus Valve, Inc.](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Body: Brass or ferrous metal.
3. Piston and Spring Assembly: **[Stainless steel] [Corrosion resistant]**, tamper proof, self-cleaning, and removable.
4. Combination Assemblies: Include bronze or brass-alloy ball valve.
5. Identification Tag: Marked with zone identification, valve number, and flow rate.
6. Size: Same as pipe in which installed.
7. Performance: Maintain constant flow, plus or minus 5 percent over system pressure fluctuations.
8. Minimum CWP Rating: **[175 psig (1207 kPa)] [300 psig (2070 kPa)]**.
9. Maximum Operating Temperature: **[200 deg F (93 deg C)] [250 deg F (121 deg C)]**.

2.3 PUMP SUCTION FITTINGS

- A. Manufacturers: Subject to compliance with requirements, provide one of the following:
1. Bell & Gossett ITT.
 2. Taco Inc.
 3. or approved equal.
- B. Fitting: Angle pattern, cast-iron body, threaded for 2 inch and smaller, flanged for 2-1/2 inch and larger, rated for 175 psig working pressure, with inlet vanes, cylinder strainer with 3/16 inch diameter openings, disposable fine mesh strainer to fit over cylinder strainer, and permanent magnet located in flow stream and removable for cleaning. Pressure drop at maximum pump flow shall not exceed 2 psig.
- C. Accessories: Adjustable foot support, blowdown tapping in bottom, gage tapping in side.

2.4 FLOW SWITCHES:

- A. Manufacturers: Subject to compliance with requirements, provide one of the following:
1. Honeywell, Inc.
 2. Watts Regulator.
 3. Johnson Control.
 4. Potter-Roemer Inc.
 5. or approved equal.
- B. Brass construction, threaded for insertion into piping system, packless, with paddle with removable segments, vapor proof electrical compartment with switches.
- C. Schedule 2 - Water Flow Sensing Elements:
1. PRODUCT DATA SHEET 1 - Dual turbine, impedance sensing flow meter with bright tin plated brass wetted parts.
 2. PRODUCT DATA SHEET 2 - Accuracy shall be 2% of actual reading from 0.4 to 20 feet per second.
 3. PRODUCT DATA SHEET 3 - Pressure drop shall be less than 1 PSI at 1100 feet per minute.
 4. PRODUCT DATA SHEET 4 - Meter shall be rated for operating pressures up to 400 PSI and temperatures up to 200 degrees F.
 5. PRODUCT DATA SHEET 5 - Approved product: Onicon, Model 1210 series.

2.5 PRESSURE AND TEMPERATURE PLUGS

- A. Manufacturers: Subject to compliance with requirements, provide one of the following:
1. Duro Instrument Co.
 2. Trerice Co.
 3. Universal.
 4. Weksler.
 5. or approved equal.
- B. Stainless steel combination pressure-temperature test plugs with neoprene valve core where shown on the drawings. Provide [2] <Insert number>" bi-metal pocket test thermometers with 0 to 220 degrees F scale and plug adapter to the DEN Project Manager. Provide two 0-100 psi, 4-1/2" dial NPT conn. pressure gauges with pressure gauge adaptors to DEN Project Manager.

2.6 AIR-CONTROL DEVICES

- A. Manual Air Vents:
1. Manual Type: Short vertical sections of 2 inch diameter pipe to form air chamber, with 1/8 inch brass needle valve at top of chamber.
 2. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Nexus Valve, Inc.](#)
 - e. [Taco, Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
3. Body: Bronze.
 4. Internal Parts: Nonferrous.
 5. Operator: Screwdriver or thumbscrew.
 6. Inlet Connection: NPS 1/2 (DN 15).
 7. Discharge Connection: NPS 1/8 (DN 6).
 8. CWP Rating: 150 psig (1035 kPa).
 9. Maximum Operating Temperature: 225 deg F (107 deg C).
- B. Automatic Air Vents:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Nexus Valve, Inc.](#)
 - e. [Taco, Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
 2. Body: Bronze or cast iron.
 3. Internal Parts: Nonferrous.
 4. Operator: Noncorrosive metal float.
 5. Inlet Connection: NPS 1/2 (DN 15).
 6. Discharge Connection: NPS 1/4 (DN 8).
 7. CWP Rating: 150 psig (1035 kPa).
 8. Maximum Operating Temperature: 240 deg F (116 deg C).
 9. Float Type: Brass body, copper, polypropylene, or solid non-metallic float, stainless steel valve and valve seat; suitable for system operating temperature and pressure; with isolating valve. Minimum ratings not less than 250 degrees F and 150 psi working pressure.
 10. Washer Type: Brass with hydroscopic fiber discs, vent ports, adjustable cap for manual shut-off, and integral spring loaded ball check valve.
- C. Expansion Tanks:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)

- c. [Bell & Gossett Domestic Pump](#).
 - d. [Taco, Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Tank: Welded steel, rated for 125-psig (860-kPa) working pressure and 375 deg F (191 deg C) maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass. Tanks shall be factory tested after taps are fabricated and shall be labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 3. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, 100-gal. (379-L) unit only; sized for compression-tank diameter. Provide tank fittings for 125-psig (860-kPa) working pressure and 250 deg F (121 deg C) maximum operating temperature.
 4. Tank Drain Fitting: Brass body, nonferrous internal parts; 125-psig (860-kPa) working pressure and 240 deg F (116 deg C) maximum operating temperature; constructed to admit air to compression tank, drain water, and close off system.
 5. Gage Glass: Full height with dual manual shutoff valves, **[3/4-inch- (20-mm-)]** **<Insert dimension>** diameter gage glass, and slotted-metal glass guard.

D. **[Diaphragm] [Bladder]-Type Expansion Tanks:**

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump](#).
 - d. [Taco, Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Tank: Welded steel, rated for 125-psig (860-kPa) working pressure and 375 deg F (191 deg C) maximum operating temperature. Factory test after taps are fabricated and supports installed and are labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. **[Diaphragm] [Bladder]:** Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.
4. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.
5. Accessories: Pressure gage and air-charging fitting, tank drain; precharge to **[12]** **<Insert number>** psig.
6. Automatic Cold Water Fill Assembly: Pressure reducing valve, **[reduced pressure] [double check valve]** back flow preventer, test cocks, strainer, vacuum breaker, and valved by-pass.
7. Size: As scheduled on the drawings.

E. Tangential-Type Air Separators:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Taco, Inc.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
2. Tank: Welded steel; ASME constructed and labeled for 125-psig (860-kPa) minimum working pressure and 375 deg F (191 deg C) maximum operating temperature.
 3. Air Collector Tube: Perforated stainless steel, constructed to direct released air into expansion tank.
 4. Tangential Inlet and Outlet Connections: Threaded for NPS 2 (DN 50) and smaller; flanged connections for NPS 2-1/2 (DN 65) and larger.
 5. Blowdown Connection: Threaded.
 6. Size: Match system flow capacity.
- F. In-Line Air Separators:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Products, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Taco, Inc.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
 2. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation.
 3. Maximum Working Pressure: Up to 175 psig (1207 kPa).
 4. Maximum Operating Temperature: Up to 300 deg F (149 deg C).
- G. Air Purgers:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [AMTROL, Inc.](#)
 - b. [Armstrong Pumps, Inc.](#)
 - c. [Bell & Gossett Domestic Pump.](#)
 - d. [Taco, Inc.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
 2. Body: Cast iron with internal baffles that slow the water velocity to separate the air from solution and divert it to the vent for quick removal.
 3. Maximum Working Pressure: 150 psig (1035 kPa).
 4. Maximum Operating Temperature: 250 deg F (121 deg C).

2.7 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: Stainless-steel, [20] [40] [60]-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: 125 psig (860 kPa).

B. Basket Strainers:

1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: [40] [60]-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig (860 kPa).

C. T-Pattern Strainers:

1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
2. End Connections: Flanged ends.
3. Strainer Screen: [40] [60]-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
4. CWP Rating: 750 psig (5170 kPa).

D. Stainless-Steel Bellow, Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
2. End Connections: Threaded or flanged to match equipment connected.
3. Performance: Capable of 3/4-inch (20-mm) misalignment.
4. CWP Rating: 150 psig (1035 kPa).
5. Maximum Operating Temperature: 250 deg F (121 deg C).

E. Spherical, Rubber, Flexible Connectors:

1. Body: Fiber-reinforced rubber body.
2. End Connections: Steel flanges drilled to align with Classes 150 and 300 steel flanges.
3. Performance: Capable of misalignment.
4. CWP Rating: 150 psig (1035 kPa).
5. Maximum Operating Temperature: 250 deg F (121 deg C).

- F. Expansion Fittings: Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping." Section 15124 "Expansion Fittings and Loops for HVAC Piping."

2.8 GLYCOL SYSTEM

- A. Mixing Tank: [45] <Insert number> gallon steel drum with fittings suitable for filling and hand pump for charging, rubber hose for connection of hand pump to system.
- B. Storage Tank: Closed type, welded steel constructed, tested and stamped in accordance with Section 8D of ASME Code; 125 psi rating; cleaned, prime coated, and supplied with steel support saddles. Construct with tapings for installation of accessories.
- C. Expansion Tank: Diaphragm expansion tank and vent fitting with air separator, and automatic air vent.
- D. Air Pressure Reducing Station: Pressure reducing valve with shut-off valves, strainer, check valve, and needle valve bypass.
- E. Glycol Solution: Inhibited propylene glycol and water solution mixed 50-50.
- F.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

- A. Install shutoff-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.
- B. Install [throttling-duty] [calibrated-orifice, balancing] valves at each branch connection to return main.
- C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.
- D. Install check valves at each pump discharge and elsewhere as required to control flow direction.
- E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.
- F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

- A. Install specialties in accordance with manufacturer's instructions to provide intended performance.
- B. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.
- C. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.
- D. Install piping from boiler air outlet, air separator, or air purger to expansion tank with a 2 percent upward slope toward tank.
- E. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 (DN 50) and larger.
- F. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.
- G. Install expansion tanks above the air separator. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.
 - 1. Install tank fittings that are shipped loose.
 - 2. Support tank from floor or structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.
- H. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.
- I. Where large air quantities can accumulate, provide enlarged air collection standpipes.
- J. For automatic air vents in ceiling spaces or other concealed locations, provide vent tubing to nearest drain.
- K. Provide air separator on suction side of system circulation pump and connect to expansion tank.
- L. Provide valved drain and hose connection on strainer blow down connection.
- M. Provide pump suction fitting on suction side of base mounted centrifugal pumps[.] [**where indicated.**] Remove temporary strainers after cleaning systems.
- N. Provide combination pump discharge valve on discharge side of base mounted centrifugal pumps[.] [**where indicated.**]
- O. Provide isolation valves on water inlet to terminal heating units such as radiation, unit heaters, and fan coil unit.

- P. Provide flow-setting balancing valves on water outlet from terminal heating units.
- Q. Provide relief valves on pressure tanks, low pressure side of reducing valves, heat exchangers, and expansion tanks.
- R. Select system relief valve capacity so that it is greater than make-up pressure reducing valve capacity. Select equipment relief valve capacity to exceed rating of connected equipment.
- S. Pipe relief valve outlet to nearest floor drain.
- T. Where one line vents several relief valves, make cross sectional area equal to sum of individual vent areas.
- U. Clean and flush glycol system before adding glycol solution.
- V. Feed glycol solution to system through make-up line with pressure regulator, venting system high points. [**Set to fill at 12 psig.**] [**Pressure system cold at 5 psig.**]
- W. Perform tests determining strength of ethylene glycol and water solution and submit written test results.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232116

SECTION 232123 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Close-coupled, in-line centrifugal pumps.
 - 2. Close-coupled, end-suction centrifugal pumps.
 - 3. Separately coupled, horizontally mounted, in-line centrifugal pumps.
 - 4. Separately coupled, vertically mounted, in-line centrifugal pumps.
 - 5. Separately coupled, base-mounted, end-suction centrifugal pumps.
 - 6. Separately coupled, base-mounted, double-suction centrifugal pumps.
 - 7. Separately coupled, vertically mounted, double-suction centrifugal pumps.
 - 8. Separately coupled, vertically mounted, turbine centrifugal pumps.
 - 9. Wet-rotor pumps.
 - 10. Automatic condensate pump units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Buna-N: Nitrile rubber.
- B. EPT: Ethylene propylene terpolymer.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of pump. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated. Indicate pump's operating point on curves.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each pump.

1. Show pump layout and connections.
2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
3. Include diagrams for power, signal, and control wiring.

C. Millwright's Certificate: Certify that base mounted pumps have been aligned.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.
 1. Include installation instructions, assembly views, lubrication instructions, and replacement parts list.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Mechanical Seals: [**One (1)**] <Insert number> mechanical seal(s) for each pump.
 2. Provide two (2) sets of cartridges for each side-stream filter.

1.7 QUALITY ASSURANCE

- A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.
- B. Product Options: Drawings indicate size, profiles, and dimensional requirements of hydronic pumps and are based on the specific system indicated. Refer to Division 1.
- C. Manufacturer: Company specializing in manufacture, assembly, and field performance of pumps with minimum of five (5) years experience.
- D. Alignment: Base mounted pumps shall be aligned by qualified millwright.
- E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- F. UL Compliance: Comply with UL 778 for motor-operated water pumps.

1.8 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Division 1.
- B. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.
- C. Store pumps in clean, dry location.
- D. Retain protective covers for flanges and protective coatings during storage. Maintain in place until installation.
- E. Protect bearings and couplings against damage from sand, grit, and other foreign matter.
- F. Comply with pump manufacturer's written rigging instructions.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Armstrong Pumps Inc.](#)
 - 2. [Aurora Pump; Division of Pentair Pump Group.](#)
 - 3. [Crane Pumps & Systems.](#)
 - 4. [Flowserve Corporation.](#)
 - 5. [Grundfos Pumps Corporation.](#)
 - 6. [ITT Corporation; Bell & Gossett.](#)
 - 7. [Mepco, LLC.](#)
 - 8. [PACO Pumps.](#)
 - 9. [Patterson Pump Co.; a subsidiary of the Gorman-Rupp Co.](#)
 - 10. [Peerless Pump Company.](#)

11. [TACO Incorporated.](#)
 12. [Thrush Company Inc.](#)
 13. <Insert manufacturer's name>.
 14. or approved equal.
- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically.
- C. Pump Construction:
1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet[, **replaceable bronze wear rings,**] and threaded [**companion-flange**] [**union-end**] connections.
 2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
 3. Pump Shaft: [**Steel, with copper-alloy shaft sleeve**] [**Stainless steel**].
 4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket. Include water slinger on shaft between motor and seal.
 5. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
 6. Pump Bearings: [**Permanently lubricated ball bearings**] [**Oil lubricated; bronze-journal or thrust type**].
- D. Motor: Single speed and rigidly mounted to pump casing.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: [**Permanently lubricated**] [**Grease-lubricated**] ball bearings.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.

- e. Efficiency: Premium efficient.
- f. NEMA Design: **<Insert designation>**.
- g. Service Factor: **<Insert value>**.

E. Capacities and Characteristics:

- 1. Capacity: **<Insert gpm (L/s)>**.
- 2. Total Dynamic Head: **<Insert feet (kPa)>**.
- 3. Maximum Operating Pressure: **[175 psig (1204 kPa)] [250 psig (1720 kPa)]**.
- 4. Maximum Continuous Operating Temperature: **[225 deg F (107 deg C)] [250 deg F (120 deg C)]**.
- 5. Inlet and Outlet Size: **<Insert NPS (DN)>**.
- 6. Impeller Size: **<Insert inches (mm)>**.
- 7. Motor Speed: **<Insert rpm>**.
- 8. Motor Horsepower: **<Insert value>**.
- 9. Electrical Characteristics:
 - a. Volts: **[120] [240] [208] [460] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.2 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- 1. [American-Marsh Pumps.](#)
- 2. [Armstrong Pumps Inc.](#)
- 3. [Aurora Pump; Division of Pentair Pump Group.](#)
- 4. [Buffalo Pumps, Inc.](#)
- 5. [Crane Pumps & Systems.](#)
- 6. [Flowserve Corporation.](#)
- 7. [ITT Corporation; Bell & Gossett.](#)
- 8. [ITT Corporation; Goulds Pumps.](#)
- 9. [Lancaster Pump.](#)
- 10. [Mepco, LLC.](#)
- 11. [PACO Pumps.](#)
- 12. [Patterson Pump Co.; a subsidiary of the Gorman-Rupp Co.](#)
- 13. [Peerless Pump Company.](#)
- 14. [Scot Pump; Div. of Ardox Corp.](#)
- 15. [TACO Incorporated.](#)
- 16. [Thrush Company Inc.](#)
- 17. **<Insert manufacturer's name>**.
- 18. or approved equal.

- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally.
- C. Pump Construction:
1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] drain plug at bottom and air vent at top of volute, threaded gage tappings at inlet and outlet, and [**threaded companion-flange**] [**flanged**] connections.
 2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
 3. Pump Shaft: [**Steel, with copper-alloy shaft sleeve**] [**Stainless steel**].
 4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket. Include water slinger on shaft between motor and seal.
 5. Pump Bearings: [**Permanently lubricated ball bearings**] [**Oil lubricated; bronze-journal or thrust type**].
- D. Motor: Single speed and rigidly mounted to pump casing with integral pump support.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: [**Permanently lubricated**] [**Grease-lubricated**] ball bearings.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: <Insert designation>.
 - g. Service Factor: <Insert value>.
- E. Capacities and Characteristics:
1. Capacity: <Insert gpm (L/s)>.
 2. Total Dynamic Head: <Insert feet (kPa)>.

3. Maximum Operating Pressure: **175 psig** (1204 kPa).
4. Maximum Continuous Operating Temperature: **[225 deg F (107 deg C)] [250 deg F (120 deg C)]**.
5. Inlet and Outlet Size: **<Insert NPS (DN)>**.
6. Impeller Size: **<Insert inches (mm)>**.
7. Motor Speed: **<Insert rpm>**.
8. Motor Horsepower: **<Insert value>**.
9. Electrical Characteristics:
 - a. Volts: **[120] [240] [208] [460] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 SEPARATELY COUPLED, HORIZONTALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Armstrong Pumps Inc.](#)
2. [Aurora Pump; Division of Pentair Pump Group.](#)
3. [Flowserve Corporation.](#)
4. [Grundfos Pumps Corporation.](#)
5. [ITT Corporation; Bell & Gossett.](#)
6. [Mepco, LLC.](#)
7. [PACO Pumps.](#)
8. [Scot Pump; Div. of Ardox Corp.](#)
9. [TACO Incorporated.](#)
10. [Thrush Company Inc.](#)
11. **<Insert manufacturer's name>**.
12. or approved equal.

- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally.

- C. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, and threaded **[companion-flange] [union-end]** connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: **[Steel, with copper-alloy shaft sleeve] [Stainless steel]**.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and **[Buna-N] [EPT]** bellows and gasket. Include water

5. slinger on shaft between motor and seal.
5. Pump Bearings: [**Permanently lubricated ball bearings**] [**Oil lubricated; bronze-journal or thrust type**].
- D. Shaft Coupling: [**Molded-rubber insert with interlocking spider**] [**Interlocking frame with interconnecting springs**] capable of absorbing vibration.
- E. Motor: Single speed and [**resiliently**] [**rigidly**] mounted to pump casing.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: [**Permanently lubricated**] [**Grease-lubricated**] ball bearings.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: <Insert designation>.
 - g. Service Factor: <Insert value>.
- F. Capacities and Characteristics:
1. Capacity: <Insert gpm (L/s)>.
 2. Total Dynamic Head: <Insert feet (kPa)>.
 3. Maximum Operating Pressure: 175 psig (1204 kPa).
 4. Maximum Continuous Operating Temperature: [225 deg F (107 deg C)] [250 deg F (120 deg C)].
 5. Inlet and Outlet Size: <Insert NPS (DN)>.
 6. Impeller Size: <Insert inches (mm)>.
 7. Motor Speed: <Insert rpm>.
 8. Motor Horsepower: <Insert value>.
 9. Electrical Characteristics:
 - a. Volts: [120] [240] [208] [460] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.

- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.4 SEPARATELY COUPLED, VERTICALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- 1. [Armstrong Pumps Inc.](#)
- 2. [Aurora Pump; Division of Pentair Pump Group.](#)
- 3. [Crane Pumps & Systems.](#)
- 4. [Flowserve Corporation.](#)
- 5. [ITT Corporation; Bell & Gossett.](#)
- 6. [Mepco, LLC.](#)
- 7. [PACO Pumps.](#)
- 8. [Peerless Pump Company.](#)
- 9. [Patterson Pump Co.; a subsidiary of the Gorman-Rupp Co.](#)
- 10. [TACO Incorporated.](#)
- 11. [Thrush Company Inc.](#)
- 12. <Insert manufacturer's name>.
- 13. or approved equal.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically.

C. Pump Construction:

- 1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet[, **replaceable bronze wear rings,**] and threaded [**companion-flange**] [**union-end**] connections.
- 2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps not frequency-drive controlled, trim impeller to match specified performance.
- 3. Pump Shaft: [**Steel, with copper-alloy shaft sleeve**] [**Stainless steel**].
- 4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket. Include water slinger on shaft between motor and seal.
- 5. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
- 6. Pump Bearings: [**Permanently lubricated ball bearings**] [**Oil lubricated; bronze-journal or thrust type**].

D. Shaft Coupling: Axially split spacer coupling.

E. Motor: Single speed and rigidly mounted to pump casing with lifting eyebolt and

supporting lugs in motor enclosure.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: [**Permanently lubricated**] [**Grease-lubricated**] ball bearings.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: <Insert designation>.
 - g. Service Factor: <Insert value>.

F. Capacities and Characteristics:

1. Capacity: <Insert gpm (L/s)>.
2. Total Dynamic Head: <Insert feet (kPa)>.
3. Maximum Operating Pressure: [**175 psig (1204 kPa)**] [**250 psig (1720 kPa)**].
4. Maximum Continuous Operating Temperature: [**225 deg F (107 deg C)**] [**250 deg F (120 deg C)**].
5. Inlet and Outlet Size: <Insert NPS (DN)>.
6. Impeller Size: <Insert inches (mm)>.
7. Motor Speed: <Insert rpm>.
8. Motor Horsepower: <Insert value>.
9. Electrical Characteristics:
 - a. Volts: [**120**] [**240**] [**208**] [**460**] <Insert value>.
 - b. Phase: [**Single**] [**Three**].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.5 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [American-Marsh Pumps.](#)
2. [Armstrong Pumps Inc.](#)
3. [Aurora Pump; Division of Pentair Pump Group.](#)
4. [Buffalo Pumps, Inc.](#)
5. [Crane Pumps & Systems.](#)
6. [Flowserve Corporation.](#)
7. [ITT Corporation; Bell & Gossett.](#)
8. [Mepco, LLC.](#)
9. [PACO Pumps.](#)
10. [Peerless Pump Company.](#)
11. [Scot Pump; Div. of Ardox Corp.](#)
12. [TACO Incorporated.](#)
13. [Thrush Company Inc.](#)
14. **<Insert manufacturer's name>.**
15. or approved equal.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal.

C. Pump Construction:

1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and [**threaded companion-flange**] [**flanged**] connections.[**Provide integral mount on volute to support the casing, and provide attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.**]
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Steel, with copper-alloy shaft sleeve**] [**Stainless steel**].
4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket.
5. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

D. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration. [**Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor.**] [**EPDM coupling sleeve for variable-speed applications.**]

- E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.
- F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.
- G. Motor: Single speed, secured to mounting frame, with adjustable alignment.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: **[Open, dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over] [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine]**.
 - b. Enclosure Materials: **[Cast iron] [Cast aluminum] [Rolled steel]**.
 - c. Motor Bearings: **[Permanently lubricated] [Grease-lubricated]** ball bearings.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: **<Insert deg C>**.
 - 2) Altitude: **<Insert feet (meters)>** above sea level.
 - 3) High humidity.
 - 4) **<Insert conditions>**.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: **<Insert designation>**.
 - g. Service Factor: **<Insert value>**.
- H. Capacities and Characteristics:
1. Capacity: **<Insert gpm (L/s)>**.
 2. Total Dynamic Head: **<Insert feet (kPa)>**.
 3. Maximum Operating Pressure: **[175 psig (1204 kPa)] [250 psig (1720 kPa)]**.
 4. Maximum Continuous Operating Temperature: **[225 deg F (107 deg C)] [250 deg F (120 deg C)]**.
 5. Inlet and Outlet Size: **<Insert NPS (DN)>**.
 6. Impeller Size: **<Insert inches (mm)>**.
 7. Motor Speed: **<Insert rpm>**.
 8. Motor Horsepower: **<Insert value>**.
 9. Electrical Characteristics:
 - a. Volts: **[120] [240] [208] [460] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.

- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.6 SEPARATELY COUPLED, BASE-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [American-Marsh Pumps.](#)
2. [Armstrong Pumps Inc.](#)
3. [Aurora Pump; Division of Pentair Pump Group.](#)
4. [Buffalo Pumps, Inc.](#)
5. [Crane Pumps & Systems.](#)
6. [Flowserve Corporation.](#)
7. [ITT Corporation; Bell & Gossett.](#)
8. [Mepco, LLC.](#)
9. [PACO Pumps.](#)
10. [Patterson Pump Co.; a subsidiary of the Gorman-Rupp Co.](#)
11. [Peerless Pump Company.](#)
12. [TACO Incorporated.](#)
13. <Insert manufacturer's name>.
14. or approved equal.

B. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal.

C. Pump Construction:

1. Casing: [**Radially**] [**Horizontally**] split, cast iron, with[**replaceable bronze wear rings,**] threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and ASME B16.1, [**Class 125**] [**Class 250**] flanges.[**Casing supports shall allow removal and replacement of impeller without disconnecting piping.**]
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket.
5. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

- D. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration. [**Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor.**] [**EPDM coupling sleeve for variable-speed applications.**]
- E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.
- F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.
- G. Motor: Single speed, secured to mounting frame, with adjustable alignment.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: Grease lubricated.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: <Insert designation>.
 - g. Service Factor: <Insert value>.
- H. Capacities and Characteristics:
1. Capacity: <Insert gpm (L/s)>.
 2. Total Dynamic Head: <Insert feet (kPa)>.
 3. Maximum Operating Pressure: [**175 psig (1204 kPa)**] [**250 psig (1720 kPa)**].
 4. Maximum Continuous Operating Temperature: [**225 deg F (107 deg C)**] [**250 deg F (120 deg C)**].
 5. Inlet and Outlet Size: <Insert NPS (DN)>.
 6. Impeller Size: <Insert inches (mm)>.
 7. Motor Speed: <Insert rpm>.
 8. Motor Horsepower: <Insert value>.
 9. Electrical Characteristics:

- a. Volts: [**120**] [**240**] [**208**] [**460**] <Insert value>.
- b. Phase: [**Single**] [**Three**].
- c. Hertz: 60.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.7 SEPARATELY COUPLED, VERTICALLY MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Armstrong Pumps Inc.](#)
2. [Aurora Pump; Division of Pentair Pump Group.](#)
3. [Buffalo Pumps, Inc.](#)
4. [Flowserve Corporation.](#)
5. [ITT Corporation; Bell & Gossett.](#)
6. [Meeco, LLC.](#)
7. [PACO Pumps.](#)
8. [Pentair Water; Fairbanks Morse.](#)
9. [Peerless Pump Company.](#)
10. [TACO Incorporated.](#)
11. <Insert manufacturer's name>.
12. or approved equal.

B. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically.

C. Pump Construction:

1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] threaded gage tappings at inlet and outlet, drain plug at bottom of volute, mounting support, and ASME B16.1, [**Class 125**] [**Class 250**] flanges.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket.
5. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

D. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration.

- E. Motor: Single speed and secured to casing.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: Grease lubricated.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: <Insert designation>.
 - g. Service Factor: <Insert value>.
- F. Capacities and Characteristics:
1. Capacity: <Insert gpm (L/s)>.
 2. Total Dynamic Head: <Insert feet (kPa)>.
 3. Maximum Operating Pressure: [175 psig (1204 kPa)] [250 psig (1720 kPa)].
 4. Maximum Continuous Operating Temperature: [225 deg F (107 deg C)] [250 deg F (120 deg C)].
 5. Inlet and Outlet Size: <Insert NPS (DN)>.
 6. Impeller Size: <Insert inches (mm)>.
 7. Motor Speed: <Insert rpm>.
 8. Motor Horsepower: <Insert value>.
 9. Electrical Characteristics:
 - a. Volts: [120] [240] [208] [460] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.8 SEPARATELY COUPLED, VERTICALLY MOUNTED, TURBINE CENTRIFUGAL PUMPS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [American-Marsh Pumps.](#)
2. [Aurora Pump; Division of Pentair Pump Group.](#)
3. [Crane Pumps & Systems.](#)
4. [Flowserve Corporation.](#)
5. [Mepco, LLC.](#)
6. [PACO Pumps.](#)
7. [Patterson Pump Co.: a subsidiary of the Gorman-Rupp Co.](#)
8. [Peerless Pump Company.](#)
9. [Pentair Water; Fairbanks Morse.](#)
10. **<Insert manufacturer's name>.**
11. or approved equal.

B. Description: Factory-assembled and -tested, [**single-stage**] [**multistage**], centrifugal, impeller-between-bearings, end-suction pump as defined in HI 2.1-2.2 and HI 2.3; designed for installation with pump and motor shafts mounted vertically and projecting into a sump.

C. Pump Construction:

1. Pump Bowl: Cast iron, with [**cone**] [**basket**] strainer[, **replaceable bronze wear ring,**] and suction bell.[**Water passages of intermediate bowls shall be coated with porcelain enamel.**]
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced and keyed to shaft. For pumps not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Carbon**] [**Stainless**] steel sized according to manufacturer's requirements.
4. Pump Bearings: Water-lubricated bronze and rubber sleeve bearings in cast-iron housing.
5. Pump Column: ASTM A 53/A 53M, Grade B steel pipe.
6. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and [**Buna-N**] [**EPT**] bellows and gasket. Include water slinger on shaft between motor and seal.
7. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.

D. Shaft Coupling: Keyed with locking collets.

E. Discharge Head: ASME B16.1, [**Class 125**] [**Class 250**] discharge flange with threaded gage tapping. Top of discharge head shall have a registered fit to accurately locate the driver.

F. Drive Ratchet: Nonreversing ratchet.

- G. Hollow Shaft Motor: Single speed and secured to discharge head.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 - b. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - c. Motor Bearings: Grease lubricated.
 - d. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (meters)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - e. Efficiency: Premium efficient.
 - f. NEMA Design: <Insert designation>.
 - g. Service Factor: <Insert value>.
- H. Capacities and Characteristics:
1. Capacity: <Insert gpm (L/s)>.
 2. Total Dynamic Head: <Insert feet (kPa)>.
 3. Minimum Static Head: <Insert feet (kPa)>.
 4. Maximum Operating Pressure: 175 psig (1204 kPa).
 5. Maximum Continuous Operating Temperature: 200 deg F (93 deg C).
 6. Outlet Size: <Insert NPS (DN)>.
 7. Impeller Size: <Insert inches (mm)>.
 8. Motor Speed: <Insert rpm>.
 9. Motor Horsepower: <Insert value>.
 10. Electrical Characteristics:
 - a. Volts: [120] [240] [208] [460] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.9 WET-ROTOR PUMPS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Armstrong Pumps Inc.](#)
 2. [Flowserve Corporation.](#)
 3. [Grundfos Pumps Corporation.](#)
 4. [ITT Corporation; Bell & Gossett.](#)
 5. [TACO Incorporated.](#)
 6. **<Insert manufacturer's name>.**
 7. or approved equal.
- B. Description: Factory-assembled and -tested, wet-rotor pump.
- C. Pump Construction:
1. Body: [**100 percent lead-free bronze**] [**Stainless steel**] [**Cast iron**].
 2. Impeller: [**Polypropylene**] [**Noryl**].
 3. Pump Shaft: Ceramic.
 4. Bearings. Double-sintered carbon.
- D. Motor: [**Single**] [**Three**] speed.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Efficiency: Premium efficient.
 - b. NEMA Design: **<Insert designation>.**
 - c. Service Factor: **<Insert value>.**
- E. Capacities and Characteristics:
1. Capacity: **<Insert gpm (L/s)>.**
 2. Total Dynamic Head: **<Insert feet (kPa)>.**
 3. Maximum Operating Pressure: **150 psig (1132 kPa).**
 4. Maximum Continuous Operating Temperature: **[225 deg F (107 deg C)] [230 deg F (111 deg C)].**
 5. Inlet and Outlet Size: **<Insert NPS (DN)>.**
 6. Impeller Size: **<Insert inches (mm)>.**
 7. Motor Speed: **<Insert rpm>.**
 8. Motor Horsepower: **<Insert value>.**
 9. Electrical Characteristics:
 - a. Volts: **[120] <Insert value>.**
 - b. Phase: **[Single] [Three].**

- c. Hertz: 60.
- d. Full-Load Amperes: **<Insert value>**.
- e. Minimum Circuit Ampacity: **<Insert value>**.
- f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.10 AUTOMATIC CONDENSATE PUMP UNITS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Beckett Corporation](#).
2. [Hartell Pumps Div.; Milton Roy Co.](#)
3. [Little Giant Pump Co.](#)
4. [Mepco, LLC](#).
5. **<Insert manufacturer's name>**.
6. or approved equal.

B. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory- or field-installed check valve and a **72-inch** (1800-mm-) minimum, electrical power cord with plug.

C. Capacities and Characteristics:

1. Capacity: **<Insert gpm (L/s)>**.
2. Total Dynamic Head: **<Insert feet (kPa)>**.
3. Maximum Height to Inlet: **<Insert inches (mm)>**.
4. Inlet and Outlet Size: **<Insert NPS (DN)>**.
5. Motor Speed: **<Insert rpm>**.
6. Motor Horsepower: **<Insert value>**.
7. Electrical Characteristics:
 - a. Volts: **[120] <Insert value>**.
 - b. Phase: Single.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.11 PUMP SPECIALTY FITTINGS

A. Suction Diffuser:

1. Angle pattern.
2. **[175-psig (1204-kPa)] [300-psig (2060-kPa)]** pressure rating, **[cast] [ductile]-iron** body and end cap, pump-inlet fitting.
3. Bronze startup and bronze or stainless-steel permanent strainers.
4. Bronze or stainless-steel straightening vanes.
5. Drain plug.

6. Factory-fabricated support.
- B. Triple-Duty Valve:
1. Angle or straight pattern.
 2. [175-psig (1204-kPa)] [300-psig (2060-kPa)] pressure rating, [cast] [ductile]-iron body, pump-discharge fitting.
 3. Drain plug and bronze-fitted shutoff, balancing, and check valve features.
 4. Brass gage ports with integral check valve and orifice for flow measurement.

PART 3 - EXECUTION

3.1 PERFORMANCE REQUIREMENTS

- A. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25 percent of midpoint of published maximum efficiency curve.

3.2 EXAMINATION

- A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.
- C. Examine foundations and inertia bases for suitable conditions where pumps are to be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 CONCRETE BASES

- A. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around full perimeter of base.
- B. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
- C. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
- D. Install anchor bolts to elevations required for proper attachment to supported equipment.
- E. Cast-in-place concrete materials and placement requirements are specified in Division

3. Comply with requirements of Division 3.

3.4 PUMP INSTALLATION

- A. Comply with **[HI 1.4]** **[and]** **[HI 2.4]**.
- B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.
- C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.
- D. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.
- E. Equipment Mounting:
 - 1. Install base-mounted pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete.]"** **[Section 033053 "Miscellaneous Cast-in-Place Concrete.]"**
 - a. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.
 - b. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- F. Equipment Mounting: Install in-line pumps with continuous-thread hanger rods and **[elastomeric hangers]** **[spring hangers]** **[spring hangers with vertical-limit stop]** of size required to support weight of in-line pumps. Fabricate brackets or supports as required.
 - 1. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

3.5 ALIGNMENT

- A. Engage a factory-authorized service representative to assist Contractor and perform alignment service.
- B. Align pump and motor shafts and piping connections after setting on foundation, grout

has been set and foundation bolts have been tightened, and piping connections have been made.

- C. Comply with requirements in Hydronics Institute standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.

- 1. Adjust pump and motor shafts for angular and offset alignment by methods specified in [HI 1.1-1.5] [HI 2.1-2.5].

- D. Comply with pump and coupling manufacturers' written instructions.

- E. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.6 CONNECTIONS

- A. Comply with requirements for piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

- B. Where installing piping adjacent to pump, allow space for service and maintenance.

- C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

- D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

- E. Install [**check, shutoff, and throttling valves**] [**check valve and throttling valve with memory stop**] [**triple-duty valve**] on discharge side of pumps.

- F. Install [**Y-type strainer**] [**suction diffuser**] and shutoff valve on suction side of pumps.

- G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

- H. Install pressure gages on pump suction and discharge or at integral pressure-gage tapping, or install single gage with multiple-input selector valve.

- I. Install check valve and gate or ball valve on each condensate pump unit discharge.

- J. Install electrical connections for power, controls, and devices.

- K. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

- L. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.7 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Check piping connections for tightness.
 3. Clean strainers on suction piping.
 4. Perform the following startup checks for each pump before starting:
 - a. Verify bearing lubrication.
 - b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
 - c. Verify that pump is rotating in the correct direction.
 5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
 6. Start motor.
 7. Open discharge valve slowly.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232123

SECTION 232300 - REFRIGERANT PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Refrigerant pipes and fittings.
 - 2. Refrigerant piping valves and specialties.
 - 3. Refrigerants.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of valve and refrigerant piping specialty. Provide general assembly of specialties, including manufacturers' catalogue information. Provide manufacturers catalog data including load capacity.
 - 1. Include pressure drop, based on manufacturer's test data, for the following:
 - a. Thermostatic expansion valves.
 - b. Solenoid valves.
 - c. Hot-gas bypass valves.
 - d. Filter dryers.
 - e. Strainers.
 - f. Pressure-regulating valves.
 - g. Include data substantiating that materials comply with requirements.
- B. Design Data: Submit design data indicating pipe sizing. Indicate load carrying capacity of trapeze, multiple pipe, and riser support hangers.
- C. Shop Drawings:
 - 1. Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes; flow capacities; valve arrangements and locations; slopes of horizontal runs; oil traps; double risers; wall and floor penetrations; and equipment connection details.

2. Show piping size and piping layout, including oil traps, double risers, specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.
3. Show interface and spatial relationships between piping and equipment.
4. Shop Drawing Scale: [1/4 inch equals 1 foot (1:50)] **<Insert value>**.

1.4 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Field quality-control reports. Indicate results of leak test, acid test.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For refrigerant valves and piping specialties to include in maintenance manuals.
 1. Include instructions for changing cartridges, assembly views, spare parts lists.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Record exact locations of equipment and refrigeration accessories on record drawings.

1.6 MAINTENANCE MATERIALS

- A. Provide two (2) refrigeration oil test kits each containing everything required to conduct one (1) test.
- B. Provide two (2) containers each with **<Insert number>** pounds of **<Insert type>** refrigerant.
- C. Provide two (2) filter-dryer cartridges of each type.

1.7 QUALITY ASSURANCE

- A. Installer: Company specializing in performing the work of this section with minimum of three (3) years experience.
- B. Design piping system under direct supervision of a Professional Engineer experienced in design of this work and licensed in the State of Colorado.

- C. Welding Qualifications: Qualify procedures and personnel according to 2010 ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
- D. Comply with ASHRAE 15, "Safety Code for Refrigeration Systems."
- E. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 PRODUCT STORAGE AND HANDLING

- A. Dehydrate and charge components such as piping and receivers, seal prior to shipment, until connected into system.
- B. Deliver and store piping and specialties in shipping containers with labeling in place.
- C. Store piping with end caps in place to ensure that piping interior and exterior are clean when installed.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Line Test Pressure for Refrigerant R-134a:
 - 1. Suction Lines for Air-Conditioning Applications: **115 psig** (793 kPa).
 - 2. Suction Lines for Heat-Pump Applications: **225 psig** (1551 kPa).
 - 3. Hot-Gas and Liquid Lines: **225 psig** (1551 kPa).
- B. Line Test Pressure for Refrigerant R-407C:
 - 1. Suction Lines for Air-Conditioning Applications: **230 psig** (1586 kPa).
 - 2. Suction Lines for Heat-Pump Applications: **380 psig** (2620 kPa).
 - 3. Hot-Gas and Liquid Lines: **380 psig** (2620 kPa).
- C. Line Test Pressure for Refrigerant R-410A:
 - 1. Suction Lines for Air-Conditioning Applications: **300 psig** (2068 kPa).
 - 2. Suction Lines for Heat-Pump Applications: **535 psig** (3689 kPa).

3. Hot-Gas and Liquid Lines: 535 psig (3689 kPa).

2.2 COPPER TUBE AND FITTINGS

- A. Copper Tube: [ASTM B 88, Type K or L (ASTM B 88M, Type A or B)] [ASTM B 280, Type ACR].
- B. Wrought-Copper Fittings: ASME B16.22.
- C. Wrought-Copper Unions: ASME B16.22.
- D. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.
- E. Brazing Filler Metals: AWS A5.8/A5.8M.
- F. Flexible Connectors:
 1. Body: Tin-bronze bellows with woven, flexible, tinned-bronze-wire-reinforced protective jacket.
 2. End Connections: Socket ends.
 3. Offset Performance: Capable of minimum 3/4-inch (20-mm) misalignment in minimum 7-inch- (180-mm-) long assembly.
 4. Working Pressure Rating: Factory test at minimum 500 psig (3450 kPa).
 5. Maximum Operating Temperature: 250 deg F (121 deg C).

2.3 STEEL PIPE AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness as selected in piping application articles.
- B. Wrought-Steel Fittings: ASTM A 234/A 234M, for welded joints.
- C. Steel Flanges and Flanged Fittings: ASME B16.5, steel, including bolts, nuts, and gaskets, bevel-welded end connection, and raised face.
- D. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- E. Flanged Unions:
 1. Body: Forged-steel flanges for NPS 1 to NPS 1-1/2 (DN 25 to DN 40) and ductile iron for NPS 2 to NPS 3 (DN 50 to DN 80). Apply rust-resistant finish at factory.
 2. Gasket: Fiber asbestos free.
 3. Fasteners: Four plated-steel bolts, with silicon bronze nuts. Apply rust-resistant finish at factory.
 4. End Connections: Brass tailpiece adapters for solder-end connections to copper tubing.
 5. Offset Performance: Capable of minimum 3/4-inch (20-mm) misalignment in

- minimum **7-inch**- (180-mm-) long assembly.
6. Pressure Rating: Factory test at minimum **400 psig** (2760 kPa).
 7. Maximum Operating Temperature: **330 deg F** (165 deg C).

F. Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, stainless-steel-wire-reinforced protective jacket.
2. End Connections:
 - a. **NPS 2** (DN 50) and Smaller: With threaded-end connections.
 - b. **NPS 2-1/2** (DN 65) and Larger: With flanged-end connections.
3. Offset Performance: Capable of minimum **3/4-inch** (20-mm) misalignment in minimum **7-inch**- (180-mm-) long assembly.
4. Pressure Rating: Factory test at minimum **500 psig** (3450 kPa).
5. Maximum Operating Temperature: **250 deg F** (121 deg C).

2.4 VALVES AND SPECIALTIES

A. Diaphragm Packless Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Heldon Technologies.](#)
 - c. [Henry Technologies.](#)
 - d. [Mueller Industries, Inc.](#)
 - e. [Parker.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
2. Body and Bonnet: Forged brass or cast bronze; globe design with straight-through or angle pattern.
3. Diaphragm: Phosphor bronze and stainless steel with stainless-steel spring.
4. Operator: Rising stem and hand wheel.
5. Seat: Nylon.
6. End Connections: Socket, union, or flanged.
7. Working Pressure Rating: **500 psig** (3450 kPa).
8. Maximum Operating Temperature: **275 deg F** (135 deg C).

B. Packed-Angle Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Heldon Technologies.](#)

- c. [Henry Technologies.](#)
 - d. [Mueller Industries, Inc.](#)
 - e. [Parker.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.
2. Body and Bonnet: Forged brass or cast bronze.
 3. Packing: Molded stem, back seating, and replaceable under pressure.
 4. Operator: Rising stem.
 5. Seat: Nonrotating, self-aligning polytetrafluoroethylene.
 6. Seal Cap: Forged-brass or valox hex cap.
 7. End Connections: Socket, union, threaded, or flanged.
 8. Working Pressure Rating: **500 psig** (3450 kPa).
 9. Maximum Operating Temperature: **275 deg F** (135 deg C).

C. Check Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Emerson Climate Technologies.](#)
 - c. [Heldon Technologies.](#)
 - d. [Henry Technologies.](#)
 - e. [Mueller Industries, Inc.](#)
 - f. [Parker.](#)
 - g. **<Insert manufacturer's name>.**
 - h. or approved equal.
2. Body: Ductile iron, forged brass, or cast bronze; globe pattern.
3. Bonnet: Bolted ductile iron, forged brass, or cast bronze; or brass hex plug.
4. Piston: Removable polytetrafluoroethylene seat.
5. Closing Spring: Stainless steel.
6. Manual Opening Stem: Seal cap, plated-steel stem, and graphite seal.
7. End Connections: Socket, union, threaded, or flanged.
8. Maximum Opening Pressure: **0.50 psig** (3.4 kPa).
9. Working Pressure Rating: **500 psig** (3450 kPa).
10. Maximum Operating Temperature: **275 deg F** (135 deg C).

D. Service Valves:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Emerson Climate Technologies.](#)
 - c. [Heldon Technologies.](#)
 - d. [Henry Technologies.](#)
 - e. [Mueller Industries, Inc.](#)
 - f. [Parker.](#)

4. Seat: Polytetrafluoroethylene.
 5. End Connections: Threaded.
 6. Working Pressure Rating: 400 psig (2760 kPa).
 7. Maximum Operating Temperature: 240 deg F (116 deg C).
- G. Thermostatic Expansion Valves: Comply with AHRI 750.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Emerson Climate Technologies.](#)
 - c. [Heldon Technologies.](#)
 - d. [Henry Technologies.](#)
 - e. [Mueller Industries, Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
 2. Body, Bonnet, and Seal Cap: Forged brass or steel.
 3. Diaphragm, Piston, Closing Spring, and Seat Insert: Stainless steel.
 4. Packing and Gaskets: Non-asbestos.
 5. Capillary and Bulb: Copper tubing filled with refrigerant charge.
 6. Suction Temperature: [40 deg F (4.4 deg C)] <Insert temperature>.
 7. Superheat: [**Adjustable**] [**Nonadjustable**].
 8. Reverse-flow option (for heat-pump applications).
 9. End Connections: Socket, flare, or threaded union.
 10. Working Pressure Rating: [700 psig (4820 kPa)] [450 psig (3100 kPa)] <Insert value>.
- H. Electronic Expansion Valves:
1. Valve:
 - a. Brass body with flared or solder connection, needle valve with floating needle and machined seat, stepper motor drive.
 - b. Capacity: Nominal <Insert number> tons.
 - c. Electrical Characteristics: 12 VA, 12 volts DC.
 2. Evaporation Control System:
 - a. Electronic microprocessor based unit in enclosed case, proportional integral control with adaptive superheat, maximum operating pressure function, preselection allowance for electrical defrost and hot gas bypass.
 - b. Electrical Characteristics: 12 VA, 115 volts, single phase, 50/60 Hz.
 3. Refrigeration System Control: Electronic microprocessor based unit in enclosed case, with proportional integral control of valve, on/off thermostat, air temperature alarm (high and low), solenoid valve control, liquid injection adaptive superheat control, maximum operating pressure function, night setback thermostat, timer for defrost control.

- I. Hot-Gas Bypass Valves: Comply with UL 429; listed and labeled by an NRTL.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Heldon Technologies.](#)
 - c. [Henry Technologies.](#)
 - d. [Parker.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
 2. Body, Bonnet, and Seal Cap: Ductile iron or steel.
 3. Diaphragm, Piston, Closing Spring, and Seat Insert: Stainless steel.
 4. Packing and Gaskets: Non-asbestos.
 5. Solenoid Tube, Plunger, Closing Spring, and Seat Orifice: Stainless steel.
 6. Seat: Polytetrafluoroethylene.
 7. Equalizer: **[Internal] [External]**.
 8. Electrical: Molded, watertight coil in NEMA 250 enclosure of type required by location with **1/2-inch (16-GRC)** conduit adapter and **[24] [115] [208]-V** ac coil.
 9. End Connections: Socket.
 10. Set Pressure: **<Insert psig (kPa)>.**
 11. Throttling Range: Maximum **5 psig (34 kPa)**.
 12. Working Pressure Rating: **500 psig (3450 kPa)**.
 13. Maximum Operating Temperature: **240 deg F (116 deg C)**.
- J. Straight-Type Strainers:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
 - b. [Heldon Technologies.](#)
 - c. [Henry Technologies.](#)
 - d. [Parker.](#)
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
 2. Body: Welded steel with corrosion-resistant coating.
 3. Screen: 100-mesh stainless steel.
 4. End Connections: Socket or flare.
 5. Working Pressure Rating: **500 psig (3450 kPa)**.
 6. Maximum Operating Temperature: **275 deg F (135 deg C)**.
- K. Angle-Type Strainers:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)

- b. [Heldon Technologies](#).
 - c. [Henry Technologies](#).
 - d. [Parker](#).
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
 2. Body: Forged brass or cast bronze.
 3. Drain Plug: Brass hex plug.
 4. Screen: 100-mesh monel.
 5. End Connections: Socket or flare.
 6. Working Pressure Rating: **500 psig** (3450 kPa).
 7. Maximum Operating Temperature: **275 deg F** (135 deg C).
- L. Moisture/Liquid Indicators:
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division](#).
 - b. [Emerson Climate Technologies](#).
 - c. [Heldon Technologies](#).
 - d. [Henry Technologies](#).
 - e. [Parker](#).
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
 2. Body: Forged brass.
 3. Window: Replaceable, clear, fused glass window with indicating element protected by filter screen.
 4. Indicator: Color coded to show moisture content in parts per million (ppm).
 5. Minimum Moisture Indicator Sensitivity: Indicate moisture above 60 ppm.
 6. End Connections: Socket or flare.
 7. Working Pressure Rating: **500 psig** (3450 kPa).
 8. Maximum Operating Temperature: **240 deg F** (116 deg C).
 9. UL listed.
- M. Replaceable-Core Filter Dryers: Comply with AHRI 730.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Danfoss LLC; Refrigeration & Air-Conditioning Division](#).
 - b. [Emerson Climate Technologies](#).
 - c. [Heldon Technologies](#).
 - d. [Henry Technologies](#).
 - e. [Parker](#).
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.

2. Body and Cover: Painted-steel shell with ductile-iron cover, stainless-steel screws, and neoprene gaskets.
3. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
4. Desiccant Media: Activated [alumina] [charcoal].
5. Designed for reverse flow (for heat-pump applications).
6. End Connections: Socket.
7. Access Ports: NPS 1/4 (DN 8) connections at entering and leaving sides for pressure differential measurement.
8. Maximum Pressure Loss: [2 psig (14 kPa)] <Insert value>.
9. Rated Flow: <Insert tons (kW)>.
10. Working Pressure Rating: 500 psig (3450 kPa).
11. Maximum Operating Temperature: 240 deg F (116 deg C).

N. Permanent Filter Dryers: Comply with AHRI 730.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
- b. [Emerson Climate Technologies.](#)
- c. [Heldon Technologies.](#)
- d. [Henry Technologies.](#)
- e. [Parker.](#)
- f. <Insert manufacturer's name>.
- g. or approved equal.

2. Body and Cover: Painted-steel shell.
3. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
4. Desiccant Media: Activated [alumina] [charcoal].
5. Designed for reverse flow (for heat-pump applications).
6. End Connections: Socket.
7. Access Ports: NPS 1/4 (DN 8) connections at entering and leaving sides for pressure differential measurement.
8. Maximum Pressure Loss: [2 psig (14 kPa)] <Insert value>.
9. Rated Flow: <Insert tons (kW)>.
10. Working Pressure Rating: 500 psig (3450 kPa).
11. Maximum Operating Temperature: 240 deg F (116 deg C).

O. Mufflers:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Danfoss LLC; Refrigeration & Air-Conditioning Division.](#)
- b. [Emerson Climate Technologies.](#)
- c. [Heldon Technologies.](#)
- d. [Henry Technologies.](#)
- e. <Insert manufacturer's name>.
- f. or approved equal.

2. Body: Welded steel with corrosion-resistant coating.
3. End Connections: Socket or flare.
4. Working Pressure Rating: 500 psig (3450 kPa).
5. Maximum Operating Temperature: 275 deg F (135 deg C).

P. Receivers: Comply with AHRI 495.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Heldon Technologies](#).
 - b. [Henry Technologies](#).
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Comply with 2010 ASME Boiler and Pressure Vessel Code; listed and labeled by an NRTL.
3. Comply with UL 207; listed and labeled by an NRTL.
4. Body: Welded steel with corrosion-resistant coating.
5. Tappings: Inlet, outlet, liquid level indicator, and safety relief valve.
6. End Connections: Socket or threaded.
7. Working Pressure Rating: 500 psig (3450 kPa).
8. Maximum Operating Temperature: 275 deg F (135 deg C).

Q. Liquid Accumulators: Comply with AHRI 495.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Emerson Climate Technologies](#).
 - b. [Heldon Technologies](#).
 - c. [Henry Technologies](#).
 - d. [Parker](#).
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
2. Body: Welded steel with corrosion-resistant coating.
3. End Connections: Socket or threaded.
4. Working Pressure Rating: 500 psig (3450 kPa).
5. Maximum Operating Temperature: 275 deg F (135 deg C).

R. Flexible Connectors:

1. Corrugated stainless steel hose with single layer of stainless steel exterior braiding, minimum 9 inches long with copper tube ends; for maximum working pressure [500] [400] [350] [300] psig.

2.5 REFRIGERANTS

A. ASHRAE 34, R-134a: Tetrafluoroethane.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Arkema Inc.](#)
 - b. [DuPont; Fluorochemicals Div.](#)
 - c. [Honeywell International Inc.; Genetron Refrigerants.](#)
 - d. [Mexichem Fluor Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.

- B. ASHRAE 34, R-407C: Difluoromethane/Pentafluoroethane/1,1,1,2-Tetrafluoroethane.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Arkema Inc.](#)
 - b. [DuPont; Fluorochemicals Div.](#)
 - c. [Honeywell International Inc.; Genetron Refrigerants.](#)
 - d. [Mexichem Fluor Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.

- C. ASHRAE 34, R-410A: Pentafluoroethane/Difluoromethane.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Arkema Inc.](#)
 - b. [DuPont; Fluorochemicals Div.](#)
 - c. [Honeywell International Inc.; Genetron Refrigerants.](#)
 - d. [Mexichem Fluor Inc.](#)
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt on inside and outside before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.2 SYSTEM - GENERAL

- A. Where more than one piping system material is specified ensure system components are compatible and joined to ensure the integrity of the system is not jeopardized.

- Provide necessary joining fittings. Ensure flanges, union, and couplings for servicing are consistently provided.
- B. Provide pipe hangers and supports in accordance with **[ASTM B31.5]** **[MSS SP69]** unless indicated otherwise, and in conformance with Section 230529 "Hangers and Supports for HVAC Piping and Equipment".
- C. Liquid Indicators:
1. Use line size liquid indicators in main liquid line leaving condenser.
 2. If receiver is provided, install in liquid line leaving receiver.
 3. Use line size on leaving side of liquid solenoid valves.
- D. Valves:
1. Use service valves on suction and discharge of compressors.
 2. Use gage taps at compressor inlet and outlet.
 3. Use gage taps at hot gas bypass regulators, inlet and outlet.
 4. Use check valves on compressor discharge.
 5. Use check valves on condenser liquid lines on multiple condenser systems.
- E. Refrigerant Charging (Packed Angle) Valve: Use in liquid line between receiver shut-off valve and expansion valve.
- F. Strainers:
1. Use line size strainer upstream of each automatic valve.
 2. Where multiple expansion valves with integral strainers are used, use single main liquid line strainer.
 3. On steel piping systems, use strainer in suction line.
 4. Use shut-off valve on each side of strainer.
- G. Pressure Relief Valves: Use on ASME receivers **[and pipe to outdoors]**.
- H. Permanent Filter-Driers:
1. Use in low temperature systems.
 2. Use in systems utilizing hermetic compressors.
 3. Use filter-driers for each solenoid valve.
- I. Replaceable Cartridge Filter-Driers:
1. Use vertically in liquid line adjacent to receivers.
 2. Use filter-driers for each solenoid valve.
 3. Provide isolation valves and bypass valve for each filter-drier.
- J. Solenoid Valves:
1. Use in liquid line of systems operating with single pump-out or pump-down compressor control.
 2. Use in liquid line of single or multiple evaporator systems, upstream of each

- expansion valve.
3. Use in oil bleeder lines from flooded evaporators to stop flow of oil and refrigerant into the suction line when system shuts down.

K. Receivers:

1. Use on systems [5] <Insert number> tons and larger, sized to accommodate pump down charge.
2. Use on systems with long piping runs.

L. Flexible Connectors: Utilize at or near compressors where piping configuration does not absorb vibration.

3.3 PIPING APPLICATIONS FOR REFRIGERANT R-134a

- A. Suction Lines [NPS 1-1/2 (DN 40) and Smaller] <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- B. Suction Lines [NPS 4 (DN 100) and Smaller] [NPS 2 to NPS 4 (DN 50 to DN 100)] <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, [Type ACR] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- C. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications]: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- D. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications]: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with soldered joints.
- E. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications]:
 1. [NPS 1-1/2 (DN 40) and Smaller] <Insert pipe size range>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
 2. [NPS 1-1/2 (DN 40) and Smaller] <Insert pipe size range>: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
 3. [NPS 4 (DN 100)] <Insert pipe size>: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- F. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.
- G. Safety-Relief-Valve Discharge Piping: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with soldered joints.

H. Safety-Relief-Valve Discharge Piping:

1. [NPS 1-1/2 (DN 40) and Smaller] <Insert pipe size range>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
2. [NPS 1-1/2 (DN 40) and Smaller] <Insert pipe size range>: Copper, [Type ACR] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
3. [NPS 4 (DN 100)] <Insert pipe size>: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.

3.4 PIPING APPLICATIONS FOR REFRIGERANT R-407C

- A. Suction Lines [NPS 1-1/2 (DN 40) and Smaller] <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- B. Suction Lines [NPS 4 (DN 100) and Smaller] [NPS 2 to NPS 4 (DN 50 to DN 100)] <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, [Type ACR] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- C. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications]: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
- D. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications]: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with soldered joints.
- E. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications]:
1. [NPS 1 (DN 25) and Smaller] <Insert pipe size range>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
 2. [NPS 1 (DN 25) and Smaller] <Insert pipe size range>: Copper, [Type ACR] [Type L (B)], drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
 3. [NPS 1-1/4 to NPS 2 (DN 32 to DN 50)] <Insert pipe size range>: Copper, Type K (A), annealed- or drawn-temper tubing and wrought-copper fittings with [brazed] [or] [soldered] joints.
 4. [NPS 4 (DN 100)] <Insert pipe size>: Copper, [Type ACR] [Type K (A)] [Type L (B)], drawn-temper tubing and wrought-copper fittings with soldered joints.
- F. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.
- G. Safety-Relief-Valve Discharge Piping: Copper, [Type ACR] [Type K (A)] [Type L (B)],

drawn-temper tubing and wrought-copper fittings with soldered joints.

H. Safety-Relief-Valve Discharge Piping:

1. **[NPS 1 (DN 25) and Smaller]** <Insert pipe size range>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
2. **[NPS 1 (DN 25) and Smaller]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
3. **[NPS 1-1/4 to NPS 2 (DN 32 to DN 50)]** <Insert pipe size range>: Copper, Type **K (A)**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
4. **[NPS 4 (DN 100)]** <Insert pipe size>: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with soldered joints.

3.5 PIPING APPLICATIONS FOR REFRIGERANT R-410A

- A. Suction Lines **[NPS 1-1/2 (DN 40) and Smaller]** <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
- B. Suction Lines **[NPS 3-1/2 (DN 90) and Smaller]** **[NPS 2 to NPS 3-1/2 (DN 50 to DN 90)]** <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, **[Type ACR]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
- C. Suction Lines **[NPS 4 (DN 100) and Smaller]** <Insert pipe size range> for Conventional Air-Conditioning Applications: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with soldered joints.
- D. Hot-Gas and Liquid Lines[, **and Suction Lines for Heat-Pump Applications**]: Copper, **[Type ACR]** **[Type L (B)]**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
- E. Hot-Gas and Liquid Lines[, **and Suction Lines for Heat-Pump Applications**]: Copper, Type **K (A)**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
- F. Hot-Gas and Liquid Lines[, **and Suction Lines for Heat-Pump Applications**]: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
- G. Hot-Gas and Liquid Lines[, **and Suction Lines for Heat-Pump Applications**]: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.
- H. Hot-Gas and Liquid Lines[, **and Suction Lines for Heat-Pump Applications**]:

1. **[NPS 5/8 (DN 18) and Smaller]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type L (B)]**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
 2. **[NPS 3/4 to NPS 1 (DN 20 to DN 25) and Smaller]** <Insert pipe size range>: Copper, Type **K (A)**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
 3. **[NPS 1-1/4 (DN 32) and Smaller]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
 4. **[NPS 1-1/2 to NPS 2 (DN 40 to DN 50)]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.
- I. Hot-Gas and Liquid Lines[, and Suction Lines for Heat-Pump Applications] **[NPS 2 to NPS 4 (DN 50 to DN 100)]** <Insert pipe size range>: Schedule 40, black-steel and wrought-steel fittings with welded joints.
- J. Safety-Relief-Valve Discharge Piping: Copper, **[Type ACR]** **[Type L (B)]**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
- K. Safety-Relief-Valve Discharge Piping: Copper, Type **K (A)**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
- L. Safety-Relief-Valve Discharge Piping: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
- M. Safety-Relief-Valve Discharge Piping: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.
- N. Safety-Relief-Valve Discharge Piping:
1. **[NPS 5/8 (DN 18) and Smaller]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type L (B)]**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
 2. **[NPS 3/4 to NPS 1 (DN 20 to DN 25) and Smaller]** <Insert pipe size range>: Copper, Type **K (A)**, annealed- or drawn-temper tubing and wrought-copper fittings with **[brazed]** **[or]** **[soldered]** joints.
 3. **[NPS 1-1/4 (DN 32) and Smaller]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
 4. **[NPS 1-1/2 to NPS 2 (DN 40 to DN 50)]** <Insert pipe size range>: Copper, **[Type ACR]** **[Type K (A)]** **[Type L (B)]**, drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.
- O. Safety-Relief-Valve Discharge Piping **[NPS 2 to NPS 4 (DN 50 to DN 100)]** <Insert pipe size range>: Schedule 40, black-steel and wrought-steel fittings with welded joints.

3.6 VALVE AND SPECIALTY APPLICATIONS

- A. Install **[diaphragm packless] [packed-angle]** valves in suction and discharge lines of compressor.
- B. Install service valves for gage taps at inlet and outlet of hot-gas bypass valves and strainers if they are not an integral part of valves and strainers.
- C. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.
- D. Except as otherwise indicated, install **[diaphragm packless] [packed-angle]** valves on inlet and outlet side of filter dryers.
- E. Install a full-size, three-valve bypass around filter dryers.
- F. Install solenoid valves upstream from each expansion valve and hot-gas bypass valve. Install solenoid valves in horizontal lines with coil at top.
- G. Install thermostatic expansion valves as close as possible to distributors on evaporators.
 - 1. Install valve so diaphragm case is warmer than bulb.
 - 2. Secure bulb to clean, straight, horizontal section of suction line using two bulb straps. Do not mount bulb in a trap or at bottom of the line.
 - 3. If external equalizer lines are required, make connection where it will reflect suction-line pressure at bulb location.
- H. Install safety relief valves where required by 2010 ASME Boiler and Pressure Vessel Code. Pipe safety-relief-valve discharge line to outside according to ASHRAE 15.
- I. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube.
- J. Install strainers upstream from and adjacent to the following unless they are furnished as an integral assembly for the device being protected:
 - 1. Solenoid valves.
 - 2. Thermostatic expansion valves.
 - 3. Hot-gas bypass valves.
 - 4. Compressor.
- K. Install filter dryers in liquid line between compressor and thermostatic expansion valve, **and in the suction line at the compressor**.
- L. Install receivers sized to accommodate pump-down charge.
- M. Install flexible connectors at compressors.

3.7 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems; indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop Drawings.
- B. Install refrigerant piping according to ASHRAE 15.
- C. Install refrigeration specialties in accordance with manufacturer's instructions.
- D. Route piping in orderly manner, with plumbing parallel to building structure, and maintain gradient.
- E. Install piping to conserve building space and not interfere with use of space.
- F. Group piping whenever practical at common elevations and locations. Slope piping one percent in direction of oil return.
- G. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.
- H. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- I. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- J. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- K. Install piping adjacent to machines to allow service and maintenance.
- L. Arrange piping to return oil to compressor. Provide traps and loops in piping, and provide double risers as required. Slope horizontal piping 0.40 percent in direction of flow.
- M. Provide clearance for installation of insulation and access to valves and fittings.
- N. Install piping free of sags and bends.
- O. Install fittings for changes in direction and branch connections.
- P. Select system components with pressure rating equal to or greater than system operating pressure.
- Q. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for solenoid valve controllers, control wiring, and sequence of operation.

- R. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.
- S. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Section 083113 "Access Doors and Frames" if valves or equipment requiring maintenance is concealed behind finished surfaces.
- T. Install refrigerant piping in protective conduit where installed belowground.
- U. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.
- V. Slope refrigerant piping as follows:
1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
 2. Install horizontal suction lines with a uniform slope downward to compressor.
 3. Install traps and double risers to entrain oil in vertical runs.
 4. Liquid lines may be installed level.
- W. When brazing or soldering, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.
1. Flood piping system with nitrogen when brazing.
- X. Before installation of steel refrigerant piping, clean pipe and fittings using the following procedures:
1. Shot blast the interior of piping.
 2. Remove coarse particles of dirt and dust by drawing a clean, lintless cloth through tubing by means of a wire or electrician's tape.
 3. Draw a clean, lintless cloth saturated with trichloroethylene through the tube or pipe. Continue this procedure until cloth is not discolored by dirt.
 4. Draw a clean, lintless cloth, saturated with compressor oil, squeezed dry, through the tube or pipe to remove remaining lint. Inspect tube or pipe visually for remaining dirt and lint.
 5. Finally, draw a clean, dry, lintless cloth through the tube or pipe.
 6. Safety-relief-valve discharge piping is not required to be cleaned but is required to be open to allow unrestricted flow.
- Y. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.
- Z. Where pipe support members are welded to structural building frame, brush clean, and apply one coat of zinc rich primer to welding.
- AA. Prepare unfinished pipe, fittings, supports, and accessories ready for finish painting. Refer to Division 9.

- BB. Insulate piping and equipment; refer to Section 230719 "HVAC Piping Insulation" and Section 230716 "HVAC Equipment Insulation".
- CC. Follow ASHRAE 15 procedures for charging and purging of systems and for disposal of refrigerant.
- DD. Provide replaceable cartridge filter-driers, with isolation valves and valved bypass.
- EE. Locate expansion valve sensing bulb immediately downstream of evaporator on suction line.
- FF. Provide external equalizer piping on expansion valves with refrigerant distributor connected to evaporator.
- GG. Install flexible connectors at right angles to axial movement of compressor, parallel to crankshaft.
- HH. Lever handle valves: Install valve handle so that the handle opens in the direction of fluid flow.
- II. Provide electrical connection to solenoid valves. Comply with requirements of Division 26.
- JJ. Identify refrigerant piping and valves according to Section 230553 "Identification for HVAC Piping and Equipment."
- KK. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- LL. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- MM. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."
- NN. Fully charge completed system with refrigerant after testing.

3.8 PIPE JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Fill pipe and fittings with an inert gas (nitrogen or carbon dioxide), during brazing or welding, to prevent scale formation.

- D. Soldered Joints: Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook."
- E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube."
 - 1. Use Type BCuP (copper-phosphorus) alloy for joining copper socket fittings with copper pipe.
 - 2. Use Type BAg (cadmium-free silver) alloy for joining copper with bronze or steel.
- F. Threaded Joints: Thread steel pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and to restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry-seal threading is specified.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- G. Steel pipe can be threaded, but threaded joints must be seal brazed or seal welded.
- H. Welded Joints: Construct joints according to AWS D10.12M/D10.12.
- I. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.9 HANGERS AND SUPPORTS

- A. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Install the following pipe attachments:
 - 1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet (6 m) long.
 - 2. Roller hangers and spring hangers for individual horizontal runs 20 feet (6 m) or longer.
 - 3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet (6 m) or longer, supported on a trapeze.
 - 4. Spring hangers to support vertical runs.
 - 5. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
- C. Install hangers for copper tubing with the following maximum spacing and minimum rod diameters:
 - 1. NPS 1/2 (DN 15): Maximum span, 78 inches (1950 mm); minimum rod, 3/8 inch (9.5 mm).
 - 2. NPS 5/8 (DN 18): Maximum span, 78 inches (1950 mm); minimum rod, 3/8 inch

3. (9.5 mm).
NPS 1 (DN 25): Maximum span, 78 inches (1950 mm); minimum rod, 3/8 inch (9.5 mm).
4. NPS 1-1/4 (DN 32): Maximum span, 78 inches (1950 mm); minimum rod, 3/8 inch (9.5 mm).
5. NPS 1-1/2 (DN 40): Maximum span, 10 feet (3.33 m); minimum rod, 3/8 inch (9.5 mm).
6. NPS 2 (DN 50): Maximum span, 10 feet (3.33 m); minimum rod, 3/8 inch (9.5 mm).
7. NPS 2-1/2 (DN 65): Maximum span, 10 feet (3.33 m); minimum rod, 1/2 inch (13 mm).
8. NPS 3 (DN 80): Maximum span, 10 feet (3.33 m); minimum rod, 1/2 inch (13 mm).
9. NPS 4 (DN 100): Maximum span, 10 feet (3.7 m); minimum rod, 5/8 inch (16 mm).

D. Install hangers for steel piping with the following maximum horizontal spacing and minimum rod diameters:

1. NPS 2 (DN 50): Maximum span, 10 feet (3 m); minimum rod, 3/8 inch (9.5 mm).
2. NPS 2-1/2 (DN 65): Maximum span, 10 feet (3 m); minimum rod, 1/2 inch (13 mm).
3. NPS 3 (DN 80): Maximum span, 10 feet (3.7 m); minimum rod, 1/2 inch (13 mm).
4. NPS 4 (DN 100): Maximum span, 10 feet (3 m); minimum rod, 5/8 inch (16 mm).
5. NPS 6 (DN 150): Maximum span, 10 feet (3 m); minimum rod, 5/8 inch (16 mm).
6. NPS 8 (DN 200): Maximum span, 14 feet (4.3 m); minimum rod, 7/8 inch (22 mm).
7. NPS 10 (DN 250): Maximum span, 14 feet (4.3 m); minimum rod, 7/8 inch (22 mm).
8. NPS 12 (DN 300): Maximum span, 14 feet (4.3 m); minimum rod, 7/8 inch (22 mm).

E. Support multifloor vertical runs at least at each floor.

3.10 FIELD QUALITY CONTROL

A. Test Witnesses: System testing shall be witnessed by DEN Mechanical Inspector, DEN Project Manager and/or a DEN appointed representative. Provide a written request for testing a minimum of 72 hours prior to test.

B. Perform the following tests and inspections:

1. Comply with ASME B31.5, Chapter VI.
2. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
3. Test high- and low-pressure side piping of each system separately at not less than the pressures indicated in "Performance Requirements" Article.
 - a. Fill system with nitrogen to the required test pressure.
 - b. System shall maintain test pressure at the manifold gage throughout duration of test.
 - c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
 - d. Remake leaking joints using new materials, and retest until no leakage and satisfactory results are achieved.

- C. Prepare test and inspection reports.

3.11 SYSTEM CHARGING

- A. Charge system using the following procedures:
 1. Install core in filter dryers after leak test but before evacuation.
 2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers (67 Pa). If vacuum holds for 12 hours, system is ready for charging.
 3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig (14 kPa).
 4. Charge system with a new filter-dryer core in charging line.

3.12 ADJUSTING

- A. Adjust thermostatic expansion valve to obtain proper evaporator superheat.
- B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.
- C. Adjust set-point temperature of air-conditioning or chilled-water controllers to the system design temperature.
- D. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:
 1. Open shutoff valves in condenser water circuit.
 2. Verify that compressor oil level is correct.
 3. Open compressor suction and discharge valves.
 4. Open refrigerant valves except bypass valves that are used for other purposes.
 5. Check open compressor-motor alignment and verify lubrication for motors and bearings.
- E. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232300

SECTION 232500 - HVAC WATER TREATMENT

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following HVAC water-treatment systems:
 - 1. Manual and automatic chemical-feed equipment and controls.
 - 2. Ozone-generator biocide equipment and controls.
 - 3. Stainless-steel pipes and fittings.
 - 4. UV-irradiation unit, biocide equipment, and controls.
 - 5. Chemical treatment test equipment.
 - 6. Chemicals.
 - 7. HVAC makeup-water softeners.
 - 8. RO equipment for HVAC makeup water.
 - 9. Water filtration equipment.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. EEPROM: Electrically erasable, programmable read-only memory.
- B. RO: Reverse osmosis.
- C. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories for the following products:
1. Bypass feeders.
 2. Water meters.
 3. Inhibitor injection timers.
 4. pH controllers.
 5. TSS controllers.
 6. Biocide feeder timers.
 7. Chemical solution tanks.
 8. Injection pumps.
 9. Ozone generators.
 10. UV-irradiation units.
 11. Chemical test equipment.
 12. Chemical material safety data sheets.
 13. Water softeners.
 14. RO units.
 15. Multimedia filters.
 16. Self-cleaning strainers.
 17. Replaceable bag- or cartridge-type filters.
 18. Centrifugal separators.
 19. Agitators.
 20. Control equipment and devices.
 21. Filters.
 22. Chemical feeders.
 23. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Pretreatment and chemical[, **and ozone-generator biocide**][, **and UV-irradiation biocide**] treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems.
- C. 1. Include plans, elevations, sections, and attachment details.
1. Indicate system schematic, equipment locations, and controls schematics, electrical characteristics, and connection requirements.
 2. Detail equipment assemblies indicating dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For [**water softeners**] [**RO equipment**] [**water filtration units**] and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.
- D. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.
- E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- F. Other Informational Submittals:
1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
 2. Water Analysis: Illustrate water quality available at Project site.
 3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, **[water softeners,]** **[RO equipment,]** **[water filtration units,]** and controllers to include in emergency, operation, and maintenance manuals.
1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.7 MAINTENANCE MATERIALS

- A. Provide sufficient chemicals for treatment and testing during warranty period.

1.8 MAINTENANCE SERVICE

- A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.
- B. Provide laboratory and technical assistance services during this maintenance period.
- C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.
- D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion and shall include the following:
 - 1. Initial water analysis and HVAC water-treatment recommendations.
 - 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
 - 3. Periodic field service and consultation.
 - 4. Customer report charts and log sheets.
 - 5. Laboratory technical analysis.
 - 6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

1.9 QUALITY ASSURANCE

- A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.
- B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.
- C. Manufacturers: Companies specializing in manufacturing the products specified in this Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters'

Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements" and Division 1.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Ampion Corp.](#)
2. [Anderson Chemical Company.](#)
3. [Aqua-Chem, Inc.](#)
4. [Barclay Water Management, Inc.](#)
5. [Boland.](#)
6. [Cascade Water Services, Inc.](#)
7. [Earthwise Environmental Inc.](#)
8. [General Electric Company; GE Water & Process Technologies.](#)
9. [H-O-H Water Technology, Inc.](#)
10. [Metro Group, Inc. \(The\); Metropolitan Refining Div.](#)
11. [Nalco; an Ecolab company.](#)
12. [Watcon, Inc.](#)
13. [Water Services Inc.](#)
14. **<Insert manufacturer's name>.**
15. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or to the environment.
- B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics,

operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

- C. Closed hydronic systems, including **[hot-water heating] [chilled water] [dual-temperature water] [and] [glycol cooling]**, shall have the following water qualities:
1. pH: Maintain a value within **[9.0 to 10.5] <Insert range>**.
 2. "P" Alkalinity: Maintain a value within **[100 to 500] <Insert range>** ppm.
 3. Boron: Maintain a value within **[100 to 200] <Insert range>** ppm.
 4. Chemical Oxygen Demand: Maintain a maximum value of **[100] <Insert number>** ppm.
 5. Soluble Copper: Maintain a maximum value of **[0.20] <Insert number>** ppm.
 6. TSS: Maintain a maximum value of **[10] <Insert number>** ppm.
 7. Ammonia: Maintain a maximum value of **[20] <Insert number>** ppm.
 8. Free Caustic Alkalinity: Maintain a maximum value of **[20] <Insert number>** ppm.
 9. Microbiological Limits:
 - a. Total Aerobic Plate Count: Maintain a maximum value of **[1000] <Insert number>** organisms/mL.
 - b. Total Anaerobic Plate Count: Maintain a maximum value of **[100] <Insert number>** organisms/mL.
 - c. Nitrate Reducers: Maintain a maximum value of **[100] <Insert number>** organisms/mL.
 - d. Sulfate Reducers: Maintain a maximum value of **[zero] <Insert number>** organisms/mL.
 - e. Iron Bacteria: Maintain a maximum value of **[zero] <Insert number>** organisms/mL.
 10. **<Insert other requirements if necessary>**.
- D. Steam Boiler and Steam Condensate:
1. Steam Condensate:
 - a. pH: Maintain a value within **[7.8 to 8.4] <Insert range>**.
 - b. Total Alkalinity: Maintain a value within **[5 to 50] <Insert range>** ppm.
 - c. Chemical Oxygen Demand: Maintain a maximum value of **[15] <Insert number>** ppm.
 - d. Soluble Copper: Maintain a maximum value of **[0.20] <Insert number>** ppm.
 - e. TSS: Maintain a maximum value of **[10] <Insert number>** ppm.
 - f. Ammonia: Maintain a maximum value of **[20] <Insert number>** ppm.
 - g. Total Hardness: Maintain a maximum value of **[2] <Insert number>** ppm.
 - h. **<Insert other requirements if necessary>**.
 2. Steam boiler operating at **15 psig (104 kPa)** and less shall have the following water qualities:

- a. "OH" Alkalinity: Maintain a value within [200 to 400] <Insert range> ppm.
 - b. TSS: Maintain a value within [600 to 3000] <Insert range> ppm.
 - c. <Insert other requirements if necessary>.
3. Steam boiler operating at more than 15 psig (104 kPa) shall have the following water qualities:
- a. "OH" Alkalinity: Maintain a value within [200 to 400] <Insert range> ppm.
 - b. TSS: Maintain a value within [600 to 1200] <Insert range> ppm to maximum 30 times RO water TSS.
 - c. <Insert other requirements if necessary>.
- E. Open hydronic systems, including [condenser] [fluid-cooler spray] water, shall have the following water qualities:
1. pH: Maintain a value within [8.0 to 9.1] <Insert range>.
 2. "P" Alkalinity: Maintain a maximum value of [100] <Insert number> ppm.
 3. Chemical Oxygen Demand: Maintain a maximum value of [100] <Insert number> ppm.
 4. Soluble Copper: Maintain a maximum value of [0.20] <Insert number> ppm.
 5. TSS: Maintain a maximum value of [10] <Insert number> ppm.
 6. Ammonia: Maintain a maximum value of [20] <Insert number> ppm.
 7. Free "OH" Alkalinity: Maintain a maximum value of [zero] <Insert number> ppm.
 8. Microbiological Limits:
 - a. Total Aerobic Plate Count: Maintain a maximum value of [10,000] <Insert number> organisms/mL.
 - b. Total Anaerobic Plate Count: Maintain a maximum value of [1000] <Insert number> organisms/mL.
 - c. Nitrate Reducers: Maintain a maximum value of [100] <Insert number> organisms/mL.
 - d. Sulfate Reducers: Maintain a maximum value of [zero] <Insert number> organisms/mL.
 - e. Iron Bacteria: Maintain a maximum value of [zero] <Insert number> organisms/mL.
 9. Polymer Testable: Maintain a minimum value within [10 to 40] <Insert range>.
 10. <Insert other requirements if necessary>.
- F. Passivation for Galvanized Steel: For the first 60 days of operation.
1. pH: Maintain a value within [7 to 8] <Insert range>.
 2. Calcium Carbonate Hardness: Maintain a value within [100 to 300] <Insert range> ppm.
 3. Calcium Carbonate Alkalinity: Maintain a value within [100 to 300] <Insert range> ppm.

2.3 MANUAL CHEMICAL-FEED EQUIPMENT

- A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum **3-1/2-inch (89-mm)** fill opening in the top, and **NPS 3/4 (DN 20)** bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.
1. Capacity: [2 gal. (7.6 L)] [5 gal. (19 L)] **<Insert value>**.
 2. Minimum Working Pressure: [125 psig (860 kPa)] [175 psig (1210 kPa)] **<Insert value>**.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT

A. Water Meter:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: **150 psig (1035 kPa)**.
4. Maximum Pressure Loss at Design Flow: **3 psig (20 kPa)**.
5. Registration: **Gallons (Liters)** or **cubic feet (cubic meters)**.
6. End Connections: Threaded.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.

B. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: **100 psig (690 kPa)**.
4. Maximum Pressure Loss at Design Flow: **3 psig (20 kPa)**.
5. Registration: **Gallons (Liters)** or **cubic feet (cubic meters)**.
6. End Connections: Threaded.
7. Controls: Low-voltage signal capable of transmitting **1000 feet (305 m)**.

C. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: [**Bronze**] [**Epoxy-coated cast iron**].
3. Minimum Working-Pressure Rating: **150 psig (1035 kPa)**.
4. Maximum Pressure Loss at Design Flow: **3 psig (20 kPa)**.
5. Registration: **Gallons (Liters)** or **cubic feet (cubic meters)**.
6. End Connections: Flanged.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.

D. Inhibitor Injection Timers:

1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status**

indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."]

2. Programmable timers with infinite adjustment over full range, and mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. Digital display makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

E. pH Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal pH indication.
5. High or low-pH-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for acid pump.
7. Internal adjustable hysteresis or deadband.

F. TSS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High- or low-conductance-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves:
 - a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.
 - b. Steam Boilers: Motorized ball valve, steel body, and TFE seats and seals.

G. Biocide Feeder Timer:

1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
 2. 24-hour timer with 14-day skip feature to permit activation any hour of day.
 3. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer. Prebleed and bleed lockout timers.
 4. Solid-state alternator to enable use of two formulations.
 5. 24-hour display of time of day.
 6. 14-day display of day of week.
 7. Battery backup so clock is not disturbed by power outages.
 8. Hand-off-auto switches for biocide pumps.
 9. Biocide A and Biocide B pump running indication.
- H. Chemical Solution Tanks:
1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
 2. Molded cover with recess for mounting pump.
 3. Capacity: [30 gal. (114 L)] [50 gal. (189 L)] [120 gal. (454 L)] <Insert value>.
- I. Chemical Solution Injection Pumps:
1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
 2. Adjustable flow rate.
 3. Metal and thermoplastic construction.
 4. Built-in relief valve.
 5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- J. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.
- K. Injection Assembly:
1. Quill: Minimum **NPS 1/2 (DN 15)** with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
 2. Ball Valve: [**Three**] [**Two**]-piece stainless steel, as described in "Stainless-Steel Pipes and Fittings" Article; selected to fit quill.
 3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
 4. Assembly Pressure/Temperature Rating: Minimum **600 psig (4137 kPa)** at **200 deg F (93 deg C)**.

2.5 OZONE-GENERATOR BIOCIDES EQUIPMENT

- A. Corona discharge generator with stainless-steel generating cells and transformer housed in a NEMA 250, Type 4 enclosure. Assembly shall be suitable for continuous duty. Provide site glasses to verify proper operation of generator.
- B. Water-cooled generators shall be provided with cooling water at maximum [70 deg F (21 deg C)] <Insert value> and [35 psig (241 kPa)] <Insert value>.
- C. Generator vessels exposed to system pressure shall be constructed according to ASME Boiler and Pressure Vessel Code and be equipped with pressure relief valve.
- D. External air compressor or induced airflow through a cleanable prefilter supplies concentrated oxygen through a molecular sieve with minus 62 deg F (minus 52 deg C) dew point to avoid the formation of nitric acid.
- E. Microprocessor-based control with software in EEPROM, surge protection, high-temperature cutout, and operational status lights. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
- F. Ozone Contactors:
 - 1. Bubble diffusers.
 - 2. Induction injection nozzle.
 - 3. Injectors with static mixers.
- G. Ozone Detector and Alarm Devices:
 - 1. Detector:
 - a. Sensor: Metal dioxide semiconductor.
 - b. Concentration Range: [0.01 to 0.14] <Insert range> ppm.
 - c. Accuracy: Plus or minus 20 percent of range.
 - d. Sensitivity: 0.01 ppm.
 - e. Response Time: Maximum 10 seconds.
 - f. Operating Temperature: 50 to 100 deg F (10 to 38 deg C).
 - g. Relative Humidity: 20 to 95 percent, noncondensing over the operating temperature range.
 - 2. Horns:
 - a. Electric-vibrating-polarized type.
 - b. 24-V dc, with provision for housing the operating mechanism behind a grille.
 - c. Horns shall produce a sound-pressure level of 90 dBA, measured 10 feet (3 m) from the horn.
 - d. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

3. Visible Alarm Devices:

- a. Xenon strobe lights listed in UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate.
- b. Rated Light Output: **[75] [110] <Insert number>** candela.
- c. Strobe Leads: Factory connected to screw terminals.

H. Self-Contained Breathing Apparatus: Open-circuit, pressure-demand compressed air includes completely assembled, portable, self-contained devices designed for hazardous breathing environment application.

1. Face Piece: EPDM or silicone rubber construction material, one-size-fits-all with double-sealing edge, stainless-steel speaking diaphragm and lens retainer, five adjustable straps to hold face piece to head (two straps on each side and one on top), exhalation valve in mask, close-fitting nose piece to ensure no CO₂ buildup, and perspiration drain to avoid skin irritation and to prevent eyepiece, spectacle, and lens fogging.
2. Backplate: Orthopedically designed of **[chemical and impact-resistant, glass-fiber composite] [aluminum]**.
3. Harness and Carrier Assembly: Large triangular back pad, backplate, and adjustable waist and shoulder straps. Modular in design, detachable components, and easy to clean and maintain. Shoulder straps padded with flame-resistant material, reinforced with stainless-steel cable, and attached with T-nuts, washers, and screws.
4. Air Cylinder: **[30] [45] [60]**-minute, low-pressure, air-supply-loaded **[fiberglass] [aluminum] [steel]** cylinders fitted with quick-fill assembly for refilling and air transfer.
5. Wall-Mounting Cabinet: Leakproof, corrosion-resistant, clear, plastic case.
6. Tested and Certified: By the National Institute for Occupational Safety and Health and by the Mine Safety and Health Administration, according to 42 CFR 84, Subpart H.

2.6 STAINLESS-STEEL PIPES AND FITTINGS

- A. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.
- B. Stainless-Steel Fittings: Comply with ASTM A 815/A 815M, Type 316, Grade WP-S.
- C. Two-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, carbon-filled TFE seats, threaded body design with adjustable stem packing, threaded ends, and **250-psig (1725-kPa)** Steam Working Pressure and **600-psig (4140-kPa)** Cold Working Pressure ratings.
- D. Three-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and **150-psig (1035-kPa)** Steam Working Pressure and **600-psig (4140-kPa)** Cold Working Pressure rating.

2.7 UV BIOCIDES EQUIPMENT

- A. Target Irradiation: Minimum 30,000 microwatts x s/sq. cm.
- B. Light Source Vessels:
 - 1. ASTM A 666, Type 304 stainless steel.
 - 2. Construct for minimum [150 psig (1035 kPa)] <Insert value> at [150 deg F (65 deg C)] <Insert value> according to ASME Boiler and Pressure Vessel Code, and equipped with pressure relief valve.
 - 3. Light Source Sleeve: Quartz, with EPDM O-ring seals.
 - 4. Light Source: Replaceable UV lamp producing minimum target irradiation of 254-nm wavelength light.
- C. Controls: Interlock with pumps to operate when water is circulating.

2.8 CHEMICAL TREATMENT TEST EQUIPMENT

- A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TSS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers; and oxidizing biocide test for open cooling systems.
- B. Sample Cooler:
 - 1. Tube: Sample.
 - a. Size: NPS 1/4 (DN 8) tubing.
 - b. Material: ASTM A 666, Type 316 stainless steel.
 - c. Pressure Rating: Minimum 2000 psig (13 790 kPa).
 - d. Temperature Rating: Minimum 850 deg F (454 deg C).
 - 2. Shell: Cooling water.
 - a. Material: ASTM A 666, Type 304 stainless steel.
 - b. Pressure Rating: Minimum 250 psig (1725 kPa).
 - c. Temperature Rating: Minimum 450 deg F (232 deg C).
 - 3. Capacities and Characteristics:
 - a. Tube: Sample.
 - 1) Flow Rate: [0.25 gpm (0.016 L/s)] <Insert value>.
 - 2) Entering Temperature: [400 deg F (204 deg C)] <Insert value>.
 - 3) Leaving Temperature: [88 deg F (31 deg C)] <Insert value>.
 - 4) Pressure Loss: [6.5 psig (44.8 kPa)] <Insert value>.
 - b. Shell: Cooling water.
 - 1) Flow Rate: [3 gpm (0.19 L/s)] <Insert value>.

- 2) Entering Temperature: [70 deg F (21 deg C)] <Insert value>.
- 3) Pressure Loss: [1.0 psig (6.89 kPa)] <Insert value>.

C. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. [Two] <Insert number>-station rack for closed-loop systems.
2. [Four] <Insert number>-station rack for open-loop systems.

2.9 CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.

B. Water Softener Chemicals:

1. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum 30,000 grains/cu. ft. (69 kg/cu. m) of calcium carbonate of resin when regenerated with 15 lb (6.8 kg) of salt.
2. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are unacceptable.

2.10 HVAC MAKEUP-WATER SOFTENER

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [CSI Water Treatment Systems.](#)
2. [Culligan International Company.](#)
3. [CUNO Incorporated.](#)
4. [Diamond Water Conditioning; a Griesbach company.](#)
5. [Diamond Water Systems, Inc.](#)
6. [Ecodyne Industrial.](#)
7. [Hungerford & Terry, Inc.](#)
8. [Kinetico Incorporated.](#)
9. [Marlo Incorporated.](#)
10. [Parker Boiler.](#)
11. [Pentair, Inc.](#)
12. [RainSoft; a division of Aquion Water Treatment Products.](#)
13. [Water King, Inc.](#)
14. <Insert manufacturer's name>.
15. or approved equal.

B. Description: Twin mineral tanks and one brine tank, factory mounted on skid.

- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.
- E. Mineral Tanks:
1. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 2. Fabricate and label Fiber Reinforced Plastic filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
 3. Pressure Rating: [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] <Insert value> minimum.
 4. Wetted Components: Suitable for water temperatures from [40 to at least 100 deg F (5 to at least 38 deg C)] <Insert range>.
 5. Freeboard: 50 percent, minimum, for backwash expansion above the normal resin bed level.
 6. Support Legs or Skirt: Constructed of structural steel, welded, or bonded to tank before testing and labeling.
 7. Finish: Hot-dip galvanized on exterior and interior of tank after fabrication.
 8. Upper Distribution System: Single-point type, fabricated from galvanized-steel pipe and fittings.
 9. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from PVC pipe and fittings with individual, fine-slotted, nonclogging polyethylene strainers; arranged for even-flow distribution through resin bed.
- F. Controls: Automatic; factory mounted on mineral tanks and factory wired.
1. Adjustable duration of regeneration steps.
 2. Push-button start and complete manual operation override.
 3. Pointer on pilot-control valve shall indicate cycle of operation.
 4. Means of manual operation of pilot-control valve if power fails.
 5. Main Operating Valves: Industrial, automatic, multiport, diaphragm type with the following features:
 - a. Slow opening and closing, nonslam operation.
 - b. Diaphragm guiding on full perimeter from fully open to fully closed.
 - c. Isolated dissimilar metals within valve.
 - d. Self-adjusting, internal, automatic brine injector that draws brine and rinses at constant rate independent of pressure.
 - e. Float-operated brine valve to automatically measure the correct amount of brine to the softener and refill with fresh water.
 - f. Sampling cocks for soft water.
 6. Flow Control: Automatic control of backwash and flush rates over variations in operating pressures that do not require field adjustments. Equip mineral tanks with automatic-reset-head water meter that electrically activates cycle controller

to initiate regeneration at preset total in **gallons (liters)** and that automatically resets after regeneration to preset total in **gallons (liters)** for next service run. Include alternator to regenerate one mineral tank with the other in service.

- G. Brine Tank: Combination measuring and wet-salt storing system.
1. Tank and Cover Material: Fiberglass a minimum of **3/16 inch (4.8 mm)** thick; or molded polyethylene a minimum of **3/8 inch (9.5 mm)** thick.
 2. Brine Valve: Float operated and plastic fitted for automatic control of brine withdrawn and freshwater refill.
 3. Size: Large enough for at least four regenerations at full salting.
- H. Factory-Installed Accessories:
1. Piping, valves, tubing, and drains.
 2. Sampling cocks.
 3. Main-operating-valve position indicators.
 4. Water meters.
- I. Water Test Kit: Include in wall-mounting enclosure for water softener.
- J. Capacities and Characteristics:
1. Continuous Service Flow Rate: **<Insert gpm (L/s)>** at **15-psig (104-kPa)** pressure loss.
 2. Peak Service Flow Rate: **<Insert gpm (L/s)>** at **25-psig (173-kPa)** pressure loss.
 3. Water Consumption: **<Insert gal./day (cu. m/day)>**.
 4. Water Demand: **<Insert number>** hours/day.
 5. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
 - g. Interrupting Capacity: **<Insert amperage>**.

2.11 RO EQUIPMENT FOR HVAC MAKEUP WATER

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [CSI Water Treatment Systems.](#)
 2. [Culligan International Company.](#)
 3. [CUNO Incorporated.](#)
 4. [Diamond Water Conditioning; a Griesbach company.](#)
 5. [Ecodyne Industrial.](#)
 6. [Hungerford & Terry, Inc.](#)

7. [Kinetico Incorporated.](#)
 8. [Marlo Incorporated.](#)
 9. [Pentair, Inc.](#)
 10. [RainSoft; a division of Aquion Water Treatment Products.](#)
 11. [Water & Power Technologies, Inc.](#)
 12. [Water King, Inc.](#)
 13. **<Insert manufacturer's name>.**
 14. or approved equal.
- B. Description: Factory fabricated and tested with RO membrane elements in housings, high-pressure pumps and motors, controls, valves, and prefilter; mounted on skid.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.
- E. Skid Assembly: Welded-steel frame coated with epoxy protective finish.
- F. RO Membrane and Housing:
1. Element: Thin-film composite with U-cup brine seal with minimum 98 percent salt rejection based on 2000-ppm water supplied at **225 psig (1551 kPa)** and **77 deg F (25 deg C)**.
 2. Housing: ASTM A 666, Type 304 stainless steel with PVC end caps held in place with stainless-steel straps.
- G. High-Pressure Pumps and Motors:
1. Pump:
 - a. Vertical, multistage centrifugal operating at 3500 rpm with ASTM A 666, Type 304 stainless-steel casing, shaft, impellers, and inlet and discharge casting.
 - b. Bearings shall be tungsten carbide and ceramic.
 - c. Cast-iron frame and flanged suction and discharge connections.
 - d. Motor: NEMA-standard, C-faced totally enclosed, fan cooled motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- H. Controls:
1. Microprocessor-based controller with digital display.
 2. Interlock for remote start/stop control.
 3. Membrane flush sequence when pumps shut down.
 4. Run time indicator.

5. Low-pressure safety cutoff.
 6. Panel-mounted gages as follows:
 - a. Product and concentrate.
 - b. Inlet, cartridge filter outlet, RO feed, RO concentrate, and RO product pressures.
 - c. Product conductivity monitor.
- I. Valves:
1. Stainless-steel pump, concentrate, and recycle throttling valves rated for minimum 300 psig (2068 kPa).
 2. Automatic inlet shutoff valve, diaphragm type; solenoid actuated, normally closed, and constructed of glass-reinforced noryl thermoplastic.
 3. PVC valves with EPDM seats and seals for isolation at inlet, and check and sample valves at product and concentrate. Sample valves at cartridge filter outlet, concentrate, and product outlet.
- J. Prefilter:
1. Housing: Polypropylene with built-in relief or vent valve.
 2. Element: Spun-wound polypropylene.
- K. Inlet Water Tempering Valve: Thermostatic water-tempering valve to maintain [77 deg F (25 deg C)] <Insert value> inlet water temperature to RO unit.
- L. Activated Carbon Filter:
1. Media Tank: Fiberglass-reinforced polyester rated for minimum 150 psig (1035 kPa) with internal backwash distributor and filtered water collector.
 2. Media: 12-by-40-mesh, bituminous coal-based activated carbon.
 3. Backwash Valve: Piston-operated control valve with drain-line, flow-control orifice.
 4. Backwash Control: Seven-day time clock.
- M. Atmospheric Storage Tank:
1. Tank: Polyethylene single piece with closed top and flat bottom with manway in top, 0.2-micron filter vent, inlet, discharge, and drain piping connections, and bulkhead fittings for level controls.
 2. Control: Level switches start and stop RO unit. Low-level limit shall stop repressurization pumps and signal an alarm.
- N. Repressurization Pumps:
1. Pumps: Two close-coupled, single-stage centrifugal pumps with mechanical seals. Wetted components ASTM A 666, Type 316 stainless steel.
 2. Controls: NEMA-4X pump control panel constructed of fiberglass to control pumps, one operating and one standby, with automatic alternator and fail-over control.

3. Motor: Open, drip proof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- O. Water Test Kit: Include in wall-mounting cabinet for RO unit.
- P. Capacities and Characteristics:
 1. RO Product Flow Rate: <Insert gpm (L/s)>.
 2. Total Water Flow Rate: <Insert gpm (L/s)>.
 3. Daily Water Consumption: <Insert gal./day (cu. m/day)>.
 4. Water Demand: <Insert number> hours/day.
 5. Storage Tank Size: <Insert gal. (L)>.
 6. RO Inlet Operating Temperature: [77 deg F (25 deg C)] <Insert value>.
 7. High-Pressure Pump:
 - a. Discharge Pressure: <Insert psig (kPa)>.
 - b. Flow Rate: <Insert gpm (L/s)>.
 - c. Horsepower: <Insert value>.
 - d. Motor Speed: [3500] <Insert number> rpm.
 8. Repressure Pumps:
 - a. Discharge Pressure: <Insert psig (kPa)>.
 - b. Flow Rate: <Insert gpm (L/s)>.
 - c. Horsepower: <Insert value>.
 - d. Motor Speed: [3500] <Insert number> rpm.
 9. Prefilter Design (at Total Water Flow Rate):
 - a. Filter Efficiency: [98] <Insert number> percent.
 - b. Particle Size: [5] <Insert number> microns and larger.
 - c. Clean Pressure Loss: [2 psig (14 kPa)] <Insert value>.
 - d. Replacement Pressure Loss: [6 psig (41 kPa)] <Insert value>.
 10. Electrical Characteristics (Single-Point Connection):
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
 - g. Interrupting Capacity: <Insert amperage>.

2.12 FILTRATION EQUIPMENT

A. Multimedia Filters:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Diamond Water Systems, Inc.](#)
 - b. [Everfilt.](#)
 - c. [LAKOS: Claude Laval Corporation.](#)
 - d. [Miami Filter LLC.](#)
 - e. [PEP Filters, Inc.](#)
 - f. [Puroflux Corporation.](#)
 - g. [United Industries, Inc.](#)
 - h. **<Insert manufacturer's name>.**
 - i. or approved equal.
2. Description: Factory-fabricated and -tested, simplex, multimedia filter system of filter tank, media, strainer, circulating pump, piping, and controls for removing particles from water.
 - a. Filter Tank: Corrosion resistant with distribution system and media.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - a. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
 - c. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - d. Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - e. FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; [**Designation E, 125-psig (0.862-MPa)**] [**or**] [**Designation F, 150-psig (1.034-MPa)**] pressure category flanges of grade same as tank material according to ASTM D 5421.
 - f. Motorized Valves: Flanged or grooved-end, ductile-iron butterfly type with [**EPDM**] **<Insert material>** valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
 - g. Strainer: Basket type mounted on pump suction.
 - h. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
 - i. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings and brazed, flanged, or grooved joints.
 - j. Safety Valves: Automatic pressure relief.

- k. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
- 1) Casing: Radially split, cast iron.
 - 2) Pressure Rating: [125 psig (860 kPa)] [150 psig (1035 kPa)] minimum.
 - 3) Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 - 4) Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
 - 5) Seal: Mechanical.
 - 6) Motor: ODP motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- l. Controls: Automatic control of circulating pump and tank backwash; factory wired for single electrical connection.
- 1) Panel: NEMA 250, [Type 4] <Insert type> enclosure with time clock and pressure gages.
 - 2) Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
 - 3) Backwash: Automatic; with time clock and differential pressure switch.
 - 4) Backwash Valve: Tank mounted with valves interlocked to single actuator.
- m. Support: Skid mounting.[**Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.**]
4. Capacities and Characteristics:
- a. Filter Design:
- 1) Water Flow: <Insert gpm (L/s)>.
 - 2) Clean Pressure Loss: [5 psig (34.5 kPa)] <Insert value>.
 - 3) Maximum Media Flow Rate: [15 gpm/sq. ft. (10.2 L/s per sq. m)] <Insert value>.
 - 4) Filtration Efficiency: [98] <Insert number> percent.
 - 5) Particle-Specific Gravity: [1.8] <Insert number>.
 - 6) Particle Size: [5] [10] [20] [45] <Insert number> microns.
- b. Filter Tank: With internal distribution piping.
- 1) Pressure Rating: <Insert psig (kPa)>.
 - 2) Diameter: <Insert inches (mm)>.
 - 3) Inlet and Outlet Size: <Insert NPS (DN)>.
 - 4) Blowdown Piping Outlet Size: <Insert NPS (DN)>.
- c. Filter Media: <Insert material>.

- d. Start Backwash Pressure Loss: [13 psig (90 kPa)] <Insert value>.
- e. Backwash Period: [10] <Insert number> minutes.
- f. Circulating Pump:
 - 1) Capacity: <Insert gpm (L/s)>.
 - 2) Total Dynamic Head: <Insert feet (kPa)>.
 - 3) Motor Speed: <Insert number> rpm.
 - 4) Inlet Size: <Insert NPS (DN)>.
 - 5) Outlet Size: <Insert NPS (DN)>.
- g. Pump Motor Size and Electrical Characteristics:
 - 1) Horsepower: <Insert value>.
 - 2) Volts: [120] [208] [240] [277] [480] <Insert number> V.
 - 3) Phase: [Single] [Three].
 - 4) Hertz: [60] <Insert number> Hz.
- h. Unit Electrical Characteristics:
 - 1) Full-Load Amperes: <Insert value>.
 - 2) Minimum Circuit Ampacity: <Insert value>.
 - 3) Maximum Overcurrent Protection: <Insert amperage>.
 - 4) Interrupting Capacity: <Insert amperage>.

B. Self-Cleaning Strainers:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Everfilt](#).
 - b. [Hayward Flow Control Systems, Inc.](#)
 - c. [Islip Flow Controls Inc.](#)
 - d. [Orival, Inc.](#)
 - e. [Sure Flow Equipment Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
2. Description: Factory-fabricated and -tested, ASTM A 126, Class B, cast-iron or steel, self-cleaning strainer system of tank, strainer, backwash arm or cleaning spiral, drive and motor, piping, and controls for removing particles from water.
 - a. Fabricate and label ASTM A 126, Class B, cast-iron or steel strainer tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. Pipe Connections:
 - 1) NPS 2 (DN 50) and Smaller: Threaded according to ASME B1.20.1.
 - 2) NPS 2-1/2 (DN 65) and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.

3. Motorized Valves: Flanged or grooved-end, ductile-iron angle type with **[EPDM]** **<Insert material>** valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
4. Strainer: ASTM A 666, Type 316 stainless steel.
5. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
6. Safety Valves: Automatic pressure relief.
7. Backwash Arm Drive:
 - a. Drive Casing: Cast iron.
 - b. Worm Gears: Immersed in oil.
 - c. Motor: ODP motor supported on the strainer-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
8. Controls: Automatic control of backwash; factory wired for single electrical connection.
 - a. Panel: NEMA 250, **[Type 4]** **<Insert type>** enclosure with time clock and pressure gages.
 - b. Backwash Arm Drive: Automatic and manual switching; manual switch position bypasses safeties and controls.
 - c. Backwash: Automatic; with time clock and differential pressure switch.
 - d. Backwash Valve: Electric actuator.
9. Support: Skid mounting. **[Fabricate supports and base and attachment to tank with reinforcement strong enough to resist strainer movement during a seismic event when strainer base is anchored to building structure.]**
10. Capacities and Characteristics:
 - a. Strainer Design:
 - 1) Water Flow: **<Insert gpm (L/s)>**.
 - 2) Clean Pressure Loss: **[5 psig (34.5 kPa)] <Insert value>**.
 - 3) Strainer Mesh: **[40] [60] [80] <Insert number>**.
 - b. Strainer Tank: With internal distribution piping.
 - 1) Material: **[Cast iron] [Steel] <Insert material>**.
 - 2) Pressure Rating: **[150 psig (1034 kPa)] <Insert value>**.
 - 3) Inlet and Outlet Size: **<Insert NPS (DN)>**.
 - 4) Backwash Piping Outlet Size: **<Insert NPS (DN)>**.
 - c. Start Backwash: **[10 psig (69 kPa)] <Insert value>**.
 - d. Backwash Period: **[5] <Insert number>** minutes.
 - e. Drive Motor Size and Electrical Characteristics:
 - 1) Horsepower: **<Insert value>**.
 - 2) Volts: **[120] [208] [240] [277] [480] <Insert number>** V.

- 3) Phase: **[Single]** **[Three]**.
- 4) Hertz: **[60]** **<Insert number>** Hz.

f. Unit Electrical Characteristics:

- 1) Full-Load Amperes: **<Insert value>**.
- 2) Minimum Circuit Ampacity: **<Insert value>**.
- 3) Maximum Overcurrent Protection: **<Insert amperage>**.
- 4) Interrupting Capacity: **<Insert amperage>**.

C. **[Bag]** **[Cartridge]**-Type Filters:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Cycron Corporation.
- b. Eden Equipment Company.
- c. Filter Specialists, Inc.
- d. Filtration Systems; Mechanical Mfg. Corporation.
- e. Hayward Flow Control Systems, Inc.
- f. Parker Hannifin Corp.; Process Filtration Div.
- g. Pentair, Inc.
- h. PEP Filters, Inc.
- i. RainSoft; a division of Aquion Water Treatment Products.
- j. Rosedale Products, Inc.
- k. RPA Process Technologies.
- l. Shelco Filters.
- m. Siemens Water Technologies.
- n. **<Insert manufacturer's name>**.
- o. or approved equal.

2. Description: Floor-mounting housing with filter **[bags]** **[cartridges]** for removing particles from water.

- a. Housing: Corrosion resistant; designed to separate inlet from outlet and to direct inlet through **[bag]** **[cartridge]**-type water filter; with **[bag support and]**base, feet, or skirt.
 - 1) Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - 2) Steel Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - 3) Plastic Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: **150-psig (1035-kPa)** plastic flanges.

b. **[Bag]** **[Cartridge]**: Replaceable; of shape to fit housing.

3. Capacities and Characteristics:

- a. Filter Design:
 - 1) Water Flow Rate: <Insert gpm (L/s)>.
 - 2) Filtration Efficiency: [98] <Insert number> percent.
 - 3) Particle Size: [10] [20] <Insert number> microns and larger.
 - 4) Clean Pressure Loss: [2 psig (14 kPa)] <Insert value>.
 - 5) Pressure Loss at Replacement: [6 psig (41 kPa)] <Insert value>.

- b. Housing:
 - 1) Material: [Carbon steel] [Plastic].
 - 2) Pressure Rating: <Insert psig (kPa)>.
 - 3) Seal Material: [Nitrile Rubber] <Insert material>.
 - 4) Diameter: <Insert inches (mm)>.
 - 5) Height or Length: <Insert inches (mm)>.
 - 6) Inlet and Outlet Size: <Insert NPS (DN)>.
 - 7) Drain Size: [Not applicable] <Insert NPS (DN)>.
 - 8) Bag Support Basket Material: [Stainless steel] <Insert material>.

- c. [Bag] [Cartridge]:
 - 1) Number Required: <Insert number>.
 - 2) Nominal Diameter: <Insert inches (mm)>.
 - 3) Nominal Length: <Insert inches (mm)>.
 - 4) Media Material: [Cotton] [Polyester] [Polypropylene] <Insert material>.

D. Centrifugal Separators:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Culligan International Company.](#)
 - b. [Ecodyne Industrial.](#)
 - c. [Griswold Controls.](#)
 - d. [LAKOS; Claude Laval Corporation.](#)
 - e. [PEP Filters, Inc.](#)
 - f. [Puroflux Corporation.](#)
 - g. [Rosedale Products, Inc.](#)
 - h. [Siemens Water Technologies.](#)
 - i. <Insert manufacturer's name>.
 - j. or approved equal.

2. Description: Simplex separator housing with baffles and chambers for removing particles from water by centrifugal action and gravity.

3. Housing: With manufacturer's proprietary system of baffles and chambers.
 - a. Construction: Fabricate and label steel separator housing to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

- b. Inlet: Designed with tangential entry to produce centrifugal flow of feedwater.
 - c. Vortex Chamber: Designed for downward vortex flow and gravity separation of particles.
 - d. Collection Chamber: Designed to hold separated particles.
 - e. Outlet: Near top of unit.
 - f. Purge: At bottom of collection chamber.
 - g. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - h. Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if tank is stainless steel.
4. Motorized Purge Valve: Gate or plug pattern valve.
- a. Motorized Valves: Butterfly-type, flanged or grooved-end, ductile-iron body, with **[EPDM]** <Insert material> valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
 - b. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
5. Strainer: Stainless-steel basket type mounted on pump suction.
6. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
7. Piping: **ASTM B 88, Type L** (ASTM B 88M, Type B) copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
8. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
- a. Casing: Radially split, cast iron.
 - b. Pressure Rating: **[125 psig (860 kPa)]** **[150 psig (1035 kPa)]** minimum.
 - c. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 - d. Shaft and Shaft Sleeve: Steel shaft with copper-alloy shaft sleeve.
 - e. Seal: Mechanical.
 - f. Motor: ODP motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - g. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
9. Controls: Automatic control of circulating pump and separator purge; factory wired for single electrical connection.
- a. Panel: NEMA 250, **[Type 4]** <Insert type> enclosure.
 - b. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.

- c. Separator Purge: Automatic and manual.
 - d. TSS Controller Interlock: Open separator purge valve with bleed-off control.
10. Support: Skid mounting. [**Fabricate supports and base and attachment to separator housing with reinforcement strong enough to resist separator movement during a seismic event when separator base is anchored to building structure.**]
11. Capacities and Characteristics:
- a. Separator Design:
 - 1) Water Flow Rate: <Insert gpm (L/s)>.
 - 2) Pressure Loss: [5 psig (34.5 kPa)] <Insert value>.
 - 3) Separator Efficiency: [98] <Insert number> percent.
 - 4) Particle-Specific Gravity: [1.8] <Insert number>.
 - 5) Particle Size: [5] [10] [20] [45] <Insert number> microns.
 - b. Housing:
 - 1) Material: [Steel] [Stainless steel] [Plastic] [Fiberglass] <Insert material>.
 - 2) Pressure Rating: <Insert psig (kPa)>.
 - 3) Diameter: <Insert inches (mm)>.
 - 4) Height: <Insert inches (mm)>.
 - 5) Inlet and Outlet Size: <Insert NPS (DN)>.
 - 6) Purge Size: <Insert NPS (DN)>.
 - c. Circulating Pump:
 - 1) Capacity: <Insert gpm (L/s)>.
 - 2) Total Dynamic Head: <Insert feet (kPa)>.
 - 3) Motor Speed: <Insert number> rpm.
 - 4) Inlet Size: <Insert NPS (DN)>.
 - 5) Outlet Size: <Insert NPS (DN)>.
 - d. Pump Motor Size and Electrical Characteristics:
 - 1) Horsepower: <Insert value>.
 - 2) Volts: [120] [208] [240] [277] [480] <Insert number> V.
 - 3) Phase: [Single] [Three].
 - 4) Hertz: [60] <Insert number> Hz.
 - 5) Full-Load Amperes: <Insert value>.
 - 6) Minimum Circuit Ampacity: <Insert value>.
 - 7) Maximum Overcurrent Protection: <Insert amperage>.
 - 8) Interrupting Capacity: <Insert amperage>.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Systems shall be operational, filled, started, and vented prior to cleaning. Use water meter to record capacity in each system.
- B. Place terminal control valves in open position during cleaning.
- C. Verify that electric power is available and of the correct characteristics.

3.2 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

- A. Install chemical application equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install water-testing equipment on wall near water-chemical-application equipment.
- D. Install interconnecting control wiring for chemical treatment controls and sensors.
- E. Mount sensors and injectors in piping circuits.
- F. Bypass Feeders: Install in closed hydronic systems, including [**hot-water heating**] [**chilled water**] [**dual-temperature water**] [**and**] [**glycol cooling**], and equipped with the following:
 - 1. Install bypass feeder in a bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 2. Install water meter in makeup-water supply.
 - 3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
 - 5. Install a swing check on inlet after the isolation valve.
- G. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:

1. Install makeup-water softener.
 2. Install water meter in makeup-water supply.
 3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
 - a. Pumps shall operate for timed interval when contacts close at water meter in makeup-water supply connection.
 4. Install test equipment and furnish test-kit to Owner.
 5. Install RO unit for makeup water.
 6. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves shall cycle to maintain maximum TSS concentration.
 7. Install inhibitor injection timer with injection pumps and solution tanks.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into main steam supply header.
- H. Install automatic chemical-feed equipment for **[condenser] [fluid-cooler spray]** water and include the following:
1. Install makeup-water softener.
 2. Install water meter in makeup-water supply.
 3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
 4. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 5. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves shall cycle to maintain maximum TSS concentration.
 6. Install pH sensor and controller with injection pumps and solution tanks.
 - a. Injector pumps shall operate to maintain required pH.
 7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
 - a. Injection pumps shall operate to feed biocide on an alternating basis.
 8. Install ozone generator with diffusers in condenser-water piping.
 - a. Ozone generator shall operate continuously with condenser-water flow.

9. Install UV-irradiation lamps in condenser-water piping.
 - a. UV lights shall operate continuously with condenser-water flow.

3.4 OZONE-GENERATOR INSTALLATION

- A. Install ozone generator and equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Pipe ozone from ozone generator to condenser water with stainless-steel pipe and fittings with welded joints.
- D. Install **[two] [three]**-piece, stainless-steel ball valve in ozone supply to condenser water.
- E. Pipe cooling water to ozone generator and to air-gap drain fitting with stainless-steel pipe and fittings with welded joints where enclosed in ozone-generator room.
- F. Install **[two] [three]**-piece, stainless-steel ball valve in cooling water supply to ozone generator.
- G. Mounting supports for ozone generator shall be ASTM A 666, Type 316 stainless steel.
- H. Mount breathing apparatus outside ozone-generator room.
- I. Mount and install ozone detector, warning lights, and audible alarm inside ozone-generator room. Mount another set of warning lights and audible alarm just outside the main entrance to ozone-generator room.

3.5 UV-IRRADIATION UNIT INSTALLATION

- A. Install UV-irradiation units on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for UV-irradiation units and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

3.6 WATER SOFTENER INSTALLATION

- A. Install water softener equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for tanks and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.
- D. Prepare mineral-tank distribution system and underbed for minerals and place specified mineral into mineral tanks.
- E. Install water-testing sets on wall adjacent to water softeners.

3.7 RO UNIT INSTALLATION

- A. Install RO unit and storage tank on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor RO unit and storage tank with pumps to substrate.
- B. Install seismic restraints for tanks and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install interconnecting piping and controls furnished by equipment manufacturer but not factory installed.
- D. Install water-testing sets on wall adjacent to RO unit.

3.8 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance.
- C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Section 232113 "Hydronic Piping."
- D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC"

Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."

- E. See Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.
- F. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- G. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- H. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.9 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 - 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 - 3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC system's startup procedures.
 - 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 - 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 - 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 - 7. Cap and subject piping to static water pressure of 50 psig (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
 - 8. Repair leaks and defects with new materials and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

- E. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report advising Owner of changes necessary to adhere to "Performance Requirements" Article for each required characteristic. Sample boiler water at [four] [six] [eight] <Insert number>-week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.
- F. At [four] [six] [eight] <Insert number>-week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising Owner of changes necessary to adhere to "Performance Requirements" Article.
- G. Comply with ASTM D 3370 and with the following standards:
 - 1. Silica: ASTM D 859.
 - 2. Steam System: ASTM D 1066.
 - 3. Acidity and Alkalinity: ASTM D 1067.
 - 4. Iron: ASTM D 1068.
 - 5. Water Hardness: ASTM D 1126.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232500

SECTION 232513 - WATER TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following water treatment for closed-loop hydronic systems:
 - 1. **[Manual] [Automatic]** chemical-feed equipment.
 - 2. Chemicals.
- B. Related Requirements:
 - 1. Section 232533 "HVAC Makeup-Water Filtration Equipment" for water softeners, RO equipment, and filtration equipment.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote control, signaling power-limited circuits.
- B. RO: Reverse osmosis.
- C. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories for the following products:
1. Bypass feeders.
 2. Water meters.
 3. Inhibitor injection timers.
 4. pH controllers.
 5. TSS controllers.
 6. Chemical solution tanks.
 7. Injection pumps.
 8. Chemical test equipment.
 9. Chemical material safety data sheets.
 10. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to hydronic systems.
1. Include plans, elevations, sections, and attachment details.
 2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.
- D. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.
- E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- F. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
2. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.
 1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.7 MAINTENANCE MATERIALS

- A. Provide sufficient chemicals for treatment and testing during warranty period.

1.8 QUALITY ASSURANCE

- A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.
- B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.
- C. Manufacturers: Companies specializing in manufacturing the products specified in this Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.

- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.9 MAINTENANCE SERVICE

- A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.
- B. Provide laboratory and technical assistance services during this maintenance period.
- C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.
- D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion and shall include the following:
 - 1. Initial water analysis and HVAC water-treatment recommendations.
 - 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
 - 3. Periodic field service and consultation.
 - 4. Customer report charts and log sheets.
 - 5. Laboratory technical analysis.
 - 6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements" and Division 1.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Ampion Corp.](#)
 2. [Anderson Chemical Company.](#)
 3. [Aqua-Chem, Inc.](#)
 4. [Barclay Water Management, Inc.](#)
 5. [Boland.](#)
 6. [Cascade Water Services, Inc.](#)
 7. [Earthwise Environmental Inc.](#)
 8. [General Electric Company; GE Water & Process Technologies.](#)
 9. [H-O-H Water Technology, Inc.](#)
 10. [Metro Group, Inc. \(The\); Metropolitan Refining Div.](#)
 11. [Nalco; an Ecolab company.](#)
 12. [Watcon, Inc.](#)
 13. [Water Services Inc.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. Water quality for hydronic systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of hydronic equipment without creating a hazard to operating personnel or the environment.
- B. Base HVAC water treatment on quality of water available at Project site, hydronic system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
- C. Closed hydronic systems, including **[hot-water heating] [chilled water] [dual-temperature water] [and] [glycol cooling]**, shall have the following water qualities:
1. pH: Maintain a value within **[9.0 to 10.5] <Insert range>**.
 2. "P" Alkalinity: Maintain a value within **[100 to 500] <Insert range>** ppm.
 3. Boron: Maintain a value within **[100 to 200] <Insert range>** ppm.
 4. Chemical Oxygen Demand: Maintain a maximum value of **[100] <Insert number>** ppm.
 5. Soluble Copper: Maintain a maximum value of **[0.20] <Insert number>** ppm.
 6. TSS: Maintain a maximum value of **[10] <Insert number>** ppm.
 7. Ammonia: Maintain a maximum value of **[20] <Insert number>** ppm.
 8. Free Caustic Alkalinity: Maintain a maximum value of **[20] <Insert number>** ppm.

9. Microbiological Limits:
- a. Total Aerobic Plate Count: Maintain a maximum value of **[1000]** <Insert number> organisms/mL.
 - b. Total Anaerobic Plate Count: Maintain a maximum value of **[100]** <Insert number> organisms/mL.
 - c. Nitrate Reducers: Maintain a maximum value of **[100]** <Insert number> organisms/mL.
 - d. Sulfate Reducers: Maintain a maximum value of **[zero]** <Insert number> organisms/mL.
 - e. Iron Bacteria: Maintain a maximum value of **[zero]** <Insert number> organisms/mL.
10. <Insert other requirements if necessary>.

2.3 MANUAL CHEMICAL-FEED EQUIPMENT

- A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum **3-1/2-inch** (89-mm) fill opening in the top, and **NPS 3/4** (DN 20) bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.
1. Capacity: **[2 gal. (7.6 L)] [5 gal. (19 L)]** <Insert value>.
 2. Minimum Working Pressure: **[125 psig (860 kPa)] [175 psig (1210 kPa)]** <Insert value>.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT

- A. Water Meter:
1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
 2. Body: Bronze.
 3. Minimum Working-Pressure Rating: **150 psig** (1035 kPa).
 4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).
 5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
 6. End Connections: Threaded.
 7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.
 8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Water Meter:
1. AWWA C701, turbine-type, totalization meter.
 2. Body: Bronze.
 3. Minimum Working-Pressure Rating: **100 psig** (690 kPa).
 4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).

5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
6. End Connections: Threaded.
7. Control: Low-voltage signal capable of transmitting **1000 feet** (305 m).
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: **[Bronze] [Epoxy-coated cast iron]**.
3. Minimum Working-Pressure Rating: **150 psig** (1035 kPa).
4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).
5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
6. End Connections: Flanged.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: **[30 gal. (114 L)] [50 gal. (189 L)] [120 gal. (454 L)] <Insert value>**.

E. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.

G. Injection Assembly:

1. Quill: Minimum **NPS 1/2** (DN 15) with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: **[Three] [Two]**-piece, stainless steel; selected to fit quill.

3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig (4137 kPa) at 200 deg F (93 deg C).

2.5 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Systems shall be operational, filled, started, and vented prior to cleaning. Use water meter to record capacity in each system.
- B. Place terminal control valves in open position during cleaning.
- C. Verify that electric power is available and of the correct characteristics.

3.2 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

- A. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install water testing equipment on wall near water chemical application equipment.
- D. Install interconnecting control wiring for chemical treatment controls and sensors.
- E. Mount sensors and injectors in piping circuits.

- F. Bypass Feeders: Install in closed hydronic systems, including [**hot-water heating**] [**chilled water**] [**dual-temperature water**] [**and**] [**glycol cooling**], and equipped with the following:
1. Install bypass feeder in a bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 2. Install water meter in makeup-water supply.
 3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below the feeder inlet.
 5. Install a swing check on the inlet after the isolation valve.

3.4 CONNECTIONS

- A. Where installing piping adjacent to equipment, allow space for service and maintenance.
- B. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 232116 "Hydronic Piping Specialties."
- C. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- D. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.
- E. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- F. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of hydronic systems' startup procedures.
 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 7. Cap and subject piping to static water pressure of **50 psig** (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
 8. Repair leaks and defects with new materials and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. At **[four] [six] [eight] <Insert number>**-week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising Owner of changes necessary to adhere to "Performance Requirements" Article.
- F. Comply with ASTM D 3370 and with the following standards:
1. Silica: ASTM D 859.
 2. Acidity and Alkalinity: ASTM D 1067.
 3. Iron: ASTM D 1068.
 4. Water Hardness: ASTM D 1126.
- 3.6 DEMONSTRATION
- A. Engage a factory-authorized service representative to assist Contractor to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.
- B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232513

SECTION 232516 - WATER TREATMENT FOR OPEN-LOOP HYDRONIC SYSTEMS

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following HVAC water-treatment systems:
 - 1. Manual chemical-feed equipment.
 - 2. Automatic chemical-feed equipment.
 - 3. Ozone-generator biocide equipment.
 - 4. Stainless-steel pipes and fittings.
 - 5. UV biocide equipment.
 - 6. Chemical treatment test equipment.
 - 7. Chemicals.
- B. Related Requirements:
 - 1. Section 232533 "HVAC Makeup-Water Filtration Equipment" for water softeners, RO equipment, and filtration equipment.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. EEPROM: Electrically erasable, programmable read-only memory.
- B. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- C. RO: Reverse osmosis.

- D. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connections, and furnished specialties and accessories for the following products:

1. Bypass feeders.
2. Water meters.
3. Inhibitor injection timers.
4. pH controllers.
5. TSS controllers.
6. Biocide feeder timers.
7. Chemical solution tanks.
8. Injection pumps.
9. Ozone generators.
10. UV-irradiation units.
11. Chemical test equipment.
12. Chemical material safety data sheets.
13. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: Pretreatment and chemical[, **and ozone-generator biocide**][, **and UV**] treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems.

1. Include plans, elevations, sections, and attachment details.
2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.

- C. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.

- D. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.
- E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- F. Other Informational Submittals:
 - 1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
 - 2. Water Analysis: Illustrate water quality available at Project site.
 - 3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to DEN Project Manager.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.
 - 1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.7 MAINTENANCE MATERIALS

- A. Provide sufficient chemicals for treatment and testing during warranty period.

1.8 QUALITY ASSURANCE

- A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.
- B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.
- C. Manufacturers: Companies specializing in manufacturing the products specified in this

Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.

- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.9 MAINTENANCE SERVICE

- A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.
- B. Provide laboratory and technical assistance services during this maintenance period.
- C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.
- D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation and biological growth for [**condenser-water piping**] and equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion and shall include the following:
 - 1. Initial water analysis and HVAC water-treatment recommendations.
 - 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
 - 3. Periodic field service and consultation.
 - 4. Customer report charts and log sheets.
 - 5. Laboratory technical analysis.
 - 6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements" and Division 1.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Ampion Corp.](#)
2. [Anderson Chemical Company.](#)
3. [Aqua-Chem, Inc.](#)
4. [Barclay Water Management, Inc.](#)
5. [Boland.](#)
6. [Cascade Water Services, Inc.](#)
7. [Earthwise Environmental Inc.](#)
8. [General Electric Company; GE Water & Process Technologies.](#)
9. [H-O-H Water Technology, Inc.](#)
10. [Metro Group, Inc. \(The\); Metropolitan Refining Div.](#)
11. [Nalco; an Ecolab company.](#)
12. [Watcon, Inc.](#)
13. [Water Services Inc.](#)
14. **<Insert manufacturer's name>.**
15. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of equipment without creating a hazard to operating personnel or the environment.
- B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
- C. Open HVAC systems, including [**condenser**] [**fluid-cooler spray**] water, shall have the following water qualities:
1. pH: Maintain a value within [**8.0 to 9.1**] **<Insert range>**.
 2. "P" Alkalinity: Maintain a maximum value of [**100**] **<Insert number>** ppm.
 3. Chemical Oxygen Demand: Maintain a maximum value of [**100**] **<Insert number>** ppm.

4. Soluble Copper: Maintain a maximum value of **[0.20] <Insert number>** ppm.
5. TSS: Maintain a maximum value of **[10] <Insert number>** ppm.
6. Ammonia: Maintain a maximum value of **[20] <Insert number>** ppm.
7. Free "OH" Alkalinity: Maintain a maximum value of **[zero] <Insert number>** ppm.
8. Microbiological Limits:
 - a. Total Aerobic Plate Count: Maintain a maximum value of **[10,000] <Insert number>** organisms/mL.
 - b. Total Anaerobic Plate Count: Maintain a maximum value of **[1000] <Insert number>** organisms/mL.
 - c. Nitrate Reducers: Maintain a maximum value of **[100] <Insert number>** organisms/mL.
 - d. Sulfate Reducers: Maintain a maximum value of **[zero] <Insert number>** organisms/mL.
 - e. Iron Bacteria: Maintain a maximum value of **[zero] <Insert number>** organisms/mL.
9. Polymer Testable: Maintain a minimum value within **[10 to 40] <Insert range>**.
10. **<Insert other requirements if necessary>**.

D. Passivation for Galvanized Steel: For the first 60 days of operation.

1. pH: Maintain a value within **[7 to 8] <Insert range>**.
2. Calcium Carbonate Hardness: Maintain a value within **[100 to 300] <Insert range>** ppm.
3. Calcium Carbonate Alkalinity: Maintain a value within **[100 to 300] <Insert range>** ppm.

2.3 MANUAL CHEMICAL-FEED EQUIPMENT

A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum **3-1/2-inch (89-mm)** fill opening in the top, and **NPS 3/4 (DN 20)** bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.

1. Capacity: **[2 gal. (7.6 L)] [5 gal. (19 L)] <Insert value>**.
2. Minimum Working Pressure: **[125 psig (860 kPa)] [175 psig (1210 kPa)] <Insert value>**.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT

A. Water Meter:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: **150 psig (1035 kPa)**.
4. Maximum Pressure Loss at Design Flow: **3 psig (20 kPa)**.
5. Registration: **Gallons (Liters) or cubic feet (cubic meters)**.

6. End Connections: Threaded.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 100 psig (690 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Threaded.
7. Control: Low-voltage signal capable of transmitting 1000 feet (305 m).
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: [Bronze] [Epoxy-coated cast iron].
3. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Flanged.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. Inhibitor Injection Timers:

1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Programmable timers with infinite adjustment over full range, and mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. Digital display makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. pH Controller:
1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
 2. Digital display and touch pad for input.
 3. Sensor probe adaptable to sample stream manifold.
 4. High, low, and normal pH indication.
 5. High- or low-pH-alarm-light trip points, field adjustable; with silence switch.
 6. Hand-off-auto switch for acid pump.
 7. Internal adjustable hysteresis or deadband.
 8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- F. TSS Controller:
1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
 2. Digital display and touch pad for input.
 3. Sensor probe adaptable to sample stream manifold.
 4. High, low, and normal conductance indication.
 5. High- or low-conductance-alarm-light trip points, field adjustable; with silence switch.
 6. Hand-off-auto switch for solenoid bleed-off valve.
 7. Bleed-off valve activated indication.
 8. Internal adjustable hysteresis or deadband.
 9. Bleed Valves:
 - a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.
 - b. Steam Boilers: Motorized ball valve, steel body, and TFE seats and seals.
- G. Biocide Feeder Timer:
1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
 2. 24-hour timer with 14-day skip feature to permit activation any hour of day.

3. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer. Prebleed and bleed lockout timers.
4. Solid-state alternator to enable use of two different formulations.
5. 24-hour display of time of day.
6. 14-day display of day of week.
7. Battery backup so clock is not disturbed by power outages.
8. Hand-off-auto switches for biocide pumps.
9. Biocide A and Biocide B pump running indication.

H. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: [30 gal. (114 L)] [50 gal. (189 L)] [120 gal. (454 L)] <Insert value>.

I. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

J. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.

K. Injection Assembly:

1. Quill: Minimum NPS 1/2 (DN 15) with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: [Three] [Two]-piece stainless steel as described in "Stainless-Steel Pipes and Fittings" Article; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig (4137 kPa) at 200 deg F (93 deg C).

2.5 OZONE-GENERATOR BIOCIDE EQUIPMENT

- A. Corona discharge generator with stainless-steel generating cells, and transformer housed in a NEMA 250, Type 4 enclosure. Assembly shall be suitable for continuous duty. Include factory-mounted site glasses to verify proper operation of generator.

- B. Generator vessels shall be constructed according to ASME Boiler and Pressure Vessel Code, bear an ASME label, and be equipped with pressure relief valve.
- C. External air compressor or induced airflow through a cleanable prefilter shall supply concentrated oxygen through a molecular sieve with **minus 62 deg F** (minus 52 deg C) dew point to avoid the formation of nitric acid.
- D. Controls: Microprocessor based with software in EEPROM, surge protection, high-temperature cutout, and operational status lights. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
- E. Ozone Contactors:
1. Bubble diffusers.
 2. Induction injection nozzle.
 3. Injectors with static mixers.
- F. Ozone Detector and Alarm Devices:
1. Detector:
 - a. Sensor: Metal dioxide semiconductor.
 - b. Concentration Range: **[0.01 to 0.14]** <Insert range> ppm.
 - c. Accuracy: Plus or minus 20 percent of range.
 - d. Sensitivity: 0.01 ppm.
 - e. Response Time: Maximum 10 seconds.
 - f. Operating Temperature: **50 to 100 deg F** (10 to 38 deg C).
 - g. Relative Humidity: 20 to 95 percent, noncondensing over the operating temperature range.
 2. Horns:
 - a. Electric-vibrating-polarized type.
 - b. 24-V dc, with provision for housing the operating mechanism behind a grille.
 - c. Horns shall produce a sound-pressure level of 90 dBA, measured **10 feet** (3 m) from the horn.
 - d. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 3. Visible Alarm Devices:
 - a. Xenon strobe lights listed in UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate.
 - b. Rated Light Output: **[75]** **[110]** <Insert number> candela.
 - c. Strobe Leads: Factory connected to screw terminals.

- d. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- G. Self-Contained Breathing Apparatus: Open-circuit, pressure-demand, compressed air includes completely assembled, portable, self-contained devices designed for hazardous breathing environment application.
1. Face Piece: EPDM or silicone rubber construction material, one-size-fits-all with double-sealing edge, stainless-steel speaking diaphragm and lens retainer, five adjustable straps to hold face piece to head (two straps on each side and one on top), exhalation valve in mask, close-fitting nose piece to ensure no CO₂ buildup, and perspiration drain to avoid skin irritation and to prevent eyepiece, spectacle, and lens fogging.
 2. Backplate: Orthopedically designed of **[chemical and impact-resistant, glass-fiber composite] [aluminum]**.
 3. Harness and Carrier Assembly: Large triangular back pad, backplate, and adjustable waist and shoulder straps. Modular in design, detachable components, and easy to clean and maintain. Shoulder straps padded with flame-resistant material, reinforced with stainless-steel cable, and attached with T-nuts, washers, and screws.
 4. Air Cylinder: **[30] [45] [60]**-minute, low-pressure, air-supply-loaded **[fiberglass] [aluminum] [steel]** cylinders fitted with quick-fill assembly for refilling and air transfer.
 5. Wall-Mounting Cabinet: Leakproof, corrosion-resistant, clear, plastic case.
 6. Tested and Certified: By the National Institute for Occupational Safety and Health and by the Mine Safety and Health Administration, according to 42 CFR 84, Subpart H.

2.6 STAINLESS-STEEL PIPES AND FITTINGS

- A. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.
- B. Stainless-Steel Fittings: Comply with ASTM A 815/A 815M, Type 316, Grade WP-S.
- C. Two-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, carbon-filled TFE seats, threaded body design with adjustable stem packing, threaded ends, and **250-psig (1725-kPa)** steam working-pressure rating and **600-psig (4140-kPa)** cold working-pressure rating.

2.7 UV BIOCIDAL EQUIPMENT

- A. Target Irradiation: Minimum 30,000 microwatts x s/sq. cm.
- B. Light Source Vessels:
 1. ASTM A 666, Type 304 stainless steel.

2. Construct for minimum [150 psig (1035 kPa)] <Insert value> at [150 deg F (65 deg C)] <Insert value> according to ASME Boiler and Pressure Vessel Code, and equipped with pressure relief valve.
3. Light Source Sleeve: Quartz, with EPDM O-ring seals.
4. Light Source: Replaceable UV lamp producing a minimum target irradiation of 254-nm wavelength light.

C. Controls: Interlock with pumps to operate when water is circulating.

2.8 CHEMICAL TREATMENT TEST EQUIPMENT

- A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TSS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.
- B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. [Four] <Insert number>-station rack for open systems.

2.9 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Systems shall be operational, filled, started, and vented prior to cleaning. Use water meter to record capacity in each system.
- B. Place terminal control valves in open position during cleaning.
- C. Verify that electric power is available and of the correct characteristics.

3.2 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

- A. Install chemical application equipment on concrete bases, level, and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install water testing equipment on wall near water chemical application equipment.
- D. Install interconnecting control wiring for chemical treatment controls and sensors.
- E. Mount sensors and injectors in piping circuits.
- F. Install automatic chemical-feed equipment for [**condenser**] [**fluid-cooler spray**] water and include the following:
 - 1. Install makeup-water softener.
 - 2. Install water meter in makeup-water supply.
 - 3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
 - 4. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 5. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves shall cycle to maintain maximum TSS concentration.
 - 6. Install pH sensor and controller with injection pumps and solution tanks.
 - a. Injector pumps shall operate to maintain required pH.
 - 7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
 - a. Injection pumps shall operate to feed biocide on an alternating basis.
 - 8. Install ozone generator with diffusers in condenser-water piping.
 - a. Ozone generator shall operate continuously with condenser-water flow.
 - 9. Install UV-irradiation lamps in condenser-water piping.

- a. UV lights shall operate continuously with condenser-water flow.

3.4 OZONE-GENERATOR INSTALLATION

- A. Install ozone generator and equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Pipe ozone from ozone generator to condenser water with stainless-steel pipe and fittings with welded joints.
- D. Install ~~[two]~~ **[three]**-piece, stainless-steel ball valve in ozone supply to condenser water.
- E. Pipe cooling water to ozone generator and to air-gap drain fitting with stainless-steel pipe and fittings with welded joints where enclosed in ozone-generator room.
- F. Install ~~[two]~~ **[three]**-piece, stainless-steel ball valve in cooling water supply to ozone generator.
- G. Mounting supports for ozone generator shall be ASTM A 666, Type 316 stainless steel.
- H. Mount breathing apparatus outside ozone-generator room.
- I. Mount and install ozone detector, warning lights, and audible alarm inside ozone-generator room. Mount another set of warning lights and audible alarm just outside the main entrance to ozone-generator room.

3.5 UV-IRRADIATION UNIT INSTALLATION

- A. Install UV-irradiation units on concrete bases, level, and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for UV-irradiation units and floor-mounting accessories and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

3.6 CONNECTIONS

- A. Where installing piping adjacent to equipment, allow space for service and maintenance.
- B. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 232116 "Hydronic Piping Specialties" for dielectric fittings.
- C. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- D. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.
- E. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- F. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.7 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 - 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 - 3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
 - 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 - 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.

6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 7. Cap and subject piping to static water pressure of **50 psig** (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
 8. Repair leaks and defects with new materials and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. At **[four]** **[six]** **[eight]** **<Insert number>**-week intervals following Substantial Completion, perform separate water analyses on HVAC systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising Owner of changes necessary to adhere to "Performance Requirements" Article.
- F. Comply with ASTM D 3370 and with the following standards:
1. Silica: ASTM D 859.
 2. Acidity and Alkalinity: ASTM D 1067.
 3. Iron: ASTM D 1068.
 4. Water Hardness: ASTM D 1126.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232516

SECTION 232519 - WATER TREATMENT FOR STEAM SYSTEM FEEDWATER

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following HVAC water-treatment systems:
 - 1. Automatic chemical-feed equipment.
 - 2. Stainless-steel pipes and fittings.
 - 3. Chemical treatment test equipment.
 - 4. Chemicals.
- B. Related Requirements:
 - 1. Section 232533 "HVAC Makeup-Water Filtration Equipment" for requirements for water softeners, reverse-osmosis equipment, and filtration equipment.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. TDS: Total dissolved solids.
- B. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories for the following products:
1. Water meters.
 2. Inhibitor injection timers.
 3. pH controllers.
 4. TDS controllers.
 5. Chemical solution tanks.
 6. Injection pumps.
 7. Chemical test equipment.
 8. Chemical material safety data sheets.
 9. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to steam systems.
1. Include plans, elevations, sections, and attachment details.
 2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.
- D. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.
- E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- F. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.

- G. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- H. Other Informational Submittals:
 - 1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
 - 2. Water Analysis: Illustrate water quality available at Project site.
 - 3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.
 - 1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.

1.7 MAINTENANCE MATERIALS

- A. Provide sufficient chemicals for treatment and testing during warranty period.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.8 QUALITY ASSURANCE

- A. Steam System Water-Treatment Service Provider Qualifications: An experienced steam systems water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.
- B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.
- C. Manufacturers: Companies specializing in manufacturing the products specified in this Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.

- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.9 MAINTENANCE SERVICE

- A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.
- B. Provide laboratory and technical assistance services during this maintenance period.
- C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.
- D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion, scale formation, and biological growth for **[heating, steam and condensate piping] [condenser-water piping]** and equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion, and shall include the following:
 - 1. Initial water analysis and steam systems water-treatment recommendations.
 - 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
 - 3. Periodic field service and consultation.
 - 4. Customer report charts and log sheets.
 - 5. Laboratory technical analysis.
 - 6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements" and Division 1.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to

satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Anderson Chemical Company.](#)
2. [Aqua-Chem, Inc.](#)
3. [Barclay Water Management, Inc.](#)
4. [Boland.](#)
5. [Cascade Water Services, Inc.](#)
6. [Earthwise Environmental Inc.](#)
7. [General Electric Company; GE Water & Process Technologies.](#)
8. [H-O-H Water Technology, Inc.](#)
9. [Metro Group, Inc. \(The\); Metropolitan Refining Div.](#)
10. [Nalco; an Ecolab company.](#)
11. [Watcon, Inc.](#)
12. [Water Services Inc.](#)
13. **<Insert manufacturer's name>.**
14. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. Water quality for steam systems shall minimize corrosion and scale buildup for optimum efficiency of steam and condensate equipment without creating a hazard to operating personnel or the environment.
- B. Base steam systems feedwater treatment on quality of water available at Project site, steam and condensate system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
- C. Steam Condensate:
1. pH: Maintain a value within **[7.8 to 8.4] <Insert range>**.
 2. Total Alkalinity: Maintain a value within **[5 to 50] <Insert range>** ppm.
 3. Chemical Oxygen Demand: Maintain a maximum value of **[15] <Insert number>** ppm.
 4. Soluble Copper: Maintain a maximum value of **[0.20] <Insert number>** ppm.
 5. TSS: Maintain a maximum value of **[10] <Insert number>** ppm.
 6. Ammonia: Maintain a maximum value of **[20] <Insert number>** ppm.
 7. Total Hardness: Maintain a maximum value of **[2] <Insert number>** ppm.
 8. **<Insert other requirements if necessary>**.

- D. Steam boiler operating at **15 psig** (104 kPa) and less shall have the following water qualities:
1. "OH" Alkalinity: Maintain a value within **[200 to 400]** <Insert range> ppm.
 2. TSS: Maintain a value within **[600 to 3000]** <Insert range> ppm.
 3. <Insert other requirements if necessary>.
- E. Steam boiler operating at more than **15 psig** (104 kPa) shall have the following water qualities:
1. "OH" Alkalinity: Maintain a value within **[200 to 400]** <Insert range> ppm.
 2. TSS: Maintain a value within **[600 to 1200]** <Insert range> ppm to maximum 30 times TDS of water treated with reverse-osmosis equipment.
 3. <Insert other requirements if necessary>.

2.3 AUTOMATIC CHEMICAL-FEED EQUIPMENT

A. Water Meter:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: **150 psig** (1035 kPa).
4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).
5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
6. End Connections: Threaded.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: **100 psig** (690 kPa).
4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).
5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
6. End Connections: Threaded.
7. Control: Low-voltage signal capable of transmitting **1000 feet** (305 m).
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: **[Bronze] [Epoxy-coated cast iron]**.
3. Minimum Working-Pressure Rating: **150 psig** (1035 kPa).

4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).
5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
6. End Connections: Flanged.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. TSS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. [**Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High- or low-conductance-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves: Motorized ball valve, steel body, and TFE seats and seals.
10. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

E. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: [30 gal. (114 L)] [50 gal. (189 L)] [120 gal. (454 L)] <Insert value>.

F. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.

H. Injection Assembly:

1. Quill: Minimum **NPS 1/2 (DN 15)** with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: **[Three] [Two]**-piece stainless steel as described in "Stainless-Steel Pipes and Fittings" Article; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum **600 psig (4137 kPa)** at **200 deg F (93 deg C)**.

2.4 STAINLESS-STEEL PIPES AND FITTINGS

A. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.

B. Stainless-Steel Fittings: Comply with ASTM A 815/A 815M, Type 316, Grade WP-S.

C. Two-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, carbon-filled TFE seats, threaded body design with adjustable stem packing, threaded ends, and **250-psig (1725-kPa)** steam working-pressure rating and **600-psig (4140-kPa)** cold working-pressure rating.

D. Three-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and **150-psig (1035-kPa)** steam working-pressure rating and **600-psig (4140-kPa)** cold working-pressure rating.

2.5 CHEMICAL TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.

B. Sample Cooler:

1. Tube: Sample.
 - a. Size: **NPS 1/4 (DN 8)** tubing.
 - b. Material: ASTM A 666, Type 316 stainless steel.
 - c. Pressure Rating: Minimum **2000 psig (13 790 kPa)**.
 - d. Temperature Rating: Minimum **850 deg F (454 deg C)**.
2. Shell: Cooling water.

- a. Material: ASTM A 666, Type 304 stainless steel.
 - b. Pressure Rating: Minimum 250 psig (1725 kPa).
 - c. Temperature Rating: Minimum 450 deg F (232 deg C).
3. Capacities and Characteristics:
- a. Tube: Sample.
 - 1) Flow Rate: [0.25 gpm (0.016 L/s)] <Insert value>.
 - 2) Entering Temperature: [400 deg F (204 deg C)] <Insert value>.
 - 3) Leaving Temperature: [88 deg F (31 deg C)] <Insert value>.
 - 4) Pressure Loss: [6.5 psig (44.8 kPa)] <Insert value>.
 - b. Shell: Cooling water.
 - 1) Flow Rate: [3 gpm (0.19 L/s)] <Insert value>.
 - 2) Entering Temperature: [70 deg F (21 deg C)] <Insert value>.
 - 3) Pressure Loss: [1.0 psig (6.89 kPa)] <Insert value>.
- C. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.
1. [Two] <Insert number>-station rack for closed-loop systems.
 2. [Four] <Insert number>-station rack for open-loop systems.

2.6 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Systems shall be operational, filled, started, and vented prior to cleaning. Use water meter to record capacity in each system.
- B. Place terminal control valves in open position during cleaning.
- C. Verify that electric power is available and of the correct characteristics.

3.2 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

- A. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install water testing equipment on wall near water chemical application equipment.
- D. Install interconnecting control wiring for chemical treatment controls and sensors.
- E. Mount sensors and injectors in piping circuits.
- F. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:
 - 1. Install water meter in makeup-water supply.
 - 2. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
 - a. Pumps shall operate for timed interval when contacts close at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
 - 3. Install test equipment and furnish test-kit to Owner.
 - 4. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves shall cycle to maintain maximum TSS concentration.
 - 5. Install inhibitor injection timer with injection pumps and solution tanks.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into main steam supply header.
- G. Install automatic chemical-feed equipment for **[condenser] [fluid-cooler spray]** water and include the following:
 - 1. Install water meter in makeup-water supply.
 - 2. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.

3. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
4. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves shall cycle to maintain maximum TSS concentration.
5. Install pH sensor and controller with injection pumps and solution tanks.
 - a. Injector pumps shall operate to maintain required pH.

3.4 CONNECTIONS

- A. Where installing piping adjacent to equipment, allow space for service and maintenance.
- B. Make piping connections between steam systems water-treatment equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 232113 "Hydronic Piping" for dielectric fittings.
- C. Install shutoff valves on steam systems water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- D. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.
- E. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- F. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. Inspect field-assembled components and equipment installation, including piping and electrical connections.

2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 3. Place steam systems water-treatment system into operation and calibrate controls during the preliminary phase of steam systems' startup procedures.
 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 7. Cap and subject piping to static water pressure of 50 psig (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
 8. Repair leaks and defects with new materials and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report advising Owner of changes necessary to adhere to "Performance Requirements" Article for each required characteristic. Sample boiler water at [four] [six] [eight] <Insert number>-week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.
- F. Comply with ASTM D 3370 and with the following standards:
1. Silica: ASTM D 859.
 2. Steam System: ASTM D 1066.
 3. Acidity and Alkalinity: ASTM D 1067.
 4. Iron: ASTM D 1068.
 5. Water Hardness: ASTM D 1126.
- 3.6 DEMONSTRATION
- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain steam systems water-treatment systems and equipment.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.
- B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232519

SECTION 232523 - WATER TREATMENT FOR HUMIDIFICATION STEAM SYSTEM FEEDWATER

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following HVAC water-treatment systems:
 - 1. Automatic chemical-feed equipment.
 - 2. Stainless-steel pipes and fittings.
 - 3. Chemical treatment test equipment.
 - 4. Chemicals.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. RO: Reverse osmosis.
- B. TDS: Total dissolved solids.
- C. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories for the following products:
1. Water meters.
 2. Inhibitor injection timers.
 3. pH controllers.
 4. TDS controllers.
 5. Chemical solution tanks.
 6. Injection pumps.
 7. Chemical test equipment.
 8. Chemical material safety data sheets.
 9. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Pretreatment and chemical[, **and ozone-generator biocide**][, **and UV-irradiation biocide**] treatment equipment showing tanks, maintenance space required, and piping connections to humidification steam feedwater systems.
1. Include plans, elevations, sections, and attachment details.
 2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For equipment and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.
- D. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.
- E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- F. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
2. Water Analysis: Illustrate water quality available at Project site.
3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to DEN Project Manager.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.
 1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIALS

- A. Provide sufficient chemicals for treatment and testing during warranty period.

1.8 QUALITY ASSURANCE

- A. Water-Treatment Humidification Steam System Feedwater Service Provider Qualifications: An experienced HVAC water-treatment for humidification steam system feedwater service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.
- B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.
- C. Manufacturers: Companies specializing in manufacturing the products specified in this Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction,

and marked for intended use.

- E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.9 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements" and Division 1.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Ampion Corp.](#)
 - 2. [Anderson Chemical Company.](#)
 - 3. [Aqua-Chem, Inc.](#)
 - 4. [Barclay Water Management, Inc.](#)
 - 5. [Boland.](#)
 - 6. [Cascade Water Services, Inc.](#)
 - 7. [Earthwise Environmental Inc.](#)
 - 8. [General Electric Company; GE Water & Process Technologies.](#)
 - 9. [H-O-H Water Technology, Inc.](#)
 - 10. [Metro Group, Inc. \(The\); Metropolitan Refining Div.](#)
 - 11. [Nalco; an Ecolab company.](#)
 - 12. [Watcon, Inc.](#)
 - 13. [Water Services Inc.](#)
 - 14. **<Insert manufacturer's name>.**
 - 15. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. Water quality for humidification steam systems shall minimize corrosion and scale buildup for optimum efficiency of humidification steam equipment without creating a hazard to operating personnel or the environment.
- B. Base HVAC water treatment on quality of water available at Project site, humidification steam system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
- C. Steam Condensate:
1. pH: Maintain a value within **[7.8 to 8.4]** <Insert range>.
 2. Total Alkalinity: Maintain a value within **[5 to 50]** <Insert range> ppm.
 3. Chemical Oxygen Demand: Maintain a maximum value of **[15]** <Insert number> ppm.
 4. Soluble Copper: Maintain a maximum value of **[0.20]** <Insert number> ppm.
 5. TDS: Maintain a maximum value of **[10]** <Insert number> ppm.
 6. Ammonia: Maintain a maximum value of **[20]** <Insert number> ppm.
 7. Total Hardness: Maintain a maximum value of **[2]** <Insert number> ppm.
 8. <Insert other requirements if necessary>.
- D. Steam boiler operating at **15 psig** (104 kPa) and less shall have the following water qualities:
1. "OH" Alkalinity: Maintain a value within **[200 to 400]** <Insert range> ppm.
 2. TDS: Maintain a value within **[600 to 3000]** <Insert range> ppm.
 3. <Insert other requirements if necessary>.
- E. Steam boiler operating at more than **15 psig** (104 kPa) shall have the following water qualities:
1. "OH" Alkalinity: Maintain a value within **[200 to 400]** <Insert range> ppm.
 2. TDS: Maintain a value within **[600 to 1200]** <Insert range> ppm to maximum 30 times RO water TDS.
 3. <Insert other requirements if necessary>.

2.3 AUTOMATIC CHEMICAL-FEED EQUIPMENT

- A. Water Meter:
1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
 2. Body: Bronze.
 3. Minimum Working-Pressure Rating: **150 psig** (1035 kPa).
 4. Maximum Pressure Loss at Design Flow: **3 psig** (20 kPa).
 5. Registration: **Gallons** (Liters) or **cubic feet** (cubic meters).
 6. End Connections: Threaded.

7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 100 psig (690 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Threaded.
7. Control: Low-voltage signal capable of transmitting 1000 feet (305 m).
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: **[Bronze] [Epoxy-coated cast iron]**.
3. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Flanged.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac, and that will close at adjustable increments of total flow.
8. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. TSS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. **[Interface for start/stop and status indication at central workstation as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."]**
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High- or low-conductance-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves: Motorized ball valve, steel body, and TFE seats and seals.

E. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: [30 gal. (114 L)] [50 gal. (189 L)] [120 gal. (454 L)] <Insert value>.

F. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.

H. Injection Assembly:

1. Quill: Minimum NPS 1/2 (DN 15) with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: [Three] [Two]-piece stainless steel as described in "Stainless-Steel Pipes and Fittings" Article; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig (4137 kPa) at 200 deg F (93 deg C).

2.4 STAINLESS-STEEL PIPES AND FITTINGS

- A. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.
- B. Stainless-Steel Fittings: Comply with ASTM A 815/A 815M, Type 316, Grade WP-S.
- C. Two-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, carbon-filled TFE seats, threaded body design with adjustable stem packing, threaded ends, and 250-psig (1725-kPa) steam working-pressure rating and 600-psig (4140-kPa) cold working-pressure rating.
- D. Three-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351/A 351M, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and 150-psig

(1035-kPa) steam working-pressure rating and 600-psig (4140-kPa) cold working-pressure rating.

2.5 CHEMICAL TREATMENT TEST EQUIPMENT

- A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.
- B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.
 - 1. [Two] <Insert number>-station rack for closed-loop systems.
 - 2. [Four] <Insert number>-station rack for open-loop systems.

2.6 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality specified in "Performance Requirements" Article.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Systems shall be operational, filled, started, and vented prior to cleaning. Use water meter to record capacity in each system.
- B. Place terminal control valves in open position during cleaning.
- C. Verify that electric power is available and of the correct characteristics.

3.2 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

- A. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

- B. Install water testing equipment on wall near water chemical application equipment.
- C. Install interconnecting control wiring for chemical treatment controls and sensors.
- D. Mount sensors and injectors in piping circuits.
- E. Install automatic chemical-feed equipment for water and include the following:
 - 1. Install water meter in makeup-water supply.
 - 2. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
 - 3. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 4. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves shall cycle to maintain maximum TSS concentration.
 - 5. Install pH sensor and controller with injection pumps and solution tanks.
 - a. Injector pumps shall operate to maintain required pH.

3.4 CONNECTIONS

- A. Where installing piping adjacent to equipment, to allow service and maintenance.
- B. Make piping connections between steam systems water-treatment equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 232113 "Hydronic Piping" for dielectric fittings.
- C. Install shutoff valves on humidifier steam system water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- D. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup water connections to potable-water systems.
- E. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- F. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 3. Place humidifier steam system water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 7. Cap and subject piping to static water pressure of 50 psig (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
 8. Repair leaks and defects with new materials and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report advising Owner of changes necessary to adhere to "Performance Requirements" Article for each required characteristic. Sample boiler water at [four] [six] [eight] <Insert number>-week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.
- F. Comply with ASTM D 3370 and with the following standards:
1. Silica: ASTM D 859.
 2. Steam System: ASTM D 1066.
 3. Acidity and Alkalinity: ASTM D 1067.

4. Iron: ASTM D 1068.
5. Water Hardness: ASTM D 1126.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232523

SECTION 232533 - HVAC MAKEUP-WATER FILTRATION EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following HVAC water filtration equipment:
 - 1. HVAC makeup-water softeners.
 - 2. RO equipment for HVAC makeup water.
 - 3. Multimedia filters.
 - 4. Self-cleaning strainers.
 - 5. Bag- or cartridge-type filters.
 - 6. Centrifugal separators.
 - 7. Water-softener chemicals.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. RO: Reverse osmosis.
- B. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:
 - 1. Water softeners.
 - 2. RO units.
 - 3. Multimedia filters.
 - 4. Self-cleaning strainers.
 - 5. Bag- or cartridge-type filters.
 - 6. Centrifugal separators.
 - 7. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: Softeners and filtration equipment, maintenance space required, and piping connections to HVAC systems.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For **[water softeners]** **[RO equipment]** **[water filtration units]** and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports.
- D. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.
- E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.
- F. Other Informational Submittals:
 - 1. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

- 1. Operation and Maintenance Data: For sensors, injection pumps, **[water softeners,]** **[RO equipment,]** **[water filtration units,]** and controllers to include in emergency, operation, and maintenance manuals. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.7 MAINTENANCE MATERIALS

- A. Provide sufficient chemicals for treatment and testing during warranty period.

1.8 QUALITY ASSURANCE

- A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-filtration service provider capable of analyzing water qualities, installing water-filtration equipment, and applying water filtration as specified in this Section.
- B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.
- C. Manufacturers: Companies specializing in manufacturing the products specified in this Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.9 MAINTENANCE SERVICE

- A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.
- B. Provide laboratory and technical assistance services during this maintenance period.
- C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.
- D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion, scale formation, and biological growth for equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion, and shall include the following:
 - 1. Periodic field service and consultation.

2. Customer report charts and log sheets.
3. Laboratory technical analysis.
4. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements" and Division 1.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 HVAC MAKEUP-WATER SOFTENER

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [CSI Water Treatment Systems.](#)
 2. [Culligan International Company.](#)
 3. [CUNO Incorporated.](#)
 4. [Diamond Water Conditioning; a Griesbach company.](#)
 5. [Diamond Water Systems, Inc.](#)
 6. [Ecodyne Industrial.](#)
 7. [Hungerford & Terry, Inc.](#)
 8. [Kinetico Incorporated.](#)
 9. [Marlo Incorporated.](#)
 10. [Parker Boiler.](#)
 11. [Pentair, Inc.](#)
 12. [RainSoft; a division of Aquion Water Treatment Products.](#)
 13. [Water King, Inc.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Description: Twin mineral tanks and one brine tank, factory mounted on skid.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- D. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.
- E. Mineral Tanks:
1. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 2. Fabricate and label fiber-reinforced plastic (FRP) filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
 3. Pressure Rating: [100 psig (690 kPa)] [125 psig (860 kPa)] [150 psig (1035 kPa)] **<Insert value>** minimum.
 4. Wetted Components: Suitable for water temperatures from [40 to at least 100 deg F (5 to at least 38 deg C)] **<Insert range>**.
 5. Freeboard: 50 percent, minimum, for backwash expansion above the normal resin bed level.
 6. Support Legs or Skirt: Constructed of structural steel, welded or bonded to tank before testing and labeling.
 7. Finish: Hot-dip galvanized on exterior and interior of tank after fabrication.
 8. Upper Distribution System: Single-point type, fabricated from galvanized-steel pipe and fittings.
 9. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from PVC pipe and fittings with individual, fine-slotted, nonclogging polyethylene strainers; arranged for even-flow distribution through resin bed.
- F. Controls: Automatic; factory mounted on mineral tanks and factory wired.
1. Adjustable duration of regeneration steps.
 2. Push-button start and complete manual operation override.
 3. Pointer on pilot-control valve shall indicate cycle of operation.
 4. Means of manual operation of pilot-control valve if power fails.
 5. Main Operating Valves: Industrial, automatic, multiport, diaphragm type with the following features:
 - a. Slow opening and closing, nonslam operation.
 - b. Diaphragm guiding on full perimeter from fully open to fully closed.
 - c. Isolated dissimilar metals within valve.
 - d. Self-adjusting, internal, automatic brine injector that draws brine and rinses at constant rate independent of pressure.
 - e. Float-operated brine valve to automatically measure the correct amount of brine to the softener and refill with fresh water.
 - f. Sampling cocks for soft water.
 6. Flow Control: Automatic control of backwash and flush rates over variations in operating pressures that do not require field adjustments. Equip mineral tanks with automatic-reset-head water meter that electrically activates cycle controller to initiate regeneration at preset total in gallons (liters) and that automatically resets after regeneration to preset total in gallons (liters) for next service run. Include alternator to regenerate one mineral tank with the other in service.

- G. Brine Tank: Combination measuring and wet-salt storing system.
1. Tank and Cover Material: Fiberglass a minimum of **3/16 inch** (4.8 mm) thick; or molded polyethylene a minimum of **3/8 inch** (9.5 mm) thick.
 2. Brine Valve: Float operated and plastic fitted for automatic control of brine withdrawn and freshwater refill.
 3. Size: Large enough for at least four regenerations at full salting.
- H. Factory-Installed Accessories:
1. Piping, valves, tubing, and drains.
 2. Sampling cocks.
 3. Main-operating-valve position indicators.
 4. Water meters.
- I. Water Test Kit: Include in wall-mounting enclosure for water softener.
- J. Capacities and Characteristics:
1. Continuous Service Flow Rate: **<Insert gpm (L/s)>** at **15-psig** (104-kPa) pressure loss.
 2. Peak Service Flow Rate: **<Insert gpm (L/s)>** at **25-psig** (173-kPa) pressure loss.
 3. Water Consumption: **<Insert gal./day (cu. m/day)>**.
 4. Water Demand: **<Insert number>** hours/day.
 5. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
 - g. Interrupting Capacity: **<Insert amperage>**.

2.2 RO EQUIPMENT FOR HVAC MAKEUP WATER

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [CSI Water Treatment Systems.](#)
 2. [Culligan International Company.](#)
 3. [CUNO Incorporated.](#)
 4. [Diamond Water Conditioning; a Griesbach company.](#)
 5. [Ecodyne Industrial.](#)
 6. [Hungerford & Terry, Inc.](#)
 7. [Kinetico Incorporated.](#)
 8. [Marlo Incorporated.](#)
 9. [Pentair, Inc.](#)
 10. [RainSoft; a division of Aquion Water Treatment Products.](#)

11. [Water & Power Technologies, Inc.](#)
 12. [Water King, Inc.](#)
 13. **<Insert manufacturer's name>**.
 14. or approved equal.
- B. Description: Factory fabricated and tested with RO membrane elements in housings, high-pressure pumps and motors, controls, valves, and prefilter; mounted on skid.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.
- E. Skid Assembly: Welded-steel frame coated with epoxy protective finish.
- F. RO Membrane and Housing:
1. Element: Thin-film composite with U-cup brine seal with minimum 98 percent salt rejection based on 2000-ppm water supplied at **225 psig (1551 kPa)** and **77 deg F (25 deg C)**.
 2. Housing: ASTM A 666, Type 304 stainless steel with PVC end caps held in place with stainless-steel straps.
- G. High-Pressure Pumps and Motors:
1. Pump:
 - a. Vertical, multistage centrifugal operating at 3500 rpm with ASTM A 666, Type 304 stainless-steel casing, shaft, impellers, and inlet and discharge casting.
 - b. Bearings shall be tungsten carbide and ceramic.
 - c. Cast-iron frame and flanged suction and discharge connections.
 2. Motor: NEMA-standard, C-faced, totally enclosed, fan-cooled motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- H. Controls:
1. Microprocessor-based controller with digital display.
 2. Interlock for remote start/stop control.
 3. Membrane flush sequence when pumps shut down.
 4. Run time indicator.
 5. Low-pressure safety cutoff.
 6. Panel-mounted gages as follows:
 - a. Product and concentrate.

- b. Inlet, cartridge filter outlet, RO feed, RO concentrate, and RO product pressures.
 - c. Product conductivity monitor.
- I. Valves:
 1. Stainless-steel pump, concentrate, and recycle throttling valves rated for minimum **300 psig** (2068 kPa).
 2. Automatic inlet shutoff valve, diaphragm type; solenoid actuated, normally closed, and constructed of glass-reinforced noryl thermoplastic.
 3. PVC valves with EPDM seats and seals for isolation at inlet, and check and sample valves at product and concentrate. Sample valves at cartridge filter outlet, concentrate, and product outlet.
- J. Prefilter:
 1. Housing: Polypropylene with built-in relief or vent valve.
 2. Element: Spun-wound polypropylene.
- K. Inlet Water Tempering Valve: Thermostatic water-tempering valve to maintain [**77 deg F** (25 deg C)] **<Insert value>** inlet water temperature to RO unit.
- L. Activated Carbon Filter:
 1. Media Tank: Fiberglass-reinforced polyester rated for minimum **150 psig** (1035 kPa) with internal backwash distributor and filtered water collector.
 2. Media: 12-by-40-mesh, bituminous coal-based activated carbon.
 3. Backwash Valve: Piston-operated control valve with drain-line, flow-control orifice.
 4. Backwash Control: Seven-day time clock.
- M. Atmospheric Storage Tank:
 1. Tank: Polyethylene single piece with closed top and flat bottom with manway in top, 0.2-micron filter vent, inlet, discharge, and drain piping connections, and bulkhead fittings for level controls.
 2. Control: Level switches start and stop RO unit. Low-level limit shall stop repressurization pumps, and signal an alarm.
- N. Repressurization Pumps:
 1. Pumps: Two close-coupled, single-stage centrifugal pumps, with mechanical seals. Wetted components ASTM A 666, Type 316 stainless steel.
 2. Controls: NEMA 250, Type 4X pump control panel constructed of fiberglass to control pumps, one operating and one standby, with automatic alternator and fail-over control.
 3. Motor: Open, drip-proof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- O. Water Test Kit: Include in wall-mounting cabinet for RO unit.
- P. Capacities and Characteristics:
1. RO Product Flow Rate: <Insert gpm (L/s)>.
 2. Total Water Flow Rate: <Insert gpm (L/s)>.
 3. Daily Water Consumption: <Insert gal./day (cu. m/day)>.
 4. Water Demand: <Insert number> hours/day.
 5. Storage Tank Size: <Insert gal. (L)>.
 6. RO Inlet Operating Temperature: [77 deg F (25 deg C)] <Insert value>.
 7. High-Pressure Pump:
 - a. Discharge Pressure: <Insert psig (kPa)>.
 - b. Flow Rate: <Insert gpm (L/s)>.
 - c. Horsepower: <Insert value>.
 - d. Motor Speed: [3500] <Insert number> rpm.
 8. Repressure Pumps:
 - a. Discharge Pressure: <Insert psig (kPa)>.
 - b. Flow Rate: <Insert gpm (L/s)>.
 - c. Horsepower: <Insert value>.
 - d. Motor Speed: [3500] <Insert number> rpm.
 9. Prefilter Design (at Total Water Flow Rate):
 - a. Filter Efficiency: [98] <Insert number> percent.
 - b. Particle Size: [5] <Insert number> microns and larger.
 - c. Clean Pressure Loss: [2 psig (14 kPa)] <Insert value>.
 - d. Replacement Pressure Loss: [6 psig (41 kPa)] <Insert value>.
 10. Electrical Characteristics (Single-Point Connection):
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
 - g. Interrupting Capacity: <Insert amperage>.

2.3 MULTIMEDIA FILTERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Diamond Water Systems, Inc.](#)
 2. [Everfilt.](#)
 3. [LAKOS; Claude Laval Corporation.](#)

4. [Miami Filter LLC.](#)
 5. [PEP Filters, Inc.](#)
 6. [Puroflux Corporation.](#)
 7. [United Industries, Inc.](#)
 8. **<Insert manufacturer's name>.**
 9. or approved equal.
- B. Description: Factory-fabricated and -tested, simplex, multimedia filter system of filter tank, media, strainer, circulating pump, piping, and controls for removing particles from water.
1. Filter Tank: Corrosion resistant with distribution system and media.
 - a. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
 - c. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - d. Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - e. FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; [**Designation E, 125-psig (0.862-MPa)**] [**or**] [**Designation F, 150-psig (1.034-MPa)**] pressure category flanges of grade same as tank material according to ASTM D 5421.
 2. Motorized Valves: Flanged or grooved-end, ductile-iron butterfly type with **[EPDM]** **<Insert material>** valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
 3. Strainer: Basket type mounted on pump suction.
 4. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
 5. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
 6. Safety Valves: Automatic pressure relief.
 7. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
 - a. Casing: Radially split, cast iron.
 - b. Pressure Rating: [**125 psig (860 kPa)**] [**150 psig (1035 kPa)**] minimum.
 - c. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 - d. Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
 - e. Seal: Mechanical.
 - f. Motor: Open, dripproof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

8. Controls: Automatic control of circulating pump and tank backwash; factory wired for single electrical connection.
 - a. Panel: NEMA 250, [Type 4] <Insert type> enclosure with time clock and pressure gages.
 - b. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
 - c. Backwash: Automatic; with time clock and differential pressure switch.
 - d. Backwash Valve: Tank mounted with valves interlocked to single actuator.
 9. Support: Skid mounting. [Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.]
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Capacities and Characteristics:
1. Filter Design:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Clean Pressure Loss: [5 psig (34.5 kPa)] <Insert value>.
 - c. Maximum Media Flow Rate: [15 gpm/sq. ft. (10.2 L/s per sq. m)] <Insert value>.
 - d. Filtration Efficiency: [98] <Insert number> percent.
 - e. Particle-Specific Gravity: [1.8] <Insert number>.
 - f. Particle Size: [5] [10] [20] [45] <Insert number> microns.
 2. Filter Tank: With internal distribution piping.
 - a. Pressure Rating: <Insert psig (kPa)>.
 - b. Diameter: <Insert inches (mm)>.
 - c. Inlet and Outlet Size: <Insert NPS (DN)>.
 - d. Blowdown Piping Outlet Size: <Insert NPS (DN)>.
 3. Filter Media: <Insert material>.
 4. Start Backwash Pressure Loss: [13 psig (90 kPa)] <Insert value>.
 5. Backwash Period: [10] <Insert number> minutes.
 6. Circulating Pump:
 - a. Capacity: <Insert gpm (L/s)>.
 - b. Total Dynamic Head: <Insert feet (kPa)>.
 - c. Motor Speed: <Insert number> rpm.
 - d. Inlet Size: <Insert NPS (DN)>.
 - e. Outlet Size: <Insert NPS (DN)>.
 7. Pump Motor Size and Electrical Characteristics:

- a. Horsepower: **<Insert value>**.
 - b. Volts: **[120] [208] [240] [277] [480] <Insert number> V**.
 - c. Phase: **[Single] [Three]**.
 - d. Hertz: **[60] <Insert number> Hz**.
8. Unit Electrical Characteristics:
- a. Full-Load Amperes: **<Insert value>**.
 - b. Minimum Circuit Ampacity: **<Insert value>**.
 - c. Maximum Overcurrent Protection: **<Insert amperage>**.
 - d. Interrupting Capacity: **<Insert amperage>**.

2.4 SELF-CLEANING STRAINERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Everfilt](#).
 2. [Hayward Flow Control Systems, Inc.](#)
 3. [Islip Flow Controls Inc.](#)
 4. [Orival, Inc.](#)
 5. [Sure Flow Equipment Inc.](#)
 6. **<Insert manufacturer's name>**.
 7. or approved equal.
- B. Description: Factory-fabricated and -tested, ASTM A 126, Class B, cast-iron or steel, self-cleaning strainer system of tank, strainer, backwash arm or cleaning spiral, drive and motor, piping, and controls for removing particles from water.
1. Fabricate and label ASTM A 126, Class B, cast-iron or steel strainer tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 2. Pipe Connections:
 - a. **NPS 2 (DN 50) and Smaller:** Threaded according to ASME B1.20.1.
 - b. **NPS 2-1/2 (DN 65) and Larger:** Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Motorized Valves: Flanged or grooved-end, ductile-iron angle type with **[EPDM] <Insert material>** valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
- E. Strainer: Stainless steel.
- F. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.

- G. Safety Valves: Automatic pressure relief.
- H. Hydraulic drive on some units makes motorized drive unnecessary.
- I. Backwash Arm Drive:
1. Drive Casing: Cast iron.
 2. Worm Gears: Immersed in oil.
 3. Motor: Open, dripproof motor supported on the strainer-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- J. Controls: Automatic control of backwash; factory wired for single electrical connection.
1. Panel: NEMA 250, **[Type 4]** <Insert type> enclosure with time clock and pressure gages.
 2. Backwash Arm Drive: Automatic and manual switching; manual switch position bypasses safeties and controls.
 3. Backwash: Automatic; with time clock and differential pressure switch.
 4. Backwash Valve: Electric actuator.
- K. Support: Skid mounting. **[Fabricate supports and base and attachment to tank with reinforcement strong enough to resist strainer movement during a seismic event when strainer base is anchored to building structure.]**
- L. Capacities and Characteristics:
1. Strainer Design:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Clean Pressure Loss: **[5 psig (34.5 kPa)]** <Insert value>.
 - c. Strainer Mesh: **[40] [60] [80]** <Insert number>.
 2. Strainer Tank: With internal distribution piping.
 - a. Material: **[Cast iron] [Steel]** <Insert material>.
 - b. Pressure Rating: **[150 psig (1034 kPa)]** <Insert value>.
 - c. Inlet and Outlet Size: <Insert NPS (DN)>.
 - d. Backwash Piping Outlet Size: <Insert NPS (DN)>.
 3. Start Backwash: **[10 psig (69 kPa)]** <Insert value>.
 4. Backwash Period: **[5]** <Insert number> minutes.
 5. Drive Motor Size and Electrical Characteristics:
 - a. Horsepower: <Insert value>.
 - b. Volts: **[120] [208] [240] [277] [480]** <Insert number> V.
 - c. Phase: **[Single] [Three]**.
 - d. Hertz: **[60]** <Insert number> Hz.
 6. Unit Electrical Characteristics:

- a. Full-Load Amperes: **<Insert value>**.
- b. Minimum Circuit Ampacity: **<Insert value>**.
- c. Maximum Overcurrent Protection: **<Insert amperage>**.
- d. Interrupting Capacity: **<Insert amperage>**.

2.5 [BAG] [CARTRIDGE]-TYPE FILTERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Cycron Corporation](#).
2. [Eden Equipment Company](#).
3. [Filter Specialists, Inc.](#)
4. [Filtration Systems; a division of Mechanical Mfg. Corporation](#).
5. [Hayward Flow Control Systems, Inc.](#)
6. [Parker Hannifin Corp.; Process Filtration Div.](#)
7. [Pentair, Inc.](#)
8. [PEP Filters, Inc.](#)
9. [RainSoft; a division of Aquion Water Treatment Products](#).
10. [Rosedale Products, Inc.](#)
11. [RPA Process Technologies](#).
12. [Shelco Filters](#).
13. [Siemens Water Technologies](#).
14. **<Insert manufacturer's name>**.
15. or approved equal.

- B. Description: Floor-mounting housing with filter [**bags**] [**cartridges**] for removing particles from water.

1. Housing: Corrosion resistant; designed to separate inlet from outlet and to direct inlet through [**bag**] [**cartridge**]-type water filter; with [**bag support and**] base, feet, or skirt.
 - a. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 - b. Steel Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
 - c. Plastic Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: **150-psig (1035-kPa)** plastic flanges.

2. [**Bag**] [**Cartridge**]: Replaceable; of shape to fit housing.

- C. Capacities and Characteristics:

1. Filter Design:
 - a. Water Flow Rate: **<Insert gpm (L/s)>**.
 - b. Filtration Efficiency: [**98**] **<Insert number>** percent.

- c. Particle Size: **[10] [20]** <Insert number> microns and larger.
 - d. Clean Pressure Loss: **[2 psig (14 kPa)]** <Insert value>.
 - e. Pressure Loss at Replacement: **[6 psig (41 kPa)]** <Insert value>.
2. Housing:
- a. Material: **[Carbon steel] [Plastic]**.
 - b. Pressure Rating: <Insertpsig (kPa)>.
 - c. Seal Material: **[Nitrile rubber]** <Insert material>.
 - d. Diameter: <Insert inches (mm)>.
 - e. Height or Length: <Insert inches (mm)>.
 - f. Inlet and Outlet Size: <Insert NPS (DN)>.
 - g. Drain Size: **[Not applicable]** <Insert NPS (DN)>.
 - h. Bag Support Basket Material: **[Stainless steel]** <Insert material>.
3. **[Bag] [Cartridge]**:
- a. Number Required: <Insert number>.
 - b. Nominal Diameter: <Insert inches (mm)>.
 - c. Nominal Length: <Insert inches (mm)>.
 - d. Media Material: **[Cotton] [Polyester] [Polypropylene]** <Insert material>.

2.6 CENTRIFUGAL SEPARATORS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Culligan International Company](#).
 2. [Ecodyne Industrial](#).
 3. [Griswold Controls](#).
 4. [LAKOS; Claude Laval Corporation](#).
 5. [PEP Filters, Inc.](#)
 6. [Puroflux Corporation](#).
 7. [Rosedale Products, Inc.](#)
 8. [Siemens Water Technologies](#).
 9. <Insert manufacturer's name>.
 10. or approved equal.
- B. Description: Simplex separator housing with baffles and chambers for removing particles from water by centrifugal action and gravity.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Housing: With manufacturer's proprietary system of baffles and chambers.
1. Construction: Fabricate and label steel separator housing to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

2. Inlet: Designed with tangential entry to produce centrifugal flow of feedwater.
 3. Vortex Chamber: Designed for downward vortex flow and gravity separation of particles.
 4. Collection Chamber: Designed to hold separated particles.
 5. Outlet: Near top of unit.
 6. Purge: At bottom of collection chamber.
 7. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded according to ASME B1.20.1.
 8. Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if tank is stainless steel.
- E. Motorized Purge Valve: Gate or plug pattern valve.
1. Motorized Valves: Butterfly-type, flanged or grooved-end, ductile-iron body, with **[EPDM] <Insert material>** valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
- F. Strainer: Stainless-steel basket type mounted on pump suction.
- G. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
- H. Piping: **ASTM B 88, Type L (ASTM B 88M, Type B)** copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
- I. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
1. Casing: Radially split, cast iron.
 2. Pressure Rating: **[125 psig (860 kPa)] [150 psig (1035 kPa)]** minimum.
 3. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 4. Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
 5. Seal: Mechanical.
 6. Motor: Open, dripproof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- J. Controls: Automatic control of circulating pump and separator purge; factory wired for single electrical connection.
1. Panel: NEMA 250, **[Type 4] <Insert type>** enclosure.
 2. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
 3. Separator Purge: Automatic and manual.
 4. TSS Controller Interlock: Open separator purge valve with bleed-off control.

K. Support: Skid mounting.[**Fabricate supports and base and attachment to separator housing with reinforcement strong enough to resist separator movement during a seismic event when separator base is anchored to building structure.**]

L. Capacities and Characteristics:

1. Separator Design:

- a. Water Flow Rate: <Insert gpm (L/s)>.
- b. Pressure Loss: [5 psig (34.5 kPa)] <Insert value>.
- c. Separator Efficiency: [98] <Insert number> percent.
- d. Particle-Specific Gravity: [1.8] <Insert number>.
- e. Particle Size: [5] [10] [20] [45] <Insert number> microns.

2. Housing:

- a. Material: [Steel] [Stainless steel] [Plastic] [Fiberglass] <Insert material>.
- b. Pressure Rating: <Insert psig (kPa)>.
- c. Diameter: <Insert inches (mm)>.
- d. Height: <Insert inches (mm)>.
- e. Inlet and Outlet Size: <Insert NPS (DN)>.
- f. Purge Size: <Insert NPS (DN)>.

3. Circulating Pump:

- a. Capacity: <Insert gpm (L/s)>.
- b. Total Dynamic Head: <Insert feet (kPa)>.
- c. Motor Speed: <Insert number> rpm.
- d. Inlet Size: <Insert NPS (DN)>.
- e. Outlet Size: <Insert NPS (DN)>.

4. Pump Motor Size and Electrical Characteristics:

- a. Horsepower: <Insert value>.
- b. Volts: [120] [208] [240] [277] [480] <Insert number> V.
- c. Phase: [Single] [Three].
- d. Hertz: [60] <Insert number> Hz.
- e. Full-Load Amperes: <Insert value>.
- f. Minimum Circuit Ampacity: <Insert value>.
- g. Maximum Overcurrent Protection: <Insert amperage>.
- h. Interrupting Capacity: <Insert amperage>.

2.7 WATER-SOFTENER CHEMICALS

A. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum 30,000 grains/cu. ft. (69 kg/cu. m) of calcium carbonate of resin when regenerated with 15 lb (6.8 kg) of salt.

- B. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are unacceptable.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Systems shall be operational, filled, started, and vented prior to cleaning. Use water meter to record capacity in each system.
- B. Place terminal control valves in open position during cleaning.
- C. Verify that electric power is available and of the correct characteristics.

3.2 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

- A. Equipment Mounting:
 1. Install [**water-softener**] [**water filtration**] equipment on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

3.4 WATER-SOFTENER INSTALLATION

- A. Install water-softener equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.
- C. Prepare mineral-tank distribution system and underbed for minerals and place specified mineral into mineral tanks.
- D. Install water-testing sets on wall adjacent to water softeners.

3.5 RO UNIT INSTALLATION

- A. Install RO unit and storage tank on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor RO unit and storage tank with pumps to substrate.
- B. Install interconnecting piping and controls furnished by equipment manufacturer but not factory installed.
- C. Install water-testing sets on wall adjacent to RO unit.

3.6 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance.
- C. Make piping connections between HVAC [**water-softener**] [**water filtration**] equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 232113 "Hydronic Piping."
- D. Install shutoff valves on HVAC [**water-softener**] [**water filtration**] equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- E. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.
- F. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- G. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing.
3. Place HVAC [**water-softener**] [**water filtration**] system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Cap and subject piping to static water pressure of 50 psig (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
8. Repair leaks and defects with new materials and retest piping until no leaks exist.

C. Equipment will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

3.8 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 232533

SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Double-wall rectangular ducts and fittings.
3. Single-wall round[**and flat-oval**] ducts and fittings.
4. Double-wall round[**and flat-oval**] ducts and fittings.
5. Sheet metal materials.
6. Duct liner.
7. Sealants and gaskets.
8. Hangers and supports.
9. Seismic-restraint devices.

B. Related Sections:

1. Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Section 233116 "Nonmetal Ducts" for fibrous-glass ducts, thermoset fiber-reinforced plastic ducts, thermoplastic ducts, PVC ducts, and concrete ducts.
3. Section 233119 "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
4. Section 233300 "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Duct Sizes: Inside clear dimensions. For lined ducts, maintain clear sizes inside lining.
- B. Low Pressure: 2 inch WG positive or negative static pressure and velocities less than 2,500 fpm.

- C. Medium Pressure: Three pressure classifications, as follows:
 - 1. 3 inch WG positive or negative static pressure and velocities less than 4,000 fpm.
 - 2. 4 inch WG positive static pressure and velocities greater than 2,000 fpm. 6 inch WG positive static pressure and velocities greater than 2,000 fpm.
- D. High Pressure: 10 inch WG positive static pressure and velocities greater than 2,000 fpm.

1.4 PERFORMANCE REQUIREMENTS

- A. No variation of duct configuration or sizes permitted except by written permission of the DEN Mechanical Engineer. Size round ducts installed in place of rectangular ducts in accordance with SMACNA **[and] [or]** ASHRAE table of equivalent rectangular and round ducts.
- B. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.
- C. Structural Performance: Duct hangers and supports **[and seismic restraints]** shall withstand the effects of gravity **[and seismic]** loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" **[and] [ASCE/SEI 7.] [SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."]** <Insert document.>
 - 1. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
 - 2. Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
 - 3. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.
- D. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.5 ACTION SUBMITTALS

- A. Product Data: Indicate duct fittings, particulars such as gages, sizes, welds, and configuration for **[duct materials] [duct liner] [duct connectors]** <Insert product>. For each type of the following products:
 - 1. Liners and adhesives.
 - 2. Sealants and gaskets.
 - 3. Seismic-restraint devices.
 - 4. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

2. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
4. Duct-Cleaning Test Report for Prerequisite IEQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-up."
5. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
6. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Factory- and shop-fabricated ducts and fittings.
3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top of ducts.
5. Dimensions of main duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment[, **seismic restraints,**] and vibration isolation.
13. **<Insert lists of areas or systems requiring Shop Drawings.>**

D. Delegated-Design Submittal:

1. Sheet metal thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports.
5. Design Calculations: Calculations[, **including analysis data signed and sealed by the qualified professional engineer responsible for their preparation**] for selecting hangers and supports[**and seismic restraints**].

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
 2. Suspended ceiling components.
 3. Structural members to which duct will be attached.
 4. Size and location of initial access modules for acoustical tile.
 5. Other systems installed in same space as ducts.
 6. Ceiling- and wall-mounting access doors and panels required to provide access to dampers and other operating devices.
 7. Ceiling-mounting items, including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
 8. Penetrations of smoke barriers and fire-rated construction.
 9. Items penetrating finished ceiling including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. Perimeter moldings.
 - g. **<Insert item>**.
- B. Welding certificates.
- C. Field quality-control reports. Indicate pressure tests performed. Include date, section tested, test pressure, and leakage rate, following SMACNA HVAC Air Duct Leakage Test Manual.

1.7 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
1. Record actual locations of ducts and duct fittings. Record changes in fitting location and type. Show additional fittings used.

1.8 QUALITY ASSURANCE

- A. Perform Work in accordance with SMACNA - HVAC Duct Construction Standards - Metal and Flexible.
- B. Maintain one copy of document on site for reference by Contractor's personnel.

- C. Welding Qualifications: Qualify procedures and personnel according to [AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.] [AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.] [AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.]
- D. Welding Qualifications: Qualify procedures and personnel according to the following:
1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
 2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
 3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.
- E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."
- F. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
- G. Construct ductwork to [NFPA 90A] [and] [NFPA 90B] [and] [NFPA 96] standards.
- H. Mockups:
1. Before installing duct systems, build mockups representing static-pressure classes in excess of [3-inch wg (750 Pa)] <Insert static-pressure class>. Build mockups to comply with the following requirements, using materials indicated for the completed Work:
 - a. [Five] <Insert number> transverse joints.
 - b. [One] <Insert number> access door(s).
 - c. [Two] <Insert number> typical branch connections, each with at least one elbow.
 - d. [Two] <Insert number> typical flexible duct or flexible-connector connections for each duct and apparatus.
 - e. [One] <Insert number> 90-degree turn(s) with turning vanes.
 - f. [One] <Insert number> fire damper(s).
 - g. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.
 2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
- 1.9 DELIVERY, STORAGE, AND HANDLING
- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1 requirements.
- B. Store all materials in location protected from water, wind, construction activities, and any other potential damage hazard.

- C. Protect <Insert item> from <Insert item> by <Insert requirement>.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. General: Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 DUCTWORK FABRICATION

- A. Fabricate and support in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible, and as indicated. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated, but not less than 1" WG positive and negative pressures.
- B. Construct T's, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows are used, provide [air foil] turning vanes. Where acoustical lining is indicated, provide turning vanes of perforated metal with glass fiber insulation.
- C. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.
- D. Fabricate continuously welded round and oval duct fittings two gages heavier than duct gages indicated in SMACNA Duct Construction Standards. Joints shall be minimum 4 inch cemented slip joint, brazed or electric welded. Prime coat welded joints.
- E. Provide standard 45 degree lateral wye takeoffs.
- F. 90 degree conical tee connections (spin-in fittings) may only be used downstream of a VAV terminal.

2.3 MANUFACTURED DUCTWORK AND FITTINGS

- A. Manufacture in accordance with SMACNA HVAC Duct Construction Standards -Metal

and Flexible, and as indicated. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated.

- B. SMANCA Type 1 offset transitions shall not be allowed without written approval from DEN Project Manager or DEN Mechanical Inspector.
- C. Flat Oval Ducts: Machine made from round spiral lockseam duct with light reinforcing corrugations; fittings manufactured of at least two gages heavier metal than duct.
- D. Double Wall Insulated Flat Oval Ducts: Machine made from round spiral lockseam duct with light reinforcing corrugations, galvanized steel outer wall, 1 inch thick fiberglass insulation, perforated galvanized steel inner wall; fittings manufactured with solid inner wall.
- E. PVC Coated Steel Ducts: UL 181, Class 1, galvanized steel duct coated with polyvinyl chloride plastic, 4 mil thick on **[outside and 2 mil thick on inside.] [both sides.]**
- F. Slab Duct Ventilation System: ASTM A 527 galvanized steel, corrugated, in standard sizes with support brackets, connecting couplings, elbows, end caps, spin-in-collar, wall discharge head, and soffit discharge head; designed for installation in cast-in-place concrete floor assemblies.
- G. Double Wall Insulated Round Ducts: Round spiral lockseam duct with galvanized steel outer wall, 1 inch thick fiberglass insulation, **[perforated]** galvanized steel inner wall; fitting with solid inner wall.
- H. Transverse Duct Connection System: **[SMACNA "E" rated] [SMACNA "F" rated] [or] [SMACNA "J" rated]** rigidly class connection, interlocking angle and duct edge connection system with sealant, gasket, cleats, and corner clips.

2.4 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
- B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction

Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.5 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [McGill AirFlow LLC.](#)
 2. [Sheet Metal Connectors, Inc.](#)
 3. **<Insert manufacturer's name>.**
 4. or approved equal.
- B. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.
- C. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
- D. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- E. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- F. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Maximum Thermal Conductivity: [0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)] **<Insert conductivity>** at 75 deg F (24 deg C) mean temperature.
 2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
 3. Coat insulation with antimicrobial coating.
 4. Cover insulation with polyester film complying with UL 181, Class 1.
- G. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.
1. Maximum Thermal Conductivity: [0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)] **<Insert conductivity>** at 75 deg F (24 deg C) mean temperature.

- H. Inner Duct: Minimum **0.028-inch (0.7-mm) [perforated galvanized sheet steel having 3/32-inch- (2.4-mm-) diameter perforations, with overall open area of 23 percent] [solid sheet steel]**.
- I. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- J. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.6 SINGLE-WALL ROUND[**AND FLAT-OVAL**] DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.
 - 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Lindab Inc.](#)
 - b. [McGill AirFlow LLC.](#)
 - c. [SEMCO Incorporated.](#)
 - d. [Sheet Metal Connectors, Inc.](#)
 - e. [Spiral Manufacturing Co., Inc.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
- B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).
- C. Flexible Ducts:
 - 1. Medium- or High-Pressure Duct System Applications: UL Class 1, rated for 10 inches WG positive and negative pressure and 4000 fpm air velocity, constructed as interlocking spiral of galvanized steel or aluminum. **[Insulation to be 1-inch thick fiberglass, maximum K-value of 0.23 at 75 degrees F, covered with fire-retardant [polyethylene] [aluminized] vapor barrier jacket.]**
- D. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Transverse Joints in Ducts Larger Than [60 Inches (1524 mm)] <Insert dimension> in Diameter: Flanged.
- E. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
1. Fabricate round ducts larger than 90 inches (2286 mm) in diameter with butt-welded longitudinal seams.
 2. Fabricate flat-oval ducts larger than 72 inches (1830 mm) in width (major dimension) with butt-welded longitudinal seams.
- F. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- 2.7 DOUBLE-WALL ROUND[AND FLAT-OVAL] DUCTS AND FITTINGS
- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Lindab Inc.
 2. McGill AirFlow LLC.
 3. SEMCO Incorporated.
 4. Sheet Metal Connectors, Inc.
 5. <Insert manufacturer's name>.
 6. or approved equal.
- B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.
- C. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.
1. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - a. Transverse Joints in Ducts Larger Than [60 Inches (1524 mm)] <Insert dimension> in Diameter: Flanged.

2. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - a. Fabricate round ducts larger than **90 inches (2286 mm)** in diameter with butt-welded longitudinal seams.
 - b. Fabricate flat-oval ducts larger than **72 inches (1830 mm)** in width (major dimension) with butt-welded longitudinal seams.
 3. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- D. Inner Duct: Minimum **0.028-inch (0.7-mm)** [**perforated galvanized sheet steel having 3/32-inch- (2.4-mm-) diameter perforations, with overall open area of 23 percent**] [**solid sheet steel**].
- E. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Maximum Thermal Conductivity: [**0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)**] **<Insert conductivity>** at **75 deg F (24 deg C)** mean temperature.
 2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
 3. Coat insulation with antimicrobial coating.
 4. Cover insulation with polyester film complying with UL 181, Class 1.
- F. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.
1. Maximum Thermal Conductivity: [**0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)**] **<Insert conductivity>** at **75 deg F (24 deg C)** mean temperature.
- ## 2.8 SHEET METAL MATERIALS
- A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
1. Galvanized Coating Designation: [**G60 (Z180)**] [**G90 (Z275)**].

2. Finishes for Surfaces Exposed to View: Mill phosphatized.
- C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
1. Galvanized Coating Designation: [G60 (Z180)] [G90 (Z275)].
 2. Minimum Thickness for Factory-Applied PVC Coating: **4 mils (0.10 mm) thick[on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil (0.025 mm) thick on opposite surface].**
 3. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.
- D. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.
- E. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.
- F. Aluminum Sheets: Comply with **ASTM B 209 (ASTM B 209M)** Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.
- G. PVC-Coated Galvanized Steel: Acceptable by authorities having jurisdiction for use in fabricating ducts with UL 181, Class 1 listing. Lock-forming-quality, galvanized sheet steel complying with ASTM A653/A653M and having [G60] [G90] coating designation. Factory-applied PVC coatings shall be 4 mils thick on sheet metal surfaces of ducts and fittings exposed to corrosive conditions and 2 mils thick on opposite surfaces.
- H. Coating For Buried Ducts: Asphalt base or PVC coating.
- I. Factory- or Shop-Applied Antimicrobial Coating:
1. Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.
 2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
 3. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested according to ASTM D 3363.
 4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
 5. Shop-Applied Coating Color: **[Black] [White].**
 6. Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.
- J. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

K. Tie Rods: Galvanized steel, **1/4-inch (6-mm)** minimum diameter for lengths **36 inches (900 mm)** or less; **3/8-inch (10-mm)** minimum diameter for lengths longer than **36 inches (900 mm)**.

2.9 DUCT LINER

A. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [CertainTeed Corporation.](#)
- b. [Johns Manville; a Berkshire Hathaway company.](#)
- c. [Knauf Insulation.](#)
- d. [Owens Corning.](#)
- e. **<Insert manufacturer's name>**.
- f. or approved equal.
- g. Maximum Thermal Conductivity:

- 1) Type I, Flexible: [**0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)**] **<Insert conductivity>** at **75 deg F (24 deg C)** mean temperature.
- 2) Type II, Rigid: [**0.23 Btu x in./h x sq. ft. x deg F (0.033 W/m x K)**] **<Insert conductivity>** at **75 deg F (24 deg C)** mean temperature.

2. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.

3. **[Solvent] [Water]-Based Liner Adhesive:** Comply with NFPA 90A or NFPA 90B and with ASTM C 916.

- a. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Aeroflex USA Inc.](#)
 - b. [Armacell LLC.](#)
 - c. [Rubatex International, LLC](#)
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
 3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
 - a. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Insulation Pins and Washers:
1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [0.106-inch- (2.6-mm-)] [0.135-inch- (3.5-mm-)] diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.
 2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick [galvanized steel] [aluminum] [stainless steel]; with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.
- D. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."
1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
 2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
 3. Butt transverse joints without gaps, and coat joint with adhesive.
 4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
 5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
 6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm (12.7 m/s).
 7. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.

8. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:
 - a. Fan discharges.
 - b. Intervals of lined duct preceding unlined duct.
 - c. Upstream edges of transverse joints in ducts where air velocities are higher than **2500 fpm** (12.7 m/s) or where indicated.
9. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.
 - a. Sheet Metal Inner Duct Perforations: **3/32-inch** (2.4-mm) diameter, with an overall open area of 23 percent.
10. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.10 BURIED UNDERGROUND METAL DUCTS

- A. Buried ducts may be [**concrete encased sheet metal**] [**PVC jacketed sheet metal**] as indicated. Reference Section 233116 "Nonmetal Ducts" for nonmetal duct types.
- B. Fabricate metal ductwork in accordance with SMACNA Low Pressure Duct Construction Standards, except as indicated. Fabricate using two gages heavier material than indicated for 2 inch WG pressure class.

2.11 KITCHEN HOOD EXHAUST DUCTWORK

- A. Fabricate in accordance with SMACNA Low Pressure Duct Construction Standards, High Pressure Duct Construction Standards, and NFPA 96.
- B. Construct of 0.055-inch-thick carbon steel or 0.044-inch-thick stainless steel (minimum), using continuous externally welded joints.
- C. Grease Duct Supports: Duct bracing and supports shall be of noncombustible material securely attached to the structure and designed to carry gravity and lateral loads within the stress limitations of governing codes. Bolts, screws, rivets and other mechanical fasteners shall not penetrate duct walls. Provide duct clean-out openings as required by NFPA 96.
- D. Reference Section 233813 "Commercial-Kitchen Hoods" for hoods.

2.12 DISHWASHER HOOD DUCTWORK

- A. Fabricate in accordance with SMACNA Low Pressure Duct Construction Standards for [2] [3] inches negative pressure.
- B. Construct ductwork of type 304 stainless steel, 18 gage, with continuous externally welded joints and perimeter reinforcing.
- C. Slope duct runs at 0.125 inches per foot to low points, provide 1-1/2 inch diameter drain discharging, through trap, to floor drain or service sink.

2.13 SEALANT AND GASKETS

- A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
- B. Two-Part Tape Sealing System:
 - 1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
 - 2. Tape Width: [3 inches (76 mm)] [4 inches (102 mm)] [6 inches (152 mm)].
 - 3. Sealant: Modified styrene acrylic.
 - 4. Water resistant.
 - 5. Mold and mildew resistant.
 - 6. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
 - 7. Service: Indoor and outdoor.
 - 8. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).
 - 9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.
 - 10. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 11. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Water-Based Joint and Seam Sealant:
 - 1. Application Method: Brush on.
 - 2. Solids Content: Minimum 65 percent.
 - 3. Shore A Hardness: Minimum 20.
 - 4. Water resistant.
 - 5. Mold and mildew resistant.
 - 6. VOC: Maximum 75 g/L (less water).
 - 7. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
 - 8. Service: Indoor or outdoor.

9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.
8. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
9. VOC: Maximum 395 g/L.
10. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
11. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
12. Service: Indoor or outdoor.
13. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

E. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

F. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

G. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg (0.14 L/s per sq. m at 250 Pa) and shall be rated for 10-inch wg (2500-Pa) static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.14 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," [Table 5-1 \(Table 5-1M\)](#), "Rectangular Duct Hangers Minimum Size," and [Table 5-2](#), "Minimum Hanger Sizes for Round Duct."
- D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.
- E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.
- F. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- H. Trapeze and Riser Supports:
 - 1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
 - 2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
 - 3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

2.15 SEISMIC-RESTRAINT DEVICES

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Cooper B-Line, Inc.; a division of Cooper Industries.](#)
 - 2. [Ductmate Industries, Inc.](#)
 - 3. [Hilti Inc.](#)
 - 4. [Kinetics Noise Control, Inc.](#)
 - 5. [Loos & Co., Inc.](#)
 - 6. [Mason Industries, Inc.](#)
 - 7. [TOLCO.](#)
 - 8. [Unistrut; an Atkore International company.](#)
 - 9. **<Insert manufacturer's name>.**
 - 10. or approved equal.
- B. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by **[an evaluation service member of the ICC Evaluation Service] [the Office of Statewide Health Planning and**

Development for the State of California] [an agency acceptable to authorities having jurisdiction].

1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least **[four]** <Insert number> times the maximum seismic forces to which they will be subjected.
- C. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.
- D. Restraint Cables: **[ASTM A 603, galvanized]** **[ASTM A 492, stainless]**-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.
- E. Hanger Rod Stiffener: **[Steel tube or steel slotted-support-system sleeve with internally bolted connections]** **[Reinforcing steel angle clamped]** to hanger rod.
- F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.
- B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- C. Provide openings in ductwork where required to accommodate thermometers and controllers. Provide pilot tube openings where required for testing of systems, complete with metal can with spring device or screw to ensure against air leakage. Where openings are provided in insulated ductwork, install insulation material inside a metal ring.
- D. Install in accordance with manufacturer's instructions.
- E. Install round[**and flat-oval**] ducts in lengths not less than 12 feet unless interrupted by fittings, and in maximum practical lengths.
- F. Install ducts with fewest possible joints.

- G. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
- H. Install couplings tight to duct wall surface with a minimum of projections into duct. Secure couplings with sheet metal screws. Install screws at intervals of 12 inches, with a minimum of 3 screws in each coupling.
- I. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines. Avoid diagonal runs.
- J. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- K. Install ducts with a clearance of 1 inch (25 mm), plus allowance for insulation thickness.
- L. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.
- M. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities.
- N. Use crimp joints with or without bead for joining round duct sizes 8 inch and smaller with crimp in direction of airflow.
- O. Use double nuts and lock washers on threaded rod supports.
- P. Cloth backed duct tape shall not be used.
- Q. Connect terminal units to supply ducts [directly or] with one foot maximum length of flexible duct. Do not use flexible duct to change direction.
- R. Connect diffusers or light troffer boots to low pressure ducts [**directly or**] with 5 feet maximum length of flexible duct held in place with strap or clamp.
- S. Connect flexible ducts to metal ducts with adhesive and draw bands plus sheet metal screws. Secure with not less than 3 sheet metal screws per joint.
- T. Set plenum doors 6 to 12 inches above floor. Arrange door swings so that fan static pressure holds door in closed position.
- U. Provide residue traps in kitchen hood exhaust ducts at base of vertical risers with provisions for clean out. Use stainless steel for ductwork exposed to view and stainless steel or carbon steel for ducts where concealed.
- V. During construction, provide temporary closures of metal or taped polyethylene on open ductwork to prevent construction dust from entering ductwork system at the end of each work shift. Protect duct interiors from the elements and foreign materials until building is enclosed. [**Follow SMACNA's "Duct Cleanliness for New Construction."**]

- W. Conceal ducts from view in finished spaces. Do not encase horizontal runs in solid partitions unless specifically indicated.
- X. Coordinate layout with suspended ceiling, fire- and smoke-control dampers, lighting layouts, and similar finished work.
- Y. Seal all joints and seams. Apply sealant to male end connectors before insertion, and afterward to cover entire joint and sheet metal screws.
- Z. Electrical Equipment Spaces: Route ducts to avoid passing through transformer vaults and electrical equipment spaces and enclosures.
- AA. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches (38 mm).
- BB. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers, sleeves, and firestopping sealant. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers.
- CC. Protect duct interiors from moisture, construction debris and dust, and other foreign materials.[**Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."**]
- DD. Painting Interiors of Metal Ducts:
 - 1. Paint interiors of metal ducts that do not have duct liner, for 24 inches upstream of registers and grilles. Apply one coat of flat, black, latex finish coat over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 9.

3.2 INSTALLATION OF EXPOSED DUCTWORK

- A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.
- B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.
- C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.
- D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.
- E. Repair or replace damaged sections and finished work that does not comply with these requirements.

- 3.3 ADDITIONAL INSTALLATION REQUIREMENTS FOR COMMERCIAL KITCHEN HOOD EXHAUST DUCT
- A. Install commercial kitchen hood exhaust ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.
 - B. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of [20 feet (6 m)] [12 feet (3.7 m)] <Insert dimension> in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings.
 - C. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.
 - D. Install ducts to allow for thermal expansion through 2000 degree temperature range.
 - E. Install ducts without dips or traps that may collect residues unless traps have continuous or automatic residue removal.
 - F. Install access openings at each change in direction and at intervals defined by NFPA 96; locate on sides of duct a minimum of 1-1/2 inches from bottom; and fit with grease-tight covers of same material as duct.
- 3.4 UNDERSLAB DUCTS, SPECIAL INSTALLATION REQUIREMENTS
- A. Verify undamaged condition of ducts before enclosure with fill or encasement.
 - B. Protect ducts from damage by equipment used in placing fill materials and concrete on or around ducts.
 - C. Protect duct openings from damage and prevent entrance of foreign materials.
 - D. Slope underground ducts to plenums or low pump out points at 1:500. Provide access doors for inspection.
 - E. Paint buried metal ductwork without factory jacket with one coat [**and seams and joints with additional coat**] of asphalt base protective coating.
 - F. Encase buried metal ductwork in 3 inch minimum of concrete. Provide adequate tie-down points to prevent ducts from floating during concrete placement. Introduce no heat into ducts for 20 days following placement of concrete.
 - G. Insulate buried supply duct runs over 70 feet long with one inch thick insulation covered with plastic vapor barrier.
- 3.5 PVC-COATED DUCT, SPECIAL INSTALLATION REQUIREMENTS
- A. Repair damage to PVC coating with manufacturer's recommended materials.
 - B. Tape joints of PVC coated metal ductwork with PVC tape.

3.6 DUCT LINER INSTALLATION REQUIREMENTS

- A. Install duct liner according to manufacturer's written instructions; with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.
- B. Keep liner materials dry during application and finishing.
- C. Apply liner with black coated surface facing the airstream.
- D. Adhere liner to sheet metal with a minimum 90% coverage of adhesive; provide mechanical fasteners spaced per manufacturer's requirements.
- E. Install metal nosing on leading edge of duct liner where duct liner is preceded by unlined metal, and at all upstream edges where velocity exceeds 2000 fpm.
- F. Install liner with longitudinal seams at corner joints only.
- G. Provide edge coating for all transverse joints, all cut in connections and branch connections that are not lined.
- H. Install duct liner in the following locations, and as indicated on the Drawings:
 - 1. Return air ducts.
 - 2. Outside air ducts.
 - 3. Transfer air ducts.
 - 4. Supply air ducts downstream of VAV boxes.

3.7 DUCT SEALING

- A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. For pressure classes lower than 2-inch wg, seal transverse joints.
- B. Seal ducts before external insulation is applied.
- C. Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":
 - 1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 2. Outdoor, Supply-Air Ducts: Seal Class A.
 - 3. Outdoor, Exhaust Ducts: Seal Class C.
 - 4. Outdoor, Return-Air Ducts: Seal Class C.
 - 5. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg (500 Pa) and Lower: Seal Class B.
 - 6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg (500 Pa): Seal Class A.
 - 7. Unconditioned Space, Exhaust Ducts: Seal Class C.

8. Unconditioned Space, Return-Air Ducts: Seal Class B.
9. Conditioned Space, Supply-Air Ducts in Pressure Classes **2-Inch wg (500 Pa)** and Lower: Seal Class C.
10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than **2-Inch wg (500 Pa)**: Seal Class B.
11. Conditioned Space, Exhaust Ducts: Seal Class B.
12. Conditioned Space, Return-Air Ducts: Seal Class C.

3.8 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 1. Where practical, install concrete inserts before placing concrete.
 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than **4 inches (100 mm)** thick.
 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than **4 inches (100 mm)** thick.
 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," **Table 5-1 (Table 5-1M)**, "Rectangular Duct Hangers Minimum Size," and **Table 5-2**, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within **24 inches (610 mm)** of each elbow and within **48 inches (1200 mm)** of each branch intersection.
- D. Hangers Exposed to View: Threaded rod and angle or channel supports.
- E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of **16 feet (5 m)**.
- F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
- G. Support horizontal ducts within 24 inches of each elbow and within 48 inches of each branch intersection.
- H. Provide a support with 12 inches of the end of a duct run, not including flexible duct.
- I. Support vertical ducts at maximum intervals of 16 feet and at each floor.

- J. Install upper attachments to structures with an allowable load not exceeding one-fourth of failure (proof-test) load.
- K. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
- L. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

3.9 SEISMIC-RESTRAINT-DEVICE INSTALLATION

- A. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."**] [**ASCE/SEI 7.**]
 - 1. Space lateral supports a maximum of [**40 feet (12 m)**] **<Insert dimension>** o.c., and longitudinal supports a maximum of [**80 feet (24 m)**] **<Insert dimension>** o.c.
 - 2. Brace a change of direction longer than **12 feet (3.7 m)**.
- B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install cable restraints on ducts that are suspended with vibration isolators.
- E. Install seismic-restraint devices using methods approved by [**an evaluation service member of the ICC Evaluation Service**] [**the Office of Statewide Health Planning and Development for the State of California**] [**an agency acceptable to authorities having jurisdiction**].
- F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.
- G. Drilling for and Setting Anchors:
 - 1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 - 2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 - 3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
 - 4. Set anchors to manufacturer's recommended torque, using a torque wrench.

5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.10 CONNECTIONS

- A. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.11 PAINTING

- A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

3.12 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Leakage Tests:
 1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
 2. For high pressure ductwork, after system is completed, test for duct leakage in accordance with SMACNA "High Pressure Duct Standards - 3rd Edition, Chapter 10 - Testing for Leakage." Repair leaks and repeat tests until total leakage is less than 1% of system design air flow.
 3. Test the following systems:
 - a. Ducts with a Pressure Class Higher Than **3-Inch wg (750 Pa)**: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than 25 percent of total installed duct area for each designated pressure class.
 - b. Supply Ducts with a Pressure Class of **[2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value>** or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than **[50] [100] <Insert value>** percent of total installed duct area for each designated pressure class.
 - c. Return Ducts with a Pressure Class of **[2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value>** or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than **[50] [100] <Insert value>** percent of total installed duct area for each designated pressure class.
 - d. Exhaust Ducts with a Pressure Class of **[2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value>** or Higher: Test representative

- duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
- e. Outdoor Air Ducts with a Pressure Class of [2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
4. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
 5. Test for leaks before applying external insulation.
 6. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
 7. Give [seven] <Insert number> days' advance notice for testing.
- C. Duct System Cleanliness Tests:
1. Visually inspect duct system to ensure that no visible contaminants are present.
 2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
 - a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.
- D. Duct system will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.
- 3.13 DUCT CLEANING
- A. Clean [new] [and] [existing] duct system(s) before testing, adjusting, and balancing.
 - B. Clean ductwork internally, unit-by-unit as it is installed, of dust and debris. Clean external surfaces of foreign substances, which might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.
 - C. Strip protective paper from stainless ductwork surfaces, and repair finish wherever it has been damaged.
 - D. Temporary Closure: At ends of ducts, which are not connected to equipment or air distribution devices at time of ductwork installation, provide temporary closure of polyethylene film or other covering, which will prevent entrance of dust and debris until time connections are to be completed.
 - E. Mark position of dampers and air-directional mechanical devices before cleaning, and

perform cleaning before air balancing.

F. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 233300 "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

G. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

H. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

I. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.

5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.
8. Cleanliness Verification:
 - a. Visually inspect metal ducts for contaminants.
 - b. Where contaminants are discovered, re-clean, and reinspect ducts.

3.14 CLEANING EXISTING SYSTEMS

- A. Use service openings, as required, for physical and mechanical entry and for inspection.
 1. Use existing service openings where possible.
 2. Create other openings to comply with duct standards.
 3. Disconnect flexible ducts as needed for cleaning and inspection.
 4. Reseal rigid fiberglass duct systems according to NAIMA recommended practices.
 5. Remove and reinstall ceiling sections to gain access during the cleaning process.
- B. Mark position of dampers and air-directional mechanical devices before cleaning, and restore to their marked position on completion.
- C. Particulate Collection and Odor Control:
 1. When venting vacuuming system inside the building, use HEPA filtration with 99.97% collection efficiency for 0.3-micron size (or larger) particles.
 2. When venting vacuuming system to the outside, use filtration to contain debris removed from HVAC system, and locate exhaust down wind and away from air intakes and other points of entry into building.
- D. Clean the following metal duct systems by removing surface contaminants and deposits:
 1. Air outlets and inlets (registers, grilles, and diffusers).
 2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
 3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
 4. Coils and related components.
 5. Return-air ducts, dampers, and actuators except in ceiling plenums and mechanical equipment rooms.

6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide operative drainage system for washdown procedures.
7. Biocidal Agents and Coatings: Apply biocidal agents if fungus is present. Apply biocidal agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Cleanliness Verification:

1. Verify cleanliness after mechanical cleaning and before application of treatment, including biocidal agents and protective coatings.
2. Visually inspect metal ducts for contaminants.
3. Where contaminants are discovered, re-clean and reinspect ducts.

G. Verification of Coil Cleaning: Cleaning must restore coil pressure drop to within 10% of pressure drop measured when coil was first installed. If original pressure drop is not known, coil will be considered clean only if it is free of foreign matter and chemical residue, based on thorough visual inspection.

3.15 FINAL CLEANING

- A. Clean duct system and force air at high velocity through duct to remove accumulated dust. To obtain sufficient air, clean half the system at a time. Protect equipment, which may be harmed by excessive dirt with temporary filters, or bypass during cleaning.
- B. Clean duct systems with high power vacuum machines. Protect equipment, which may be harmed by excessive dirt with filters, or bypass during cleaning. Provide adequate access into ductwork for cleaning purposes.

3.16 START UP

- A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.17 DUCTWORK APPLICATION SCHEDULE - GENERAL

- A. The following Table indicates general ductwork materials for specific air systems. Reference Section 233116 "Nonmetal Ducts" for nonmetal duct type applications.

Air System:	Ductwork Material:
Low Pressure Heating Supply	Galvanized Steel, Aluminum
Low Pressure Supply (System w/Cooling Coils)	Galvanized Steel, Aluminum
Buried Supply or Return	Galvanized Steel
Medium and High Pressure Supply	Galvanized Steel
Return and Relief	Galvanized Steel, Aluminum
General Exhaust	Galvanized Steel, Aluminum
Kitchen Hood Exhaust	Welded Steel, Stainless Steel
Dishwasher Exhaust	Welded Stainless Steel
Fume Hood Exhaust	Stainless Steel
Outside Air Intake	Galvanized Steel
Combustion Air	Galvanized Steel
Evaporative Condenser	Galvanized Steel Intake and Exhaust
Emergency Generator	Steel Ventilation

3.18 DUCT SCHEDULE

- A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:
- Underground Ducts: Concrete-encased, [galvanized sheet steel] [PVC-coated, galvanized sheet steel with thicker coating on duct exterior] [stainless steel].
 - <Insert requirements>.
- B. Supply Ducts:
- Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:
 - Pressure Class: Positive [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value>.
 - Minimum SMACNA Seal Class: [A] [B] [C].
 - SMACNA Leakage Class for Rectangular: [12] [24] <Insert value>.
 - SMACNA Leakage Class for Round and Flat Oval: [12] [24] <Insert value>.
 - Ducts Connected to Constant-Volume Air-Handling Units <Insert equipment>:
 - Pressure Class: Positive [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - Minimum SMACNA Seal Class: [A] [B].
 - SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.

- d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] <Insert value>.
3. Ducts Connected to Variable-Air-Volume Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] <Insert value>.
 4. Ducts Connected to Equipment Not Listed Above:
 - a. Pressure Class: Positive [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] [12] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] <Insert value>.
- C. Return Ducts:
1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:
 - a. Pressure Class: Positive or negative [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] [C].
 - c. SMACNA Leakage Class for Rectangular: [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [12] [24] <Insert value>.
 2. Ducts Connected to Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] <Insert value>.
 3. Ducts Connected to Equipment Not Listed Above:
 - a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] [12] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] <Insert value>.

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
 - a. Pressure Class: Negative [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] [C] if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] <Insert value>.
2. Ducts Connected to Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] [24] <Insert value>.
3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.
 - a. Exposed to View: Type 304, stainless-steel sheet, [No. 4] [No. 3] <Insert finish> finish.
 - b. Concealed: [Type 304, stainless-steel sheet, No. 2D finish] [Carbon-steel sheet].
 - c. Welded seams and joints.
 - d. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - e. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
 - f. SMACNA Leakage Class: 3.
4. Ducts Connected to Dishwasher Hoods:
 - a. Type 304, stainless-steel sheet.
 - b. Exposed to View: [No. 4] [No. 3] <Insert finish> finish.
 - c. Concealed: [No. 2D] <Insert finish> finish.
 - d. Welded seams and flanged joints with watertight EPDM gaskets.
 - e. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - f. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
 - g. SMACNA Leakage Class: 3.
5. Ducts Connected to Fans Exhausting Laboratory and Process (ASHRAE 62.1, Class 3 and 4) Air:
 - a. [Type 316] [Type 304], stainless-steel sheet.

- 1) Exposed to View: [No. 4] [No. 3] <Insert finish> finish.
 - 2) Concealed: [No. 2B] [No. 2D] <Insert finish> finish.
 - b. PVC-coated, galvanized sheet steel with thicker coating on duct interior.
 - c. Pressure Class: Positive or negative [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] [6-inch wg (1500 Pa)] <Insert value>.
 - d. Minimum SMACNA Seal Class: [A] [Welded seams, joints, and penetrations].
 - e. SMACNA Leakage Class: 3.
6. Ducts Connected to Equipment Not Listed Above:
- a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] [24] <Insert value>.
- E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:
1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:
 - a. Pressure Class: Positive or negative [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] [C].
 - c. SMACNA Leakage Class for Rectangular: [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] <Insert value>.
 2. Ducts Connected to Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] [24] <Insert value>.
 3. Ducts Connected to Equipment Not Listed Above:
 - a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] [12] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] <Insert value>.

F. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: **[Galvanized steel] [Carbon steel coated with zinc-chromate primer] [Galvanized steel or carbon steel coated with zinc-chromate primer]**.
2. PVC-Coated Ducts:
 - a. Exposed to Airstream: Match duct material.
 - b. Not Exposed to Airstream: **[Galvanized] [Match duct material]**.
3. Stainless-Steel Ducts:
 - a. Exposed to Airstream: Match duct material.
 - b. Not Exposed to Airstream: **[Galvanized] [Match duct material]**.
4. Aluminum Ducts: **[Aluminum][or galvanized sheet steel coated with zinc chromate]**.

G. Liner:

1. Supply Air Ducts: **[Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber]**, [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.
2. Return Air Ducts: **[Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber]**, [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.
3. Exhaust Air Ducts: **[Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber]**, [1 inch (25 mm)] <Insert thickness> thick.
4. Supply Fan Plenums: **[Fibrous glass, Type II] [Flexible elastomeric] [Natural fiber]**, [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.
5. Return- and Exhaust-Fan Plenums: **[Fibrous glass, Type II] [Flexible elastomeric] [Natural fiber]**, [2 inches (51 mm)] <Insert thickness> thick.
6. Transfer Ducts: **[Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber]**, [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.

H. Double-Wall Duct Interstitial Insulation:

1. Supply Air Ducts: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.
2. Return Air Ducts: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.
3. Exhaust Air Ducts: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.

I. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

- a. Velocity 1000 fpm (5 m/s) or Lower:
 - 1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
 - 2) Mitered Type RE 4 without vanes.
 - b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s):
 - 1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
 - 2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
 - 3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
 - c. Velocity 1500 fpm (7.6 m/s) or Higher:
 - 1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
 - 2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
 - 3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
 - b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
 - c. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
 3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."
 - a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.
 - 1) Velocity 1000 fpm (5 m/s) or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
 - 2) Velocity 1000 to 1500 fpm (5 to 7.6 m/s): 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
 - 3) Velocity 1500 fpm (7.6 m/s) or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
 - 4) Radius-to Diameter Ratio: 1.5.

- b. Round Elbows, [12 Inches (305 mm)] <Insert dimension> and Smaller in Diameter: Stamped or pleated.
- c. Round Elbows, [14 Inches (356 mm)] <Insert dimension> and Larger in Diameter: [Standing seam] [Welded].

J. Branch Configuration:

- 1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."
 - a. Rectangular Main to Rectangular Branch: 45-degree entry.
 - b. Rectangular Main to Round Branch: Spin in.
- 2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.
 - a. Velocity 1000 fpm (5 m/s) or Lower: 90-degree tap.
 - b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s): Conical tap.
 - c. Velocity 1500 fpm (7.6 m/s) or Higher: 45-degree lateral.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233113

SECTION 233116 - NONMETAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Fibrous-glass ducts and fittings.
2. Phenolic-foam ducts and fittings.
3. Thermoset FRP ducts and fittings.
4. PVC ducts and fittings.

- B. Related Sections:

1. Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for nonmetal ducts.
2. Section 233113 "Metal Ducts" for single- and double-wall, rectangular and round ducts.
3. Section 233119 "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
4. Section 233300 "Air Duct Accessories" for dampers, duct-mounting access doors and panels, turning vanes, and flexible ducts.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Duct Sizes: Inside clear dimensions. For lined ducts, maintain clear sizes inside lining.

- B. Low Pressure: 2 inch WG positive or negative static pressure and velocities less than 2,500 fpm.

- C. Medium Pressure: Three pressure classifications, as follows:

1. 3 inch WG positive or negative static pressure and velocities less than 4,000 fpm.
2. 4 inch WG positive static pressure and velocities greater than 2,000 fpm. 6 inch WG positive static pressure and velocities greater than 2,000 fpm.

- D. High Pressure: 10 inch WG positive static pressure and velocities greater than 2,000 fpm.

1.4 PERFORMANCE REQUIREMENTS

- A. No variation of duct configuration or sizes permitted except by written permission of the DEN Mechanical Engineer. Size round ducts installed in place of rectangular ducts in accordance with SMACNA [and] [or] ASHRAE table of equivalent rectangular and round ducts.
- B. Delegated Duct Design: Duct construction, including duct closure, reinforcements, and hangers and supports, shall comply with SMACNA's "Fibrous Glass Duct Construction Standards" and performance requirements and design criteria indicated.

1. Static-Pressure Classes:

- a. Supply Ducts (except in Mechanical Rooms): [1-inch wg (250 Pa)] <Insert value>.
- b. Supply Ducts (Upstream from Air Terminal Units): [2-inch wg (500 Pa)] <Insert value>.
- c. Supply Ducts (Downstream from Air Terminal Units): [1-inch wg (250 Pa)] <Insert value>.
- d. Supply Ducts (in Mechanical Equipment Rooms): [2-inch wg (500 Pa)] <Insert value>.
- e. Return Ducts (Negative Pressure): [1-inch wg (250 Pa)] <Insert value>.
- f. Exhaust Ducts (Negative Pressure): [1-inch wg (250 Pa)] <Insert value>.
- g. <Insert duct systems and static-pressure class>.

- C. Structural Performance: Duct hangers and supports[and seismic restraints] shall withstand the effects of gravity[and seismic] loads and stresses within limits and under conditions to comply with [ASCE/SEI 7.] [SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."] <Insert document.>

1. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
2. Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
3. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.

- D. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.5 ACTION SUBMITTALS

- A. Product Data: Indicate duct fittings, particulars such as gages, sizes, and configuration for [duct materials] [duct connectors] <Insert product> For each type of the following products:
1. Fibrous-glass duct materials.
 2. Phenolic-foam duct materials.
 3. Thermoset FRP duct materials.

4. PVC duct materials.
5. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
4. Duct-Cleaning Test Report for Prerequisite IEQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-up."
5. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
6. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Duct layout indicating sizes and pressure classes.
3. Elevation of top of ducts.
4. Dimensions of main duct runs from building grid lines.
5. Fittings.
6. Reinforcement and spacing.
7. Seam and joint construction.
8. Penetrations through fire-rated and other partitions.
9. Equipment installation based on equipment being used on Project.
10. Hangers and supports, including methods for duct and building attachment[, **seismic restraints,**] and vibration isolation.

D. Delegated-Design Submittal:

1. Duct materials and thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Design Calculations: Calculations[, **including analysis data signed and sealed by the qualified professional engineer responsible for their preparation**] for selecting hangers and supports[**and seismic restraints**].

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
 2. Suspended ceiling components.
 3. Structural members to which duct will be attached.
 4. Size and location of initial access modules for acoustical tile.
 5. Other systems installed in same space as ducts.
 6. Ceiling- and wall-mounting access doors and panels required to provide access to dampers and other operating devices.
 7. Ceiling-mounting items, including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
 8. Penetrations of smoke barriers and fire-rated construction.
 9. Items penetrating finished ceiling including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. Perimeter moldings.
 - g. <Insert item>.
- B. Welding certificates.
- C. Field quality-control reports. Indicate pressure tests performed. Include date, section tested, test pressure, and leakage rate, following SMACNA HVAC Air Duct Leakage Test Manual.

1.7 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
1. Record actual locations of ducts and duct fittings. Record changes in fitting location and type. Show additional fittings used.

1.8 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to [AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports] [AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports].
- B. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
 2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."
- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
- E. NFPA Compliance:
1. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
 2. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
- F. Mockups:
1. Before installing duct systems, build mockups representing static-pressure classes [3-inch wg (750 Pa)] <Insert static-pressure class> and higher. Build mockups to comply with the following requirements, using materials indicated for the completed Work:
 - a. [Five] <Insert number> transverse joints.
 - b. [One] <Insert number> access door(s).
 - c. [Two] <Insert number> typical branch connections, each with at least one elbow.
 - d. [Two] <Insert number> typical flexible duct or flexible-connector connections for each duct and apparatus.
 - e. [One] <Insert number> 90-degree turn(s) with turning vanes.
 - f. [One] <Insert number> fire damper(s).
 - g. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.
 2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
- 1.9 DELIVERY, STORAGE, AND HANDLING
- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1 requirements.
 - B. Store all materials in location protected from water, wind, construction activities, and any other potential damage hazard.
 - C. Protect <Insert item> from <Insert item> by <Insert requirement>.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. General: Comply with SMACNA "Fibrous Glass Duct Construction Standards" for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated.

2.2 DUCTWORK FABRICATION

- A. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated, but not less than 1" WG positive and negative pressures.
- B. Construct T's, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows are used, provide [air foil] turning vanes. Where acoustical lining is indicated, provide turning vanes of perforated metal with glass fiber insulation.
- C. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.
- D. Fabricate continuously welded round and oval duct fittings two gages heavier than duct gages indicated in SMACNA Duct Construction Standards. Joints shall be minimum 4 inch cemented slip joint, brazed or electric welded. Prime coat welded joints.
- E. Provide standard 45 degree lateral wye takeoffs.
- F. 90 degree conical tee connections (spin-in fittings) may only be used downstream of a VAV terminal.

2.3 MANUFACTURED DUCTWORK AND FITTINGS

- A. Manufacture in accordance with SMACNA "Fibrous Glass Duct Construction Standards," and as indicated. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated.

2.4 FIBROUS-GLASS DUCTS AND FITTINGS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [CertainTeed Corporation; Insulation Group.](#)
 2. [Johns Manville.](#)
 3. [Knauf Insulation.](#)
 4. [Owens Corning.](#)
 5. **<Insert manufacturer's name>.**
 6. or approved equal.
- B. Fibrous-Glass Duct Materials: Resin-bonded fiberglass, faced on the outside surface with fire-resistive FSK vapor retarder and with a smooth fiberglass mat finish on the air-side surface.
1. Duct Board: Factory molded into rectangular boards.
 2. Round Duct: Factory molded into straight round duct and smooth fittings.
 3. Temperature Limits: **40 to 250 deg F** (5 to 121 deg C) inside ducts; **150 deg F** (66 deg C) ambient temperature surrounding ducts.
 4. Maximum Thermal Conductivity: [**0.24 Btu x in./h x sq. ft. x deg F** (0.035 W/m x K)] **<Insert conductivity>** at **75 deg F** (24 deg C) mean temperature.
 5. Moisture Absorption: Not exceeding 5 percent by weight at **120 deg F** (49 deg C) and 95 percent relative humidity for 96 hours when tested according to ASTM C 1104/C 1104M.
 6. Permeability: **0.02 perms** (1.15 ng/Pa x s x sq. m) maximum when tested according to ASTM E 96/E 96M, Procedure A.
 7. Antimicrobial Agent: Compound shall be tested for efficacy by an NRTL, and registered by the EPA for use in HVAC systems.
 8. Noise-Reduction Coefficient: 0.65 minimum when tested according to ASTM C 423, Mounting A.
 9. Required Markings: EI rating, UL label, and other markings required by UL 181 on each full sheet of duct board.
- C. Closure Materials:
1. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-P," the manufacturer's name, and a date code.
 - a. Tape: Aluminum foil-scrim tape imprinted with listing information.
 - b. Minimum Tape Width: **2-1/2 inches** (64 mm); **3 inches** (76 mm) for duct board thicker than **1 inch** (25 mm).
 - c. Staples: **1/2-inch** (13-mm) outward clinching, **2 inches** (51 mm) o.c. in tabs, one tab per joint.
 - d. Water resistant.
 - e. Mold and mildew resistant.
 2. Heat-Activated Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-H," the manufacturer's name, and a date code.

- a. Tape: Aluminum foil-scrim tape imprinted with listing information.
 - b. Minimum Tape Width: **3 inches** (76 mm).
 - c. Heat-Sensitive Imprint: Printed indicator on tape to show proper heating during application has been achieved.
 - d. Water resistant.
 - e. Mold and mildew resistant.
3. Two-Part Tape Sealing System: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-M," the manufacturer's name, and a date code.
- a. Tape: Woven glass fiber impregnated with mineral gypsum.
 - b. Minimum Tape Width: **3 inches** (76 mm).
 - c. Sealant: Modified styrene acrylic.
 - d. Water resistant.
 - e. Mold and mildew resistant.
 - f. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - g. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Fabrication:

1. Select joints, seams, transitions, elbows, and branch connections and fabricate according to [**SMACNA's "Fibrous Glass Duct Construction Standards," Chapter 2, "Specifications and Closure," and Chapter 4, "Fittings and Connections."**] [**NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section II, "Fabrication of Straight Duct Modules," Section III, "Fabrication of Fittings from Modules or Flat Board," and Section IV, "Closure."**]
2. Fabricate 90-degree mitered elbows to include turning vanes.
3. Reinforcements: Comply with requirements in [**SMACNA's "Fibrous Glass Duct Construction Standards," Chapter 5, "Reinforcement"**] [**NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section V, "Reinforcement"**] for channel- and tie-rod reinforcement materials, spacing, and fabrication.
4. Preformed Round Duct: Comply with NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section VII, "Preformed Round Duct."

2.5 PHENOLIC-FOAM DUCTS AND FITTINGS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. **Knauf Insulation.**
 2. **<Insert manufacturer's name>.**
 3. or approved equal.

- B. Duct Panel: CFC-free phenolic-foam bonded on both sides with factory-applied 0.001-inch- (0.025-mm-) thick, aluminum foil reinforced with fiberglass scrim.
1. Maximum Temperature: 158 deg F (70 deg C) inside ducts or ambient temperature surrounding ducts.
 2. Maximum Thermal Conductivity: [0.13 Btu x in./h x sq. ft. x deg F (0.019 W/m x K)] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.
 3. Permeability: 0.0002 perms (0.0115 ng/Pa x s x sq. m) maximum when tested according to ASTM E 96/E 96M, Procedure A.
 4. Antimicrobial Agent: Compound shall be tested for efficacy by an NRTL, and registered by the EPA for use in HVAC systems.
 5. Noise-Reduction Coefficient: 0.65 minimum when tested according to ASTM C 423, Mounting A.
 6. Required Markings: UL label and other markings required by UL 181 on each full sheet of duct panel; UL ratings for closure materials.
- C. Closure Materials:
1. V-Groove Adhesive: Silicone.
 - a. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
 2. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-P," the manufacturer's name, and a date code.
 - a. Tape: Aluminum foil tape imprinted with listing information.
 - b. Minimum Tape Width: 3 inches (76 mm).
 - c. Water resistant.
 - d. Mold and mildew resistant.
 3. Polymeric Sealing System:
 - a. Structural Membrane: Woven glass fiber.
 - b. Minimum Tape Width: 3 inches (76 mm).
 - c. Sealant: Water based.
 - d. Color: White.
 - e. Water resistant.
 - f. Mold and mildew resistant.
 - g. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - h. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Fabrication:

1. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, access doors and panels, and damage repairs according to Knauf Insulation's "Knauf KoolDuct System Design Guide," Section 4, "Duct Construction," and Section 5, "Ductwork System General."
2. Fabricate 90-degree mitered elbows to include turning vanes.

2.6 THERMOSET FRP DUCTS AND FITTINGS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [McGill AirFlow LLC.](#)
2. [Perry Fiberglass Products, Inc.](#)
3. [Spunstrand Inc.](#)
4. **<Insert manufacturer's name>.**
5. or approved equal.

B. Duct and Fittings:

1. Thermoset FRP Resin: Manufacture duct with resin that complies with UL 181, Class 1, maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL according to ASTM E 84.
2. Inner Liner: FSK liner rated by an NRTL to comply with UL 181, Class 1.
3. Round Duct: ASTM D 2996, Type I, Grade 2, Class E, filament-wound duct, minimum [0.125-inch (3.2-mm)] **<Insert thickness>** wall thickness, with tapered bell and spigot ends for adhesive joints, or plain ends with couplings.
4. Round Fittings: Compression or spray-up/contact, molded of same material, pressure class, and joining method as duct.
5. Rectangular Fittings: Minimum [0.125-inch- (3.2-mm-)] **<Insert thickness>** thick flat sheet with fiberglass roving and resin-reinforced joints and seams.
6. Double-Wall Insulated Duct: Inner and outer duct complying with requirements for "Round Duct" description above. Polyurethane foam or isocyanurate insulation with maximum thermal conductivity of [0.14 Btu x in./h x sq. ft. x deg F (0.020 W/m x K)] **<Insert conductivity>** at 75 deg F (24 deg C) mean temperature.

C. Joining Materials: Roving and polyester resin.

1. Fiberglass adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Fabrication:

1. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, and access doors and panels according to SMACNA's "Thermoset FRP Duct Construction Manual," Chapter 7, "Requirements."
 2. Fabricate 90-degree rectangular mitered elbows to include turning vanes, 90-degree round elbows with a minimum of three segments for **12 inches** (300 mm) and smaller and a minimum of five segments for **14 inches** (350 mm) and larger.
- E. Drains: Formed drain pockets with a minimum of **NPS 1 (DN 25)** threaded pipe connections.

2.7 PVC DUCTS AND FITTINGS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [General Plastics, Inc.](#)
 2. [GPK Products, Inc.](#)
 3. [Harvel Plastics, Inc.](#)
 4. [Kroy Industries, Inc.](#)
 5. [Northern Pipe Product Inc.; an Otter Tail company.](#)
 6. [Plastinetics Inc.](#)
 7. [Spears Manufacturing Company.](#)
 8. **<Insert manufacturer's name>**.
 9. or approved equal.
- B. Duct and Fittings:
1. Round Duct: Comply with cell Classification 12454-B in ASTM D 1784, with external loading properties of ASTM D 2412.
 2. Round Fittings: Socket end molded of same material, pressure class, and joining method as duct.
 3. Rectangular Fittings: Minimum [**0.125-inch- (3.2-mm-)**] **<Insert thickness>** thick flat sheet with heat-formed corners and continuous welded butt joints.
- C. Joining Materials: PVC solvent cement complying with ASTM D 2564.
1. PVC solvent cement shall have a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 2. Adhesive primer shall have a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. Fabrication:

1. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, and access doors and panels according to SMACNA's "Thermoplastic Duct (PVC) Construction Manual," Chapter 3, "Standards of Construction for PVC Duct Systems."
2. Fabricate 90-degree rectangular mitered elbows to include turning vanes, 90-degree round elbows with a minimum of three segments for **12 inches (300 mm)** and smaller and a minimum of five segments for **14 inches (350 mm)** and larger.

- E. Drains: PVC drain pockets with a minimum of **NPS 1 (DN 25)** threaded PVC pipe connections.

2.8 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," [Table 5-1 \(Table 5-1M\)](#), "Rectangular Duct Hangers Minimum Size," and [Table 5-2](#), "Minimum Hanger Sizes for Round Duct."
- D. Steel Cables: [**ASTM A 603, galvanized**] [**ASTM A 492, stainless**] steel with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- E. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- F. Trapeze and Riser Supports: Steel shapes complying with ASTM A 36/A 36M.

2.9 SEISMIC-RESTRAINT DEVICES

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Cooper B-Line, Inc.; a division of Cooper Industries.](#)
 2. [Ductmate Industries, Inc.](#)
 3. [Hilti Corp.](#)
 4. [Kinetics Noise Control.](#)
 5. [Loos & Co.; Cableware Division.](#)
 6. [Mason Industries.](#)
 7. [TOLCO; a brand of NIBCO INC.](#)
 8. [Unistrut Corporation; Tyco International, Ltd.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.

- B. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by **[an evaluation service member of the ICC Evaluation Service] [the Office of Statewide Health Planning and Development for the State of California] [an agency acceptable to authorities having jurisdiction]**.
1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least **[four] <Insert number>** times the maximum seismic forces to which they will be subjected.
- C. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.
- D. Restraint Cables: **[ASTM A 603, galvanized] [ASTM A 492, stainless]**-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.
- E. Hanger Rod Stiffener: **[Steel tube or steel slotted-support-system sleeve with internally bolted connections] [Reinforcing steel angle clamped]** to hanger rod.
- F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Provide openings in ductwork where required to accommodate thermometers and controllers. Provide pilot tube openings where required for testing of systems, complete with metal can with spring device or screw to ensure against air leakage. Where openings are provided in insulated ductwork, install insulation material inside a metal ring.
- C. Install ducts with fewest possible joints.
- D. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines. Avoid diagonal runs.
- E. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- F. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities.

- G. Cloth backed duct tape shall not be used.
 - H. Conceal ducts from view in finished spaces. Do not encase horizontal runs in solid partitions unless specifically indicated.
 - I. Coordinate layout with suspended ceiling, fire- and smoke-control dampers, lighting layouts, and similar finished work.
 - J. Electrical Equipment Spaces: Route ducts to avoid passing through transformer vaults and electrical equipment spaces and enclosures.
 - K. Install ducts with a clearance of **1 inch (25 mm)**, plus allowance for insulation thickness.
 - L. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges. Overlap openings on four sides by at least **1-1/2 inches (38 mm)**.
 - M. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers.
 - N. Protect duct interiors from the moisture, construction debris and dust, and other foreign materials. [**Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."**]
 - O. Install fibrous-glass ducts and fittings to comply with [**NAIMA AH116, "Fibrous Glass Duct Construction Standards"**] [**SMACNA's "Fibrous Glass Duct Construction Standards"**]."
 - P. Install foam ducts and fittings to comply with Knauf Insulation's "Knauf KoolDuct System Design Guide."
 - Q. Install thermoset FRP ducts and fittings to comply with SMACNA's "Thermoset FRP Duct Construction Manual."
 - R. Install PVC ducts and fittings to comply with SMACNA's "Thermoplastic Duct (PVC) Construction Manual."
- 3.2 HANGER AND SUPPORT INSTALLATION
- A. Install hangers and supports for fibrous-glass ducts and fittings to comply with [**SMACNA's "Fibrous Glass Duct Construction Standards," Chapter 6, "Hangers and Supports."**] [**NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section VI, "Hangers and Supports."**]
 - B. Install hangers and supports for phenolic-foam ducts and fittings to comply with Knauf Insulation's "Knauf KoolDuct System Design Guide," Section 5, "Ductwork System General."

- C. Install hangers and supports for thermoset FRP ducts and fittings to comply with SMACNA's "Thermoset FRP Duct Construction Manual," Chapter 7, "Requirements."
- D. Install hangers and supports for PVC ducts and fittings to comply with SMACNA's "Thermoplastic Duct (PVC) Construction Manual," Chapter 3, "Standards of Construction for PVC Duct Systems."
- E. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 - 1. Install concrete inserts before placing concrete.
 - 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 - 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches (100 mm) thick.
 - 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches (100 mm) thick.
 - 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
- G. Support horizontal ducts within 24 inches of each elbow and within 48 inches of each branch intersection.
- H. Provide a support with 12 inches of the end of a duct run, not including flexible duct.
- I. Support vertical ducts at maximum intervals of 16 feet and at each floor.
- J. Install upper attachments to structures with an allowable load not exceeding one-fourth of failure (proof-test) load.
- K. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
- L. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

3.3 SEISMIC-RESTRAINT-DEVICE INSTALLATION

- A. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with [SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."] [ASCE/SEI 7.]
 - 1. Space lateral supports a maximum of [40 feet (12 m)] <Insert dimension> o.c., and longitudinal supports a maximum of [80 feet (24 m)] <Insert dimension> o.c.
 - 2. Brace a change of direction longer than 12 feet (3.7 m).

- B. Select sizes of components so strength will be adequate to carry present and future static and seismic loads within restraint device capacity.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install cable restraints where ducts are suspended with vibration isolators.
- E. Install seismic-restraint devices using methods approved by **[an evaluation service member of the ICC Evaluation Service] [the Office of Statewide Health Planning and Development for the State of California] [an agency acceptable to authorities having jurisdiction]**.
- F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure to flanges of beams, to upper truss chords of bar joists, or to concrete members.
- G. Drilling for and Setting Anchors:
 - 1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 - 2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 - 3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
 - 4. Set anchors to manufacturer's recommended torque, using a torque wrench.
 - 5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.4 PAINTING

- A. Paint interior of **[thermoset FRP] [and] [PVC]** ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Section 099123 "Interior Painting."

3.5 UNDERSLAB DUCTS, SPECIAL INSTALLATION REQUIREMENTS

- A. Verify undamaged condition of ducts before enclosure with fill or encasement.
- B. Protect ducts from damage by equipment used in placing fill materials and concrete on or around ducts.
- C. Protect duct openings from damage and prevent entrance of foreign materials.

- D. Slope underground ducts to plenums or low pump out points at 1:500. Provide access doors for inspection.
- E. Encase buried nonmetal ductwork in 3 inch minimum of concrete. Provide adequate tie-down points to prevent ducts from floating during concrete placement. Introduce no heat into ducts for 20 days following placement of concrete.
- F. Insulate buried supply duct runs over 70 feet long with one inch thick insulation covered with plastic vapor barrier.

3.6 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Leakage Tests:
 - 1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
 - 2. For high pressure ductwork, after system is completed, test for duct leakage in accordance with SMACNA "High Pressure Duct Standards - 3rd Edition, Chapter 10 - Testing for Leakage." Repair leaks and repeat tests until total leakage is less than 1% of system design airflow.
 - 3. Test the following systems:
 - a. Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa): Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than 25 percent of total installed duct area for each designated pressure class.
 - b. Supply Ducts with a Pressure Class of [2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
 - c. Return Ducts with a Pressure Class of [2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
 - d. Exhaust Ducts with a Pressure Class of [2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
 - e. Outdoor Air Ducts with a Pressure Class of [2-Inch wg (500 Pa)] [3-Inch wg (750 Pa)] [4-Inch wg (1000 Pa)] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.

4. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
5. Test for leaks before applying external insulation.
6. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give **[seven]** <Insert number> days' advance notice for testing.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of nonmetal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
 - a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.7 DUCT CLEANING

A. Clean **[new]** **[and]** **[existing]** duct system(s) before testing, adjusting, and balancing.

B. Clean ductwork internally, unit-by-unit as it is installed, of dust and debris. Clean external surfaces of foreign substances, which might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.

C. Strip protective paper from stainless ductwork surfaces, and repair finish wherever it has been damaged.

D. Temporary Closure: At ends of ducts, which are not connected to equipment or air distribution devices at time of ductwork installation, provide temporary closure of polyethylene film or other covering, which will prevent entrance of dust and debris until time connections are to be completed.

E. Mark position of dampers and air-directional mechanical devices before cleaning, and perform cleaning before air balancing.

F. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch duct as recommended by duct manufacturer. Comply with Section 233300 "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.

3. Remove and reinstall ceiling to gain access during the cleaning process.

G. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

H. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

I. Mechanical Cleaning Methodology:

1. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
2. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of ducts or duct accessories.
3. Clean fibrous-glass duct with HEPA vacuuming equipment; do not permit duct to get wet. Replace fibrous-glass duct that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
4. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
5. Provide drainage and cleanup for wash-down procedures.
6. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

J. Cleanliness Verification:

1. Visually inspect metal ducts for contaminants.
2. Where contaminants are discovered, re-clean and reinspect ducts.

3.8 CLEANING EXISTING SYSTEMS

- A. Use service openings, as required, for physical and mechanical entry and for inspection.
1. Use existing service openings where possible.
 2. Create other openings to comply with duct standards.
 3. Disconnect flexible ducts as needed for cleaning and inspection.
 4. Reseal rigid fiberglass duct systems according to NAIMA recommended practices.
 5. Remove and reinstall ceiling sections to gain access during the cleaning process.
- B. Mark position of dampers and air-directional mechanical devices before cleaning, and restore to their marked position on completion.
- C. Particulate Collection and Odor Control:
1. When venting vacuuming system inside the building, use HEPA filtration with 99.97% collection efficiency for 0.3-micron size (or larger) particles.
 2. When venting vacuuming system to the outside, use filtration to contain debris removed from HVAC system, and locate exhaust down wind and away from air intakes and other points of entry into building.
- D. Clean the following metal duct systems by removing surface contaminants and deposits:
1. Air outlets and inlets (registers, grilles, and diffusers).
 2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
 3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
 4. Coils and related components.
 5. Return-air ducts, dampers, and actuators except in ceiling plenums and mechanical equipment rooms.
 6. Supply-air ducts, dampers, actuators, and turning vanes.
 7. Dedicated exhaust and ventilation components and makeup air systems.
- E. Mechanical Cleaning Methodology:
1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
 2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
 3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
 4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit

- duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
 6. Provide operative drainage system for washdown procedures.
 7. Biocidal Agents and Coatings: Apply biocidal agents if fungus is present. Apply biocidal agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Cleanliness Verification:

1. Verify cleanliness after mechanical cleaning and before application of treatment, including biocidal agents and protective coatings.
2. Visually inspect metal ducts for contaminants.
3. Where contaminants are discovered, re-clean and reinspect ducts.

- G. Verification of Coil Cleaning: Cleaning must restore coil pressure drop to within 10% of pressure drop measured when coil was first installed. If original pressure drop is not known, coil will be considered clean only if it is free of foreign matter and chemical residue, based on thorough visual inspection.

3.9 FINAL CLEANING

- A. Clean duct system and force air at high velocity through duct to remove accumulated dust. To obtain sufficient air, clean half the system at a time. Protect equipment, which may be harmed by excessive dirt with temporary filters, or bypass during cleaning.
- B. Clean duct systems with high power vacuum machines. Protect equipment, which may be harmed by excessive dirt with filters, or bypass during cleaning. Provide adequate access into ductwork for cleaning purposes.

3.10 START UP

- A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.11 DUCT SCHEDULE

A. Indoor Ducts and Fittings:

1. Fibrous-Glass Rectangular Ducts and Fittings:
 - a. Minimum Flexural Rigidity: EI-[475] [800] [1400].
 - b. Minimum Board Thickness: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)].
2. Fibrous-Glass Round Ducts and Fittings:

- a. Minimum Thickness: [1 inch (25 mm)] <Insert thickness>.
3. Phenolic-Foam Rectangular Ducts and Fittings:
 - a. Minimum Panel Thickness: [7/8 inch (22 mm)] [1-3/32 inches (28 mm)].
 - b. Aluminum Cladding: Minimum 0.025 inch (0.635 mm) thick.
- B. Outdoor Ducts and Fittings:
 1. Phenolic-Foam Rectangular Ducts and Fittings:
 - a. Minimum Panel Thickness: [7/8 inch (22 mm)] [1-3/32 inches (28 mm)].
 - b. Aluminum Cladding: Minimum 0.032 inch (0.813 mm) thick.
 - c. Polymeric Sealing System: Coat ducts, including gang-nail couplings, grip flanges, and couplings.
 2. Thermoset FRP Round Ducts and Fittings:
 - a. Double-Wall Insulated Ducts: Minimum [5/8-inch (15.9-mm)] [7/8-inch (22.2-mm)] <Insert thickness> insulation thickness.
 3. PVC Round Ducts and Fittings:
- C. Underground Ducts:
 1. Thermoset FRP Round Ducts and Fittings:
 - a. Insulation Thickness: [1 inch (25 mm)] <Insert thickness>.
 - b. Drain: Minimum NPS 1 (DN 25) PVC pipe with P-trap to air-gap drain.
 2. PVC Round Ducts and Fittings:
 - a. Drain: Minimum NPS 1 (DN 25) PVC pipe with P-trap to air-gap drain.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233116

SECTION 233119 - HVAC CASINGS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
- [Factory] [Shop]-fabricated, field-assembled, [single] [double] [single- and double]-wall casings for HVAC equipment.**
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Static-Pressure Classes:
- Upstream from Fan(s): **[2-inch wg (500 Pa)] <Insert value>**.
 - Downstream from Fan(s): **[2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] [6-inch wg (1500 Pa)] [10-inch wg (2500 Pa)] <Insert value>**.
- B. Acoustical Performance:
- NRC: **[1.09] [0.94] <Insert number>** according to ASTM C 423.
 - STC: **[40] [34] <Insert number>** according to ASTM E 90.
- C. Structural Performance:
- Casings shall be fabricated to withstand 133 percent of the indicated static pressure without structural failure. Wall and roof deflection at the indicated static pressure shall not exceed **1/8 inch per foot (0.97 mm per meter)** of width.
 - Fabricate outdoor casings to withstand wind load of **15 lbf/sq. ft. (720 N/sq. m)** and snow load of **30 lbf/sq. ft. (1440 N/sq. m)**.
- D. Seismic Performance: HVAC casings shall withstand the effects of earthquake motions determined according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" **[and] [ASCE/SEI 7] <Insert requirement>**.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

A. Product Data: For each type of the following products:

1. Factory-fabricated casings.
2. Liners and adhesives.
3. Sealants and gaskets.
4. Seismic-restraint devices.
5. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that HVAC casings comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that HVAC casings comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
4. Duct-Cleaning Test Report for Prerequisite IEQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-up."
5. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
6. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings: For HVAC casings. Include plans, elevations, sections, components, and attachments to other work.

1. Detail HVAC casing assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Sheet metal thickness(es).
3. Reinforcement and spacing.
4. Seam and joint construction.
5. Access doors including frames, hinges, and latches.
6. Filter, coil, humidifier, and other apparatus being installed in and mounted on casing.
7. Locations for access to internal components.
8. Hangers and supports including methods for building attachment, vibration isolation,[**seismic restraints**,] and casing attachment.

9. Interior lighting, including switches.

1.5 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Product Certificates: For acoustically critical casings, from manufacturer.
1. Show sound-absorption coefficients in each octave band lower than those scheduled when tested according to ASTM C 423.
 2. Show airborne sound transmission losses lower than those scheduled when tested according to ASTM E 90.
- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to [**AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports**] [**AWS D9.1M/D9.1, "Sheet Metal Welding Code," for casing joint and seam welding**].
- B. Welding Qualifications: Qualify procedures and personnel according to the following:
1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
 2. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for casing joint and seam welding.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."
- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

- B. Coordinate sizes and locations of steel supports. Supports are specified in Section 055000 "Metal Fabrications."
- C. Coordinate installation of roof curbs, [**equipment supports**,]and roof penetrations. These items are specified in Section 077200 "Roof Accessories."

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1 requirements.
- B. Store all materials in location protected from water, wind, construction activities, and any other potential damage hazard.
- C. Protect <Insert item> from <Insert item> by <Insert requirement>.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL CASING FABRICATION REQUIREMENTS

- A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 9, "Equipment and Casings," for acceptable materials, material thicknesses, and casing construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
 1. Fabricate casings with more than 3-inch wg (750-Pa) negative static pressure according to SMACNA's "Rectangular Industrial Duct Construction Standards."
 2. Casings with more than 2-inch wg (500-Pa) positive static pressure may be fabricated according to SMACNA's "Rectangular Industrial Duct Construction Standards."
 3. Fabricate with a minimum number of joints.
 4. Weld exterior and interior shells to perimeter; to interior, longitudinal, galvanized-steel channels; and to box-end internal closures. Paint welds.
 5. Exterior Shell Thickness: 0.040 inch minimum.
 6. Interior Shell Thickness: 0.034 inch minimum.
 7. Interior Shell Thickness: 0.034 inch minimum, with 3/32-inch perforations at 3/16-inch staggered spacing for 23% open area.
 8. Fabricate perimeter and interior, longitudinal channel members with galvanized-steel shapes.

9. Fill each panel assembly with insulating material that is noncombustible, inert, mildew resistant, and vermin proof, and that complies with NFPA 90A.
 10. Fabricate panels with tongue-and-groove, continuous self-locking joints effective inside and outside each panel.
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
1. Exterior Surface Galvanized Coating Designation: [G60 (Z180)] [G90 (Z275)].
 2. Interior Surface Galvanized Coating Designation:
 - a. Sections Not Exposed to Moisture: [G60 (Z180)] [G90 (Z275)].
 - b. Sections Housing and Downstream from Cooling Coil and Humidifiers: [G90 (Z275)].
- C. Stainless Steel: ASTM A 480/A 480M, [Type 304] [Type 316], and having a [No. 2D] <Insert finish> finish.
- D. Factory- or Shop-Applied Antimicrobial Coating:
1. Apply to the interior sheet metal surfaces of casing in contact with the airstream. Apply untreated clear coating to the exterior surface.
 2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
 3. Coating containing the antimicrobial compound shall have a hardness of 2H minimum when tested according to ASTM D 3363.
 4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 according to UL 723; certified by an NRTL.
 5. Applied Coating Color: [Standard] [Black] [White].
- E. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
- F. Sealing Requirement: SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Seal Class A. Seal all seams, joints, connections, and abutments to building.
- G. Penetrations: Seal all penetrations airtight. Cover with escutcheons and gaskets, or fill with suitable compound so there is no exposed insulation. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping." Provide shaft seals where fan shafts penetrate casing.
- H. Access Doors: Fabricate access doors according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 9-15, "Casing Access Doors - 2-inch wg (500 Pa)," and Figure 9-16, "Casing Access Doors - 3-10-inch wg (750-2500 Pa)"; and according to pressure class of the plenum or casing section in which access doors are to be installed.
1. Size: [24 by 60 inches (580 by 1500 mm)] <Insert size>.
 2. Vision Panel: Double-glazed, wire-reinforced safety glass with an airspace between panes and sealed with interior and exterior rubber seals.

3. Hinges: Install a minimum of two ball-bearing butt hinges and latches, number and size according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 4. Latches: Minimum of two wedge-lever-type latches, operable from inside and outside.
 5. Neoprene gaskets around entire perimeters of door frames.
 6. Doors shall open against air pressure.
 7. Fabricate windows in doors consisting of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.
- I. Condensate Drain Pans: Formed sections of **[Type 304, stainless-steel sheet]** **[G90 (Z275) coated, galvanized sheet steel]** complying with requirements in ASHRAE 62.1. Pans shall extend a minimum of **12 inches (300 mm)** past coil.
1. Double-wall construction shall have space between walls filled with foam insulation and sealed moisture tight.
 2. Intermediate drain pan or drain trough shall collect condensate from top coil for units with stacked coils or stacked eliminators.
 3. Insulation: Polystyrene or polyurethane.
 4. Slopes shall be in a minimum of two planes to collect condensate from cooling coils (including coil piping connections and return bends), eliminators, and humidifiers when units are operating at maximum catalogued face velocity across cooling coil.
 5. Each drain pan connection shall have a trap. **[Drain traps with depth and height differential between inlet and outlet equal or greater to the design static pressure plus 2-inch wg (500 Pa.)]** Include slab height in trap calculation.
- J. Structural Performance: Fabricate plenum to be self-supporting and capable of withstanding internal static pressures as scheduled, without any panel joint exceeding deflection of L/200 where "L" is the unsupported span length within completed casings.
1. Fabricate outdoor casings to withstand wind load of 15 lbf/sq. ft. and snow load of 30 lbf/sq. ft..
 2. Acoustic Performance: Certified by an independent acoustical testing agency listing sound-absorption and transmission-loss characteristics of panel assemblies.
 3. Thermal Conductivity (k-Value): 0.26 at 75oF mean temperature.
- K. Static-Pressure Classifications: Unless otherwise indicated, fabricate HVAC casings according to the following:
1. Before Fans: **[2-inch wg] [3-inch wg] <Insert pressure class>**.
 2. After Fans: **[2-inch wg] [3-inch wg] [4-inch wg] [6-inch wg] [10-inch wg] <Insert pressure class>**.

2.2 SHOP-FABRICATED CASINGS

- A. Single- and Double-Wall Casings: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
- B. Double-Wall Casing Inner Panel: Perforated, galvanized sheet steel having 3/32-inch- (2.4-mm-) diameter perforations, with overall open area of [23] <Insert number> percent. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
- C. Double-Wall Casing Inner Panel: Solid sheet steel. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
- D. Interstitial Insulation: Polyurethane foam complying with NFPA 90A or NFPA 90B.
- E. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
 - 1. Maximum Thermal Conductivity: [0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.
 - 2. Coat insulation with antimicrobial coating.
 - 3. Cover insulation with polyester film complying with UL 181, Class 1.
- F. Interstitial Insulation: Flexible-elastomeric duct liner complying with ASTM C 534, Type II for sheet materials and with NFPA 90A or NFPA 90B.
 - 1. Maximum Thermal Conductivity: [0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.
- G. Fabricate casings with standing seams and angle-iron reinforcements unless otherwise indicated.
- H. Fabricate close-off sheets from casing to dampers, filter frames, and coils and between stacked coils. Use galvanized sheet steel of same thickness as casing and with a galvanized coating designation of G90 (Z275).
- I. Bolt close-off sheets to frame flanges and housings. Support coils on stands fabricated from galvanized-steel angles or channels.
- J. Reinforce casings with galvanized-steel angles.

2.3 MANUFACTURED CASINGS

- A. Description: Double-wall, insulated, pressurized equipment casing.

- B. **Manufacturers:** Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
1. [Acoustical Surfaces, Inc.](#)
 2. [AeroSonics, Inc.; a division of TUTCO, Inc.](#)
 3. [Buffalo Air Handling.](#)
 4. [CertainTeed Corp.; Insulation Group.](#)
 5. [CLEANPAK International.](#)
 6. [D&D Sound Control.](#)
 7. [IACL.](#)
 8. [Industrial Noise Control, Inc.](#)
 9. [McGill AirSilence LLC.](#)
 10. [SEMCO Incorporated.](#)
 11. [Vibro-Acoustics.](#)
 12. **<Insert manufacturer's name>.**
- C. Double-Wall Panel Fabrication: Solid, galvanized sheet steel exterior wall and **[solid] [perforated]**, galvanized sheet steel interior wall; with space between wall filled with insulation.
1. Wall Thickness: **[2 inches (50 mm)] [4 inches (100 mm)]**.
 2. Fabricate with a minimum number of joints.
 3. Weld exterior and interior walls to perimeter; to interior, longitudinal, galvanized-steel channels; and to box-end internal closures. Paint welds.
 4. Sheet metal thickness shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for static-pressure class indicated for casing.
 5. Sheet Metal Thicknesses:
 - a. Exterior Wall Thickness: **[0.040 inch (1.0 mm)] <Insert dimension>** minimum.
 - b. Interior Wall Thickness: **[0.034 inch (0.85 mm)] <Insert dimension>** minimum.
 6. Double-Wall Casing Inner Panel: Perforated, galvanized sheet steel having **3/32-inch- (2.4-mm-)** diameter perforations, with overall open area of **[23] <Insert number>** percent.
 7. Double-Wall Casing Inner Panel: Solid sheet steel.
 8. Fill each panel assembly with insulating material that is noncombustible, inert, mildew resistant and vermin proof and that complies with NFPA 90A.
 9. Fabricate panels with continuous **[tongue-and-groove] [self-locking] [tongue-and-groove or self-locking]** joints effective inside and outside each panel.
- D. Trim Items: Fabricate from a minimum of **0.052-inch (1.3-mm)** galvanized sheet steel, furnished in standard lengths for field cutting.

2.4 CASING LINER

- A. Fibrous-Glass Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. **Manufacturers:** Subject to compliance with requirements, [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. [CertainTeed Corp.: Insulation Group.](#)
 - b. [Johns Manville.](#)
 - c. [Knauf Insulation.](#)
 - d. [Owens Corning.](#)
 - e. <Insert manufacturer's name>.
 2. Maximum Thermal Conductivity:
 - a. Type I, Flexible: [0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.
 - b. Type II, Rigid: [0.23 Btu x in./h x sq. ft. x deg F (0.033 W/m x K)] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.
 3. Antimicrobial Erosion-Resistant Coating: Apply to surface of the liner that will form the interior surface of casing to act as a moisture repellent and an erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
 4. **[Solvent] [Water]-Based Liner Adhesive:** Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
 - a. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- B. Flexible-Elastomeric Casing Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1, and with NFPA 90A or NFPA 90B.
1. **Manufacturers:** Subject to compliance with requirements, [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:
 - a. [Aeroflex USA Inc.](#)
 - b. [Armacell LLC.](#)
 - c. [Rubatex International, LLC.](#)
 - d. <Insert manufacturer's name>.

2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
 3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
 - a. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Natural-Fiber Casing Liner: 85 percent cotton, 10 percent borate, and 5 percent polybinding fibers, treated with a microbial growth inhibitor, and complying with NFPA 90A or NFPA 90B.
1. **Manufacturers:** Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. [Bonded Logic, Inc.](#)
 - b. [Reflectix Inc.](#)
 - c. **<Insert manufacturer's name>**.
 2. Maximum Thermal Conductivity: **[0.24 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)] <Insert conductivity>** at **75 deg F (24 deg C)** mean temperature when tested according to ASTM C 518.
 3. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
 4. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
 - a. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. Insulation Pins and Washers:
1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, **[0.106-inch- (2.6-mm-)] [0.135-inch- (3.5-mm-)]** diameter shank, length to suit depth of insulation indicated with integral **1-1/2-inch (38-mm)** galvanized carbon-steel washer.
 2. Insulation-Retaining Washers: Self-locking washers formed from **0.016-inch- (0.41-mm-)** thick, **[galvanized] [stainless]** steel, with beveled edge sized as

required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

- E. Shop or Factory Application of Casing Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."
1. Adhere a single layer of indicated thickness of casing liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of casing liner is prohibited.
 2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
 3. Butt transverse joints without gaps, and coat joint with adhesive.
 4. Fold and compress liner in corners of casings or cut and fit to ensure butted-edge overlapping.
 5. Apply adhesive coating on longitudinal seams in casings with air velocity of 2500 fpm (12.7 m/s).
 6. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.
 7. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from casing wall. Fabricate edge facings at the following locations:
 - a. Fan discharges.
 - b. Intervals of lined casing preceding unlined duct.
 - c. Upstream edges of transverse joints in casings where air velocities are higher than 2500 fpm (12.7 m/s) or where indicated.
 8. Secure insulation between perforated sheet metal inner wall of same thickness as specified for outer wall. Use mechanical fasteners that maintain inner wall at uniform distance from outer wall without compressing insulation.

2.5 SEALANT MATERIALS

- A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
- B. Water-Based Joint and Seam Sealant:
1. Application Method: Brush on.
 2. Solids Content: Minimum 65 percent.
 3. Shore A Hardness: Minimum 20.
 4. Water resistant.
 5. Mold and mildew resistant.
 6. VOC: Maximum 75 g/L (less water).
 7. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

8. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
9. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
10. Service: Indoor or outdoor.
11. Substrate: Compatible with galvanized sheet steel or stainless steel.

C. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.
8. VOC: Maximum 395 g/L.
9. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
10. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
11. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
12. Service: Indoor or outdoor.
13. Substrate: Compatible with galvanized sheet steel or stainless steel.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single component, acid curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine [**concrete bases**] [**roof curbs**] [**and**] [**steel supports**] for compliance with requirements for conditions affecting installation and performance of HVAC casings.
- B. Examine casing insulation materials and liners before installation. Reject casings that are wet, moisture damaged, or mold damaged.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install casings according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- B. Equipment Mounting:
 - 1. Install HVAC casings on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- C. Apply sealant to joints, connections, and mountings.
- D. Field-cut openings for pipe and conduit penetrations; insulate and seal according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- E. Support casings on floor or foundation system. Secure and seal to base.
- F. Support components rigidly with ties, braces, brackets, [**seismic restraints**], and anchors of types that will maintain housing shape and prevent buckling.
- G. Align casings accurately at connections, with **1/8-inch (3-mm)** misalignment tolerance and with smooth interior surfaces.

3.3 FIELD QUALITY CONTROL

- A. Tests and Inspections:
 - 1. Perform field tests and inspections according to SMACNA's "HVAC Air Duct Leakage Test Manual."
 - 2. Test the following systems:

- a. Systems required by ASHRAE/IESNA 90.1.
 - b. Supply Air: **[100] [50] <Insert value>** percent of total installed duct area with a pressure class of **[3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>** or higher.
 - c. **<Insert requirements of other systems>**.
3. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give seven days' advance notice for testing.
 4. Determine leakage from entire system or section of system by relating leakage to surface area of test section. Comply with requirements for leakage classification of ducts connected to casings.
 5. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
- B. HVAC casings will be considered defective if they do not pass tests and inspections.
 - C. Prepare test and inspection reports.

3.4 CLEANING

- A. Comply with requirements for cleaning in Section 233113 "Metal Ducts."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233119

SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Backdraft and pressure relief dampers.
2. Barometric relief dampers.
3. Manual volume dampers.
4. Control dampers.
5. Fire dampers.
6. Ceiling radiation dampers.
7. Smoke dampers.
8. Combination fire and smoke dampers.
9. Corridor dampers.
10. Flange connectors.
11. Duct silencers.
12. Turning vanes.
13. Remote damper operators.
14. Duct-mounted access doors.
15. Flexible connectors.
16. Flexible ducts.
17. Duct security bars.
18. Duct accessory hardware.

- B. Related Requirements:

1. Section 233723 "HVAC Gravity Ventilators" for roof-mounted ventilator caps.
2. Section 283111 "Digital, Addressable Fire-Alarm System" for duct-mounted fire and smoke detectors.
3. Section 283112 "Zoned (DC-Loop) Fire-Alarm System" for duct-mounted fire and smoke detectors.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. For duct silencers, include dimension data, materials, pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.
 - a. Design Data: Provide engineering calculations, referenced to specifications and **[AMCA 301] [AMCA 302] [AMCA 303] [ARI 270] [ASA 49 (ANSI S12.1)]** standards indicating that maximum room sound levels are not exceeded.
2. Provide for shop fabricated assemblies including **[volume control dampers] [duct access doors] [and] [hardware used]**. Include electrical characteristics and connection requirements.
3. Fire, Smoke, and Combination Fire Smoke Dampers: Submit manufacturer's product data.
 - a. Include UL ratings for leakage class (I, II, or III), velocity (2000, 3000, or 4000 fpm), differential pressure (4, 6, or 8 inches WG) and elevated temperature (250 or 350 degrees F).
 - b. Indicate materials, construction, and dimensions.
 - c. Verify conformance to NFPA, UL, and applicable building code.
 - d. Include pressure drop data for air flow in either direction for all damper sizes in accordance with AMCA 500-D test figures 5.2 (Ducted Inlet, Free Outlet), 5.3 (Ducted Inlet, Ducted Outlet) and 5.5 (Free Inlet, Free Outlet).
 - e. Include a copy of UL Installation Instructions.
 - f. Damper access and identification label product data a sample.
4. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that duct insulation R-values comply with tables in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air Conditioning."

C. Shop Drawings: For duct accessories. Include plans, elevations, sections, details, and attachments to other work.

1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:
 - a. Special fittings.
 - b. Manual volume damper installations.

- c. Control-damper installations.
- d. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
- e. Duct security bars.
- f. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.
- B. Test Reports: Indicate **[dynamic insertion loss and noise generation values of silencers.] [acoustic housings meet or exceed specified sound transmission loss values.]**
- C. Source quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Record actual locations of **[access doors] [test holes] <Insert item>**.
 2. Record actual locations of **[cross-talk silencers.] [acoustic housings.] [ductwork lagging.]**

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Fusible Links: Furnish quantity equal to **[ten (10)] <Insert number>** percent of amount installed.

1.7 QUALITY ASSURANCE

- A. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

- B. Perform sound attenuator Work in accordance with [**AMCA 300**] [**ANSI S1.13**] [**ARI 575**] [**ASA 16 (ANSI S1.36)**] standards and recommendations of [**ASHRAE 68.**] [**NEBB.**].
- C. Design application of [**duct silencers**] [**acoustic housings**] under direct supervision of a Professional Engineer experienced in design of this work and licensed at the place where the Project is located.
- D. Conform to City and County of Denver code for sound levels at property line.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Store all materials in location protected from water, construction activities, and any other potential damage hazard.
- C. Protect dampers from damage to operating linkages and blades.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

- A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

- A. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
 - 1. Galvanized Coating Designation: [**G60 (Z180)**] [**G90 (Z275)**].
 - 2. Exposed-Surface Finish: Mill phosphatized.

- B. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a **[No. 2] <Insert finish designation>** finish for concealed ducts and **<Insert finish designation>** finish for exposed ducts.
- C. Aluminum Sheets: Comply with **ASTM B 209** (ASTM B 209M), Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.
- D. Extruded Aluminum: Comply with **ASTM B 221** (ASTM B 221M), Alloy 6063, Temper T6.
- E. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.
- F. Tie Rods: Galvanized steel, **1/4-inch** (6-mm) minimum diameter for lengths **36 inches** (900 mm) or less; **3/8-inch** (10-mm) minimum diameter for lengths longer than **36 inches** (900 mm).

2.3 BACKDRAFT AND PRESSURE RELIEF DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Air Balance Inc.; a division of Mestek, Inc.](#)
 - 2. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 - 3. [Cesco Products; a division of Mestek, Inc.](#)
 - 4. [Greenheck Fan Corporation.](#)
 - 5. [Lloyd Industries, Inc.](#)
 - 6. [Nailor Industries Inc.](#)
 - 7. [NCA Manufacturing, Inc.](#)
 - 8. [Pottorff.](#)
 - 9. [Ruskin Company.](#)
 - 10. [Vent Products Company, Inc.](#)
 - 11. **<Insert manufacturer's name>**.
 - 12. or approved equal.
- B. Description: Gravity balanced.
- C. Maximum Air Velocity: [**1000 fpm** (5.1 m/s)] [**1250 fpm** (6.4 m/s)] [**2000 fpm** (10 m/s)] [**3000 fpm** (15 m/s)] **<Insert value>**.
- D. Maximum System Pressure: [**1-inch wg** (0.25 kPa)] [**2-inch wg** (0.5 kPa)] [**3-inch wg** (0.8 kPa)] [**6-inch wg** (1.5 kPa)] **<Insert value>**.
- E. Frame: Hat-shaped, [**0.05-inch-** (1.3-mm-) **thick, galvanized sheet steel**] [**0.094-inch-** (2.4-mm-) **thick, galvanized sheet steel**] [**0.063-inch-** (1.6-mm-) **thick extruded aluminum**] [**0.03-inch-** (0.8-mm-) **thick stainless steel**] [**0.05-inch-** (1.3-mm-) **thick stainless steel**], with welded corners or mechanically attached[**and mounting flange**].

- F. Blades: Multiple single-piece blades, [**center pivoted,**] [**off-center pivoted,**] [**end pivoted,**] maximum **6-inch** (150-mm) width, [**0.025-inch-** (0.6-mm-) **thick, roll-formed aluminum**] [**0.050-inch-** (1.2-mm-) **thick aluminum sheet**] [**noncombustible, tear-resistant, neoprene-coated fiberglass**] with sealed edges.
- G. Blade Action: Parallel.
- H. Blade Seals: [**Felt**] [**Vinyl foam**] [**Extruded vinyl, mechanically locked**] [**Neoprene, mechanically locked**].
- I. Blade Axles:
1. Material: [**Nonferrous metal**] [**Galvanized steel**] [**Plated steel**] [**Stainless steel**] [**Nonmetallic**] [**Aluminum**].
 2. Diameter: [**0.20 inch** (5 mm)] <Insert value>.
- J. Tie Bars and Brackets: [**Aluminum**] [**Galvanized steel**].
- K. Return Spring: Adjustable tension.
- L. Bearings: [**Steel ball**] [**or**] [**synthetic pivot bushings**].
- M. Accessories:
1. Adjustment device to permit setting for varying differential static pressure.
 2. Counterweights and spring-assist kits for vertical airflow installations.
 3. Electric actuators.
 4. Chain pulls.
 5. Screen Mounting: Front mounted in sleeve.
 - a. Sleeve Thickness: **20 gage** (1.0 mm) minimum.
 - b. Sleeve Length: **6 inches** (152 mm) minimum.
 6. Screen Mounting: Rear mounted.
 7. Screen Material: [**Galvanized steel**] [**Aluminum**].
 8. Screen Type: [**Bird**] [**Insect**].
 9. 90-degree stops.

2.4 BAROMETRIC RELIEF DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Air Balance Inc.; a division of Mestek, Inc.](#)
 2. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 3. [Cesco Products; a division of Mestek, Inc.](#)
 4. [Greenheck Fan Corporation.](#)
 5. [Lloyd Industries, Inc.](#)
 6. [Nailor Industries Inc.](#)
 7. [NCA Manufacturing, Inc.](#)

8. [Pottorff](#).
 9. [Ruskin Company](#).
 10. [Vent Products Company, Inc.](#)
 11. **<Insert manufacturer's name>**.
 12. or approved equal.
- B. Suitable for horizontal or vertical mounting.
- C. Maximum Air Velocity: [1000 fpm (5.1 m/s)] [1250 fpm (6.4 m/s)] [2000 fpm (10 m/s)] [2500 fpm (13 m/s)] **<Insert value>**.
- D. Maximum System Pressure: [2-inch wg (0.5 kPa)] [3-inch wg (0.8 kPa)] [6-inch wg (1.5 kPa)] [10-inch wg (2.5 kPa)] **<Insert value>**.
- E. Frame: Hat-shaped, [0.05-inch- (1.3-mm-) **thick, galvanized sheet steel**] [0.094-inch- (2.4-mm-) **thick, galvanized sheet steel**] [0.063-inch- (1.6-mm-) **thick extruded aluminum**] [0.03-inch- (0.8-mm-) **thick stainless steel**] [0.05-inch- (1.3-mm-) **thick stainless steel**], with welded corners or mechanically attached[**and mounting flange**].
- F. Blades:
1. Multiple, [0.025-inch- (0.6-mm-) **thick, roll-formed aluminum**] [0.050-inch- (1.2-mm-) **thick aluminum sheet**].
 2. Maximum Width: **6 inches** (150 mm).
 3. Action: Parallel.
 4. Balance: Gravity.
 5. [**Eccentrically pivoted**] [**Off-center pivoted**] [**End pivoted**].
- G. Blade Seals: [Vinyl] [Neoprene].
- H. Blade Axles: [**Galvanized steel**] [**Nonferrous metal**] [**Plated steel**] [**Stainless steel**] [**Nonmetallic**].
- I. Tie Bars and Brackets:
1. Material: [**Aluminum**] [**Galvanized steel**].
 2. Rattle free with 90-degree stop.
- J. Return Spring: Adjustable tension.
- K. Bearings: [**Synthetic**] [**Stainless steel**] [**Bronze**].
- L. Accessories:
1. Flange on intake.
 2. Adjustment device to permit setting for varying differential static pressures.
 3. **<Insert accessories>**.

2.5 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Balance Inc.; a division of Mestek, Inc.](#)
 - b. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 - c. [Flexmaster U.S.A., Inc.](#)
 - d. [McGill AirFlow LLC.](#)
 - e. [Nailor Industries Inc.](#)
 - f. [Pottorff.](#)
 - g. [Ruskin Company.](#)
 - h. [Trox USA Inc.](#)
 - i. [Vent Products Company, Inc.](#)
 - j. **<Insert manufacturer's name>.**
 - k. or approved equal.
2. Standard leakage rating[, **with linkage outside airstream**].
3. Suitable for horizontal or vertical applications.
4. Frames:
 - a. Frame: Hat-shaped, [**0.094-inch-** (2.4-mm-) **thick, galvanized sheet steel**] [**0.05-inch-** (1.3-mm-) **thick stainless steel**].
 - b. Mitered and welded corners.
 - c. Flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:
 - a. Multiple or single blade.
 - b. Parallel- or opposed-blade design.
 - c. Stiffen damper blades for stability.
 - d. [**Galvanized**] [**Stainless**]-steel, **0.064 inch** (1.62 mm) thick.
6. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
7. Bearings:
 - a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Oil-impregnated stainless-steel sleeve**] [**Stainless-steel sleeve**].
 - b. Dampers in ducts with pressure classes of **3-inch wg** (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
8. Tie Bars and Brackets: Galvanized steel.

B. Standard, Aluminum, Manual Volume Dampers:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. [Air Balance Inc.; a division of Mestek, Inc.](#)
 - b. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 - c. [McGill AirFlow LLC.](#)
 - d. [Nailor Industries Inc.](#)
 - e. [Pottorff.](#)
 - f. [Ruskin Company.](#)
 - g. [Trox USA Inc.](#)
 - h. [Vent Products Company, Inc.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Standard leakage rating[, **with linkage outside airstream**].
 3. Suitable for horizontal or vertical applications.
 4. Frames: Hat-shaped, **0.10-inch-** (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
 5. Blades:
 - a. Multiple or single blade.
 - b. Parallel- or opposed-blade design.
 - c. Stiffen damper blades for stability.
 - d. Roll-Formed Aluminum Blades: **0.10-inch-** (2.5-mm-) thick aluminum sheet.
 - e. Extruded-Aluminum Blades: **0.050-inch-** (1.2-mm-) thick extruded aluminum.
 6. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
 7. Bearings:
 - a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Stainless-steel sleeve**].
 - b. Dampers in ducts with pressure classes of **3-inch wg** (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
 8. Tie Bars and Brackets: Aluminum.
- C. Low-Leakage, Steel, Manual Volume Dampers:
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Air Balance Inc.; a division of Mestek, Inc.](#)
 - b. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 - c. [McGill AirFlow LLC.](#)
 - d. [Nailor Industries Inc.](#)
 - e. [Pottorff.](#)
 - f. [Ruskin Company.](#)
 - g. [Trox USA Inc.](#)
 - h. [Vent Products Company, Inc.](#)
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.

2. Comply with AMCA 500-D testing for damper rating.
3. Low-leakage rating[, **with linkage outside airstream,**] and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
4. Suitable for horizontal or vertical applications.
5. Frames:
 - a. **[Hat] [U] [Angle]** shaped.
 - b. **[0.094-inch- (2.4-mm-) thick, galvanized sheet steel] [0.05-inch- (1.3-mm-) thick stainless steel]**.
 - c. Mitered and welded corners.
 - d. Flanges for attaching to walls and flangeless frames for installing in ducts.
6. Blades:
 - a. Multiple or single blade.
 - b. Parallel- or opposed-blade design.
 - c. Stiffen damper blades for stability.
 - d. **[Galvanized] [Stainless]**, roll-formed steel, **0.064 inch (1.62 mm)** thick.
7. Blade Axles: **[Galvanized steel] [Stainless steel] [Nonferrous metal]**.
8. Bearings:
 - a. **[Oil-impregnated bronze] [Molded synthetic] [Oil-impregnated stainless-steel sleeve] [Stainless-steel sleeve]**.
 - b. Dampers in ducts with pressure classes of **3-inch wg (750 Pa)** or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
9. Blade Seals: **[Felt] [Vinyl] [Neoprene]**.
10. Jamb Seals: Cambered **[stainless steel] [aluminum]**.
11. Tie Bars and Brackets: **[Galvanized steel] [Aluminum]**.
12. Accessories:
 - a. Include locking device to hold single-blade dampers in a fixed position without vibration.

D. Low-Leakage, Aluminum, Manual Volume Dampers:

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. [Air Balance Inc.; a division of Mestek, Inc.](#)
 - b. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 - c. [McGill AirFlow LLC.](#)
 - d. [Nailor Industries Inc.](#)
 - e. [Pottorff.](#)
 - f. [Ruskin Company.](#)
 - g. [Trox USA Inc.](#)
 - h. [Vent Products Company, Inc.](#)
 - i. **<Insert manufacturer's name>.**

- j. or approved equal.
 2. Comply with AMCA 500-D testing for damper rating.
 3. Low-leakage rating[, **with linkage outside airstream,**] and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
 4. Suitable for horizontal or vertical applications.
 5. Frames: [**Hat**] [**U**] [**Angle**]-shaped, **0.10-inch-** (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
 6. Blades:
 - a. Multiple or single blade.
 - b. Parallel- or opposed-blade design.
 - c. Roll-Formed Aluminum Blades: **0.10-inch-** (2.5-mm-) thick aluminum sheet.
 - d. Extruded-Aluminum Blades: **0.050-inch-** (1.2-mm-) thick extruded aluminum.
 7. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
 8. Bearings:
 - a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Oil-impregnated stainless-steel sleeve**] [**Stainless-steel sleeve**].
 - b. Dampers in ducts with pressure classes of **3-inch wg** (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
 9. Blade Seals: [**Felt**] [**Vinyl**] [**Neoprene**].
 10. Jamb Seals: Cambered [**stainless steel**] [**aluminum**].
 11. Tie Bars and Brackets: [**Galvanized steel**] [**Aluminum**].
 12. Accessories:
 - a. Include locking device to hold single-blade dampers in a fixed position without vibration.
- E. Jackshaft:
1. Size: [**0.5-inch** (13-mm)] [**1-inch** (25-mm)] diameter.
 2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
 3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.
- F. Damper Hardware:
1. Zinc-plated, die-cast core with dial and handle made of **3/32-inch-** (2.4-mm-) thick zinc-plated steel, and a **3/4-inch** (19-mm) hexagon locking nut.
 2. Include center hole to suit damper operating-rod size.
 3. Include elevated platform for insulated duct mounting.

2.6 CONTROL DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [American Warming and Ventilating; a division of Mestek, Inc.](#)
 2. [Arrow United Industries; a division of Mestek, Inc.](#)
 3. [Cesco Products; a division of Mestek, Inc.](#)
 4. [Greenheck Fan Corporation.](#)
 5. [Lloyd Industries, Inc.](#)
 6. [McGill AirFlow LLC.](#)
 7. [Metal Form Manufacturing, Inc.](#)
 8. [Nailor Industries Inc.](#)
 9. [NCA Manufacturing, Inc.](#)
 10. [Pottorff.](#)
 11. [Ruskin Company.](#)
 12. [Vent Products Company, Inc.](#)
 13. [Young Regulator Company.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Low-leakage rating[, **with linkage outside airstream,**] and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
- C. Frames:
1. **[Hat] [U] [Angle]** shaped.
 2. **[0.094-inch- (2.4-mm-) thick, galvanized sheet steel] [0.05-inch- (1.3-mm-) thick stainless steel].**
 3. **[Mitered and welded] [Interlocking, gusseted]** corners.
- D. Blades:
1. Multiple blade with maximum blade width of **[6 inches (152 mm)] [8 inches (200 mm)].**
 2. **[Parallel] [Parallel- and opposed] [Opposed]**-blade design.
 3. **[Galvanized-steel] [Stainless steel] [Aluminum].**
 4. **[0.064 inch (1.62 mm) thick single skin] [or] [0.0747-inch- (1.9-mm-) thick dual skin].**
 5. Blade Edging: **[Closed-cell neoprene] [PVC].**
 6. Blade Edging: Inflatable seal blade edging, or replaceable rubber seals.
- E. Blade Axles: **1/2-inch- (13-mm-) diameter; [galvanized steel] [stainless steel] [nonferrous metal];** blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
1. Operating Temperature Range: From **minus 40 to plus 200 deg F** (minus 40 to plus 93 deg C).
- F. Bearings:

1. **[Oil-impregnated bronze] [Molded synthetic] [Oil-impregnated stainless-steel sleeve] [Stainless-steel sleeve].**
2. Dampers in ducts with pressure classes of **3-inch wg (750 Pa)** or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
3. Thrust bearings at each end of every blade.

2.7 FIRE DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Air Balance Inc.; a division of Mestek, Inc.](#)
 2. [Arrow United Industries; a division of Mestek, Inc.](#)
 3. [Cesco Products; a division of Mestek, Inc.](#)
 4. [Greenheck Fan Corporation.](#)
 5. [Nailor Industries Inc.](#)
 6. [NCA Manufacturing, Inc.](#)
 7. [Pottorff.](#)
 8. [Prefco; Perfect Air Control, Inc.](#)
 9. [Ruskin Company.](#)
 10. [Vent Products Company, Inc.](#)
 11. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)
 12. **<Insert manufacturer's name>.**
 13. or approved equal.
- B. Type: **[Static] [Dynamic] [Static and dynamic]**; rated and labeled according to UL 555 by an NRTL, and requirements of NFPA 90A, 92A, 92B, and 101, as applicable.
- C. Closing rating in ducts up to **[4-inch wg (1-kPa)] <Insert value>** static pressure class and minimum **[2000-fpm (10-m/s)] <Insert value>** velocity.
- D. Fire Rating: **[1-1/2] [and] [3]** hours.
- E. Frame: **[Curtain type with blades inside airstream] [Curtain type with blades outside airstream] [Multiple-blade type] [Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream]**; fabricated with roll-formed, **0.034-inch- (0.85-mm-)** thick galvanized steel; with mitered and interlocking corners.
- F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.
1. Minimum Thickness: **[0.05 (1.3 mm)] [0.138 inch (3.5 mm)] [or] [0.39 inch (9.9 mm)]** thick, as indicated, and of length to suit application.
 2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.
- G. Mounting Orientation: Vertical or horizontal as indicated.

- H. Ceiling Dampers: Galvanized steel, 22 gage frame and 16 gage flap, two layers 0.125 inch ceramic fiber on top side [, **and one layer on bottom side for round flaps**], with locking clip. Configure with blades [**in**] [**out**] of air stream.
- I. Horizontal Dampers: Galvanized steel, 22 gage frame, stainless steel closure spring, and lightweight, heat retardant non asbestos fabric blanket.
- J. Curtain Type Dampers: Galvanized steel with interlocking blades. Provide stainless steel closure springs and latches for [horizontal installations] [closure under air flow conditions]. Configure with blades out of air stream except for [**1.0 inch**] <Insert **number**> pressure class ducts up to 12 inches in height.
- K. Multiple Blade Dampers: 16 gage galvanized steel frame and blades, oil impregnated bronze or stainless steel sleeve bearings and plated steel axles, 1/8 x 1/2 inch plated steel concealed linkage, stainless steel closure spring, blade stops, and lock.
- L. Blades: Roll-formed, interlocking, [**0.024-inch- (0.61-mm)**] [**0.034-inch- (0.85-mm-)**] thick, galvanized sheet steel. In place of interlocking blades, use full-length, **0.034-inch- (0.85-mm-)** thick, galvanized-steel blade connectors.
- M. Blade Stops: Each blade stop (at top and bottom of damper frame) shall occupy no more than 1/2" of the damper opening area to allow for maximum free area and to minimize pressure loss across the damper.
- N. Horizontal Dampers: Include blade lock and stainless-steel closure spring.
- O. Heat-Responsive Device: Replaceable, [**165 deg F (74 deg C)**] [**212 deg F (100 deg C)**] <Insert **temperature**> rated, fusible links.
- P. Heat-Responsive Device: [**Electric**] [**Pneumatic**], [**resettable**] [**replaceable**] link and switch package, factory installed, [**165 deg F (74 deg C)**] [**and**] [**212 deg F (100 deg C)**] <Insert **temperature**> rated.
- Q. Source Quality Control
 - 1. Factory Tests: Factory cycle damper and actuator assemblies to assure proper operation.

2.8 CEILING RADIATION DAMPERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. [Air Balance Inc.; a division of Mestek, Inc.](#)
 - 2. [Cesco Products; a division of Mestek, Inc.](#)
 - 3. [Nailor Industries Inc.](#)
 - 4. [Pottorff.](#)
 - 5. [Prefco; Perfect Air Control, Inc.](#)
 - 6. [Ruskin Company.](#)
 - 7. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)

8. **<Insert manufacturer's name>**.
9. or approved equal.

B. General Requirements:

1. Labeled according to UL 555C by an NRTL.
2. Comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL's "Fire Resistance Directory."

C. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.

D. Blades: Galvanized sheet steel with refractory insulation.

E. Heat-Responsive Device: Replaceable, [165 deg F (74 deg C)] [212 deg F (100 deg C)] **<Insert temperature>** rated, fusible links.

F. Fire Rating: [1] [2] [3] **<Insert number>** hours.

2.9 SMOKE DAMPERS

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Air Balance Inc.; a division of Mestek, Inc.](#)
2. [Cesco Products; a division of Mestek, Inc.](#)
3. [Greenheck Fan Corporation.](#)
4. [Nailor Industries Inc.](#)
5. [Pottorff.](#)
6. [Ruskin Company.](#)
7. **<Insert manufacturer's name>**.
8. or approved equal.

B. General Requirements: Label according to UL 555S by an NRTL. All automatically actuated smoke dampers shall be furnished and installed under this Section per the manufacturer's UL-conforming installation instructions.

C. Standards and Testing: Smoke dampers shall be tested, rated, and labeled in accordance with Underwriters' Laboratories Standard UL 555S, listing R13447 for:

1. Leakage Class I (4 cfm/SF at 1 inch W.G.) performance after 30 minute exposure at [250 degrees F] [+350 degrees F]; required for applications in which supply fans rated for more than 3 inches W.G. of external static pressure serve more than one smoke control zone.
2. Leakage Class II (10 cfm/SF at 1 inch W.G.) performance after 30 minute exposure at [250 degrees F] [+350 degrees F]; suitable for applications in which supply or return fans rated for 3 inches W.G. or less of external static pressure serve more than one smoke control zone.

D. Dampers shall bear the AMCA Certified Ratings Seal for Air Performance in accordance with AMCA 511.

- E. Dampers shall meet requirements for smoke dampers in accordance with:
1. NFPA 90A, 92A, 92B, and 101, as applicable.
 2. Applicable Building Codes.
- F. Damper frames shall be constructed of **[minimum #16 gauge galvanized steel channel] [or] [6063 T5 aluminum channel, 0.125 inch wall thickness,]** and shall have flanges for duct mounting. All blade-to-blade linkage on each section shall be concealed within the damper frame. In no case shall the section linkage be exposed to the air stream. The maximum size of single section dampers shall be 60 inches or less in width and 72 inches or less in height. Larger dampers shall be made up of multiple damper sections, with each section not larger than 48 inches or less in width and 72 inches or less in height. The blades of multiple section dampers shall be interconnected with appropriate jackshafts.
- G. Smoke Detector: Integral, factory wired for single-point connection.
- H. Frame: Hat-shaped, **0.094-inch- (2.4-mm-)** thick, galvanized sheet steel, with **[welded] [interlocking, gusseted] [or] [mechanically attached] corners[and mounting flange]**.
- I. Blades: Roll-formed, horizontal, **[interlocking] [overlapping]**, **[0.034-inch- (0.85-mm-)] [0.063-inch- (1.6-mm)]** thick, galvanized sheet steel **[or] [6063 T5 extruded aluminum]**.
- J. Damper blades shall not exceed 6 inches in width. Larger damper sections shall be of multiple blade type construction. Blade pins and linkage shall be zinc-plated steel. Bearings shall be stainless steel or oil-impregnated sintered bronze. Blade seals shall be silicone rubber, compression type flexible steel, or a combination of both.
- K. Blade Stops: Each blade stop (at top and bottom of damper frame) shall occupy no more than 1/2" of the damper opening area to allow for maximum free area and to minimize pressure loss across the damper.
- L. Operators shall be mounted by the damper manufacturer at the time of damper fabrication and shall be provided with the damper as a single unit. Operators shall be qualified and labeled under UL 555S, latest version. Operators shall be **[pneumatic, 20 psi, rated to 250 degrees F] [or] [electric, 120 VAC, rated to [250 degrees F] [350 degrees F]]**. The operators shall be of sufficient demonstrated power to open the dampers from a fully-closed position against a **[4] [6] [8]** inch W.G. static pressure differential and to close the dampers from a fully-open flow rate of **[2000] [3000] [4000]** fpm. Operators shall be mounted outside of the air stream and shall be for **[normally-open] [or] [normally-closed]** damper operation **[as shown on the drawings]**.
- M.
- N. Rated pressure and velocity to exceed design airflow conditions.

- O. Mounting Sleeve: Factory-installed, [0.039-inch- (1.0-mm-)] [0.05-inch- (1.3-mm-)] thick, galvanized sheet steel; length to suit wall or floor application[**with factory-furnished silicone caulking**].
- P. Damper Motors: [**Modulating**] [**or**] [**two-position**] action.
- Q. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
 3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
 4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of **150 in. x lbf** (17 N x m) and breakaway torque rating of **150 in. x lbf** (17 N x m).
 5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at **minus 40 deg F** (minus 40 deg C).
 6. Nonspring-Return Motors: For dampers larger than **25 sq. ft.** (2.3 sq. m), size motor for running torque rating of **150 in. x lbf** (17 N x m) and breakaway torque rating of **300 in. x lbf** (34 N x m).
 7. Electrical Connection: [**115 V, single phase, 60 Hz**] <Insert values>.
- R. Accessories:
1. Auxiliary switches for [**signaling**] [**fan control**] [**or**] [**position indication**].
 2. [**Momentary test switch**] [**Test and reset switches**], [**damper**] [**remote**] mounted.
- S. Source Quality Control
1. Factory Tests: Factory cycle damper and actuator assemblies to assure proper operation. Assemblies shall have passed a 20,000-cycle test.
- 2.10 COMBINATION FIRE AND SMOKE DAMPERS
- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Air Balance Inc.; a division of Mestek, Inc.](#)
 2. [Cesco Products; a division of Mestek, Inc.](#)
 3. [Greenheck Fan Corporation.](#)
 4. [Nailor Industries Inc.](#)

5. [Pottorff](#).
 6. [Ruskin Company](#).
 7. **<Insert manufacturer's name>**.
 8. or approved equal.
- B. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.
1. Leakage Class II (10 cfm/SF at 1 inch W.G.) at [250 degrees F] [350 degrees F], required for applications in which supply or return fans serve more than one smoke control zone.
- C. Dampers shall bear the AMCA Certified Ratings Seal for Air Performance in accordance with AMCA 511.
- D. Dampers shall meet requirements for smoke dampers in accordance with:
1. NFPA 90A, 92A, 92B, and 101, as applicable.
 2. Applicable Building Codes.
- E. Dampers shall be of multi-blade type construction. Damper frames shall be constructed of minimum #16 gauge galvanized steel channel and shall have flanges for duct mounting. The maximum size of single section dampers shall not exceed 60 inches in width or 72 inches in height. Larger dampers shall be made up of multiple damper sections, with each section no larger than 48 inches in width and 72 inches in height. The blades of multiple section dampers shall be interconnected with appropriate jackshafts.
- F. Closing rating in ducts up to [4-inch wg (1-kPa)] **<Insert value>** static pressure class and minimum [2000-fpm (10-m/s)] **<Insert value>** velocity.
- G. Fire Rating: [1-1/2] [and] [3] hours.
- H. Frame: Hat-shaped, 0.094-inch- (2.4-mm-) thick, galvanized sheet steel, with [welded] [interlocking, gusseted] [or] [mechanically attached] corners[and mounting flange].
- I. Heat-Responsive Device: [Resettable] [Replaceable], [165 deg F (74 deg C)] [212 deg F (100 deg C)] rated, [fusible links] [fire-closure device], shall cause the damper to fully close by spring action and lock in a closed position. Spring shall have sufficient demonstrated power to fully close the damper against a fully-open flow rate of [2000] [3000] [4000] fpm. Fusible link and spring actuator shall be mounted by the damper manufacturer at the time of damper fabrication and shall be provided with the damper as a single unit.
- J. Heat-Responsive Device: [Electric] [Pneumatic] resettable [link] [device] and switch package, factory installed, rated, shall cause the damper to fully close by spring action and lock in a closed position. Spring shall have sufficient demonstrated power to fully close the damper against a fully-open flow rate of [2000] [3000] [4000] fpm. Fusible link and spring actuator shall be mounted by the damper manufacturer at the time of damper fabrication and shall be provided with the damper as a single unit.

- K. Smoke Detector: Integral, factory wired for single-point connection.
- L. Blades: Roll-formed, horizontal, [**interlocking**] [**overlapping**], [**0.063-inch- (1.6-mm-)**] [**0.034-inch- (0.85-mm-)**] thick, galvanized sheet steel.
- M. Damper blades shall not exceed 6 inches in width and shall be constructed of galvanized steel with minimum [**#14**] [**#16**] gauge equivalent thickness. Blade pins and linkage shall be zinc-plated steel. Bearings shall be stainless steel or oil-impregnated sintered bronze. Blade and jamb seals for smoke control shall be [**silicone rubber,**] [**compression type flexible steel,**] [**metal-to-metal incorporated into the blade shapes,**] [**or**] [**a combination of**] [**both**], **UL 555S rated to [250 degrees F] [350 degrees F]**. Flame seals shall be galvanized steel, rated to [**1900 degrees F**] <Insert number>.
- N. Blade Stops: Each blade stop (at top and bottom of damper frame) shall occupy no more than 1/2" of the damper opening area to allow for maximum free area and to minimize pressure loss across the damper.
- O. Operators for smoke control shall be mounted by the damper manufacturer at the time of damper fabrication and shall be provided with the damper as a single unit. Smoke control operators shall be qualified to and labeled under UL 555S, latest version. Operators shall be [**pneumatic, 20 psi, rated to 250 degrees F**] [**or**] [**electric, 120 VAC, rated to [250 degrees F] [350 degrees F]**]. The operators shall be of sufficient demonstrated power to open the dampers from a fully-closed position against a static pressure differential of 4 inches W.G. and to close the dampers against a fully-open flow rate of 3500 fpm. Operators shall be mounted [**outside**] [**inside**] of the air stream and shall be for [**normally-open**] [**or**] [**normally-closed**] damper operation [**as shown on the drawings**].
- P.
- Q. Rated pressure and velocity to exceed design airflow conditions.
- R. Mounting Sleeve: Factory-installed, [**0.039-inch- (1.0-mm-)**] [**0.05-inch- (1.3-mm-)**] thick, galvanized sheet steel; length to suit wall or floor application[**with factory-furnished silicone caulking**].
- S. Master control panel for use in dynamic smoke-management systems.
- T. Damper Motors: [**Modulating**] [**or**] [**two-position**] action.
- U. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of **150 in. x lbf** (17 N x m) and breakaway torque rating of **150 in. x lbf** (17 N x m).
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at **minus 40 deg F** (minus 40 deg C).
6. Nonspring-Return Motors: For dampers larger than **25 sq. ft.** (2.3 sq. m), size motor for running torque rating of **150 in. x lbf** (17 N x m) and breakaway torque rating of **300 in. x lbf** (34 N x m).
7. Electrical Connection: 115 V, single phase, 60 Hz.

V. Accessories:

1. Auxiliary switches for [**signaling**] [**fan control**] [**or**] [**position indication**].
2. [**Momentary test switch**] [**Test and reset switches**], [**damper**] [**remote**] mounted.

2.11 CORRIDOR DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Air Balance Inc.; a division of Mestek, Inc.](#)
 2. [Cesco Products; a division of Mestek, Inc.](#)
 3. [Nailor Industries Inc.](#)
 4. [Pottorff.](#)
 5. [Ruskin Company.](#)
 6. **<Insert manufacturer's name>**.
 7. or approved equal.
- B. General Requirements: Label combination fire and smoke dampers according to UL 555 for 1-hour or 1-1/2-hour rating by an NRTL.
- C. Heat-Responsive Device: Replaceable, [**165 deg F** (74 deg C)] [**212 deg F** (100 deg C)] rated, fusible links.
- D. Heat-Responsive Device: [**Electric**] [**Pneumatic**] resettable [**link**] [**device**] and switch package, factory installed, rated.
- E. Frame: Hat-shaped, **0.094-inch-** (2.4-mm-) thick, galvanized sheet steel, with [**welded**] [**interlocking, gusseted**] [**or**] [**mechanically attached**] corners[**and mounting flange**].
- F. Blades: Roll-formed, horizontal, [**interlocking**] [**overlapping**], **0.034-inch-** (0.85-mm-) thick, galvanized sheet steel.

- G. Mounting Sleeve: Factory-installed, [0.039-inch- (1.0-mm-)] [0.05-inch- (1.3-mm-)] thick, galvanized sheet steel; length to suit wall or floor application.
- H. Damper Motors: **[Modulating]** [or] **[two-position]** action.
- I. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - 2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
 - 3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
 - 4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
 - 5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F (minus 40 deg C).
 - 6. Nonspring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
 - 7. Electrical Connection: 115 V, single phase, 60 Hz.

2.12 SPLITTER DAMPERS

- A. Material: Same gage as duct to 24 inches size in either direction, and two gages heavier for sizes over 24 inches.
- B. Blade: Fabricate of **[single]** **[double]** thickness sheet metal to streamline shape, secured with continuous hinge or rod.
- C. Operator: Minimum 1/4 inch diameter rod in self aligning, universal joint action, flanged bushing with set screw.
- D. Single Blade Dampers: Fabricate for duct sizes up to **[6 x 30 inch.]** **[12 x 48 inch.]**
- E. Multi-Blade Damper: Fabricate of opposed blade pattern with maximum blade sizes 8 x 72 inch. Assemble center and edge crimped blades in prime coated or galvanized channel frame with suitable hardware.
- F. End Bearings: Except in round ductwork 12 inches and smaller, provide end bearings. On multiple blade dampers, provide oil-impregnated nylon or sintered bronze bearings.
- G. Quadrants:

1. Provide locking, indicating quadrant regulators on single and multi-blade dampers.
2. On insulated ducts mount quadrant regulators on stand-off mounting brackets, bases, or adapters.
3. Where rod lengths exceed 30 inches provide regulator at both ends.

2.13 FLANGE CONNECTORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Ductmate Industries, Inc.](#)
2. [Nexus PDQ; Division of Shilco Holdings Inc.](#)
3. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

B. Description: **[Add-on] [or] [roll-formed]**, factory-fabricated, slide-on transverse flange connectors, gaskets, and components.

C. Material: Galvanized steel.

D. Gage and Shape: Match connecting ductwork.

2.14 DUCT SILENCERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Dynasonics.](#)
2. [Industrial Noise Control, Inc.](#)
3. [McGill AirFlow LLC.](#)
4. [Ruskin Company.](#)
5. [Vibro-Acoustics.](#)
6. **<Insert manufacturer's name>**.
7. or approved equal.

B. General Requirements:

1. Factory fabricated.
2. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E 84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Shape:

1. Rectangular straight with splitters or baffles.

2. Round straight with center bodies or pods.
 3. Rectangular elbow with splitters or baffles.
 4. Round elbow with center bodies or pods.
 5. Rectangular transitional with splitters or baffles.
- D. Rectangular Silencer Outer Casing: ASTM A 653/A 653M, [G90 (Z275)] [G60 (Z180)], galvanized sheet steel, [0.034 inch (0.85 mm)] [0.040 inch (1.02 mm)] thick.
- E. Round Silencer Outer Casing: ASTM A 653/A 653M, [G90 (Z275)] [G60 (Z180)], galvanized sheet steel.
1. Sheet Metal Thickness for Units up to 24 Inches (600 mm) in Diameter: 0.034 inch (0.85 mm) thick.
 2. Sheet Metal Thickness for Units 26 through 40 Inches (660 through 1000 mm) in Diameter: 0.040 inch (1.02 mm) thick.
 3. Sheet Metal Thickness for Units 42 through 52 Inches (1060 through 1300 mm) in Diameter: 0.05 inch (1.3 mm) thick.
 4. Sheet Metal Thickness for Units 54 through 60 Inches (1370 through 1500 mm) in Diameter: 0.064 inch (1.62 mm) thick.
- F. Inner Casing and Baffles: ASTM A 653/A 653M, [G90 (Z275)] [G60 (Z180)] galvanized sheet metal, 0.034 inch (0.85 mm) thick, and with 1/8-inch- (3-mm-) diameter perforations.
- G. Special Construction:
1. Suitable for outdoor use.
 2. High transmission loss[**to achieve STC 45**].
- H. Connection Sizes: Match connecting ductwork unless otherwise indicated.
- I. Principal Sound-Absorbing Mechanism:
1. Controlled impedance membranes and broadly tuned resonators without absorptive media.
 2. **[Dissipative] [Film-lined]** type with fill material.
 - a. Fill Material: **[Inert and vermin-proof fibrous material, packed under not less than 5 percent compression] [Inert and vermin-proof fibrous material, packed under not less than 15 percent compression] [Moisture-proof nonfibrous material]**.
 - b. Erosion Barrier: Polymer bag enclosing fill, and heat sealed before assembly.
 3. Lining: **[None] [Mylar] [Tedlar] [Fiberglas cloth] <Insert material>**.
- J. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.

1. Joints: **[Lock formed and sealed] [continuously welded] [or] [flanged connections]**.
 2. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
 3. Reinforcement: Cross or trapeze angles for rigid suspension.
- K. Accessories:
1. Integral **[1-1/2] [3]-hour** fire damper with access door.**[Access door to be high transmission loss to match silencer.]**
 2. Factory-installed end caps to prevent contamination during shipping.
 3. Removable splitters.
 4. Airflow measuring devices.
- L. Source Quality Control: Test according to ASTM E 477.
1. Testing **[of mockups]**to be witnessed by **[DEN Project Manager] [Owner]**.
 2. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least **2000-fpm (10-m/s)** face velocity.
 3. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or **6-inch wg (1500-Pa)** static pressure, whichever is greater.
- M. Capacities and Characteristics:
1. Configuration: **[Straight] [90-degree elbow] <Insert configuration>**.
 2. Shape: **[Rectangular] [Round]**.
 3. Attenuation Mechanism: **[Acoustical glass fiber] [Acoustical glass fiber with protective film liner] [Helmholtz resonator mechanism with no internal media]**.
 4. Maximum Pressure Drop: **[0.35-inch wg (0.09 kPa)] <Insert value>**.
 5. Casing:
 - a. Attenuation: **[Standard] [High transmission loss]**.
 - b. Outer Material: **[Galvanized steel] [Stainless steel] [Aluminum]**.
 - c. Inner Material: **[Galvanized steel] [Stainless steel] [Aluminum]**.
 6. Velocity Range: **<Insert fps (L/s)> to <Insert fps (L/s)>**.
 7. End Connection: **[1-inch (25-mm) slip joint] [Flange]**.
 8. Length: **<Insert inches (mm)>**.
 9. Face Dimension:
 - a. Width: **<Insert inches (mm)>**.
 - b. Height: **<Insert inches (mm)>**.
 10. Face Velocity: **<Insert fpm (m/s)>**.
 11. Dynamic Insertion Loss: **<Insert dBA>**.
 12. Generated Noise: **<Insert dBA>**.
 13. Accessories:
 - a. Access door.

b. Birdscreen.

2.15 CROSS-TALK SILENCERS

- A. Description: Duct sections with sheet metal outer casing, sound absorbing fill material [**and inner casing of perforated sheet metal**]; incorporating interior baffles of similar construction. Fabricate in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible.
- B. Configuration: Rectangular, lined [**with inner casing**] with splitters with radiused nosed and contoured tails.
- C. Materials:
1. Outer Casing: Minimum 22 gage galvanized steel with mastic filled lock formed or welded seams, 3 inch long, 11 gage slip joint on both ends.
 2. Inner Casing and Splitters: Minimum 24 gage thick perforated galvanized steel.
 3. Fill: Glass fiber or mineral wool of minimum 3 lb/cu ft density.
 4. Fill Liner: Bonded glass fiber matting covered with 1 mil mylar film.
- D. Ratings: As shown in schedules on the drawings.

2.16 ACOUSTIC HOUSINGS

- A. Description: Modular panels, including access doors and windows, nominal 4 inches thick, with filled outer and inner casing. Fabricate and support in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible.
- B. Materials:
1. Outer Casing: Minimum 18 gage galvanized steel stiffened as required, with mastic filled lock formed seams for [**internal flange butt**] [**covering strip butt**] [**overlapping lip**] [**tongue and groove**] joining.
 2. Inner Casing and Splitters: Minimum 22 gage thick perforated galvanized steel.
 3. Fill: Glass fiber or mineral wool of minimum 4 lb/cu ft density.
 4. Fill Liner: Bonded glass fiber matting covered with 1 mil mylar film.
 5. Window: **<Insert number>** x **<Insert number>** inch double glazed with 1/4 inch safety glass.
- C. Rating: As shown in equipment schedules on the drawings.

2.17 DUCTWORK LAGGING

- A. Acoustic Insulation: [**2 inches**] **<Insert number>** thick, 3 to 5 lb/cu ft density glass fiber or mineral wool insulation.
- B. Covering: [**Plaster**] [**or**] [**gypsum board**] with surface weight minimum 4 lb/sq ft.

2.18 ACOUSTICAL LOUVERS

- A. Configuration: [8] [12] <Insert number> inch [200] [300] <Insert number> mm deep louvers with blades on 45 degree slope; sound absorbing fill material, and inner surface of perforated sheet metal, heavy channel frame, birdscreen.
- B. Materials:
1. Louvers: [16 gage galvanized steel] [or] [12 gage extruded aluminum], welded assembly, with factory [prime coat] [baked enamel] [color anodized] finish.
 2. Inner Surface: Minimum 24 gage thick perforated galvanized steel.
 3. Fill: Glass fiber or mineral wool of minimum [4 lb/cu ft] [3 lb/cu ft] density.
 4. Fill Liner: [Bonded glass fiber matting.] [1 mil mylar film.]
 5. Birdscreen: [1] [1/2] [3/4] inch square wire mesh.
 6. Mounting: [Interior] [Exterior] [flat flange.] [angle flange.] [Screw holes in jambs.] [Masonry strap anchors.]
- C. Rating: As shown in equipment schedules on the drawings.

2.19 TURNING VANES

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Ductmate Industries, Inc.](#)
 2. [Duro Dyne Inc.](#)
 3. [Elgen Manufacturing.](#)
 4. [METALAIRE, Inc.](#)
 5. [SEMCO Incorporated.](#)
 6. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)
 7. <Insert manufacturer's name>.
 8. or approved equal.
- B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.
1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.
- C. Manufactured Turning Vanes for Nonmetal Ducts: Fabricate curved blades of resin-bonded fiberglass with acrylic polymer coating; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.
- D. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vanes and Vane Runners," and 4-4, "Vane Support in Elbows."
- E. Vane Construction: [Single] [Double] wall.

- F. Vane Construction: Single wall for ducts up to [48 inches (1200 mm)] <Insert dimension> wide and double wall for larger dimensions.

2.20 REMOTE DAMPER OPERATORS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Pottorff.](#)
2. [Ventfabrics, Inc.](#)
3. [Young Regulator Company.](#)
4. <Insert manufacturer's name>.
5. or approved equal.

- B. Description: Cable system designed for remote manual damper adjustment.

- C. Tubing: [Brass] [Copper] [Aluminum].

- D. Cable: [Stainless steel] [Steel].

- E. Wall-Box Mounting: [Recessed] [Surface].

- F. Wall-Box Cover-Plate Material: [Steel] [Stainless steel].

2.21 DUCT-MOUNTED ACCESS DOORS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [American Warming and Ventilating; a division of Mestek, Inc.](#)
2. [Cesco Products; a division of Mestek, Inc.](#)
3. [Ductmate Industries, Inc.](#)
4. [Elgen Manufacturing.](#)
5. [Flexmaster U.S.A., Inc.](#)
6. [Greenheck Fan Corporation.](#)
7. [McGill AirFlow LLC.](#)
8. [Nailor Industries Inc.](#)
9. [Pottorff.](#)
10. [Ventfabrics, Inc.](#)
11. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)
12. <Insert manufacturer's name>.
13. or approved equal.

- B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2 (7-2M), "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct."

1. Door:

- a. Double wall, rectangular.
 - b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
 - c. Vision panel.
 - d. Hinges and Latches: **1-by-1-inch (25-by-25-mm)** butt or piano hinge and cam latches.
 - e. Fabricate doors airtight and suitable for duct pressure class.
2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
 3. Number of Hinges and Locks:
 - a. Access Doors Less Than **12 Inches (300 mm)** Square: No hinges and two sash locks.
 - b. Access Doors up to **[18 Inches (460 mm)]** Square: **[Two hinges]** **[Continuous]** and two sash locks.
 - c. Access Doors up to **24 by 48 Inches (600 by 1200 mm)**: **[Three hinges]** **[Continuous]** and two compression latches **[with outside and inside handles]**.
 - d. Access Doors Larger Than **24 by 48 Inches (600 by 1200 mm)**: **[Four hinges]** **[Continuous]** and two compression latches with outside and inside handles.

C. Pressure Relief Access Door:

1. Door and Frame Material: Galvanized sheet steel.
2. Door: **[Single wall]** **[Double wall with insulation fill]** with metal thickness applicable for duct pressure class.
3. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.
4. Factory set at **[3.0- to 8.0-inch wg (800 to 2000 Pa)]** **[10-inch wg (2500 Pa)]** **<Insert value>**.
5. Doors close when pressures are within set-point range.
6. Hinge: Continuous piano.
7. Latches: Cam.
8. Seal: Neoprene or foam rubber.
9. Insulation Fill: **1-inch- (25-mm-)** thick, fibrous-glass or polystyrene-foam board.

2.22 DUCT ACCESS PANEL ASSEMBLIES

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Ductmate Industries, Inc.](#)
2. [Flame Gard, Inc.](#)
3. [3M.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

B. Labeled according to UL 1978 by an NRTL.

- C. Panel and Frame: Minimum thickness [0.0528-inch (1.3-mm) **carbon**] [0.0428-inch (1.1-mm) **stainless**] steel.
- D. Fasteners: [**Carbon**] [**Stainless**] steel. Panel fasteners shall not penetrate duct wall.
- E. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F (1093 deg C).
- F. Minimum Pressure Rating: 10-inch wg (2500 Pa), positive or negative.

2.23 DUCT TEST HOLES

- A. Temporary Test Holes: Cut or drill holes in ducts as required. Cap with neat patches, neoprene plugs, threaded plugs, or threaded or twist-on metal caps.
- B. Permanent Test Holes: Factory fabricated, airtight flanged fittings with screw cap. Provide extended neck fittings to clear insulation.

2.24 FLEXIBLE CONNECTORS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Ductmate Industries, Inc.](#)
 - 2. [Duro Dyne Inc.](#)
 - 3. [Elgen Manufacturing.](#)
 - 4. [Ventfabrics, Inc.](#)
 - 5. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)
 - 6. **<Insert manufacturer's name>**.
 - 7. or approved equal.
- B. Materials: Flame-retardant or noncombustible fabrics.
- C. Coatings and Adhesives: Comply with UL 181, Class 1.
- D. Metal-Edged Connectors: Factory fabricated with a fabric strip [3-1/2 inches (89 mm)] [5-3/4 inches (146 mm)] wide attached to two strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized sheet steel or 0.032-inch- (0.8-mm-) thick aluminum sheets. Provide metal compatible with connected ducts.
- E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.
 - 1. Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).
 - 2. Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.
 - 3. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).
- F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.

1. Minimum Weight: 24 oz./sq. yd. (810 g/sq. m).
 2. Tensile Strength: 530 lbf/inch (93 N/mm) in the warp and 440 lbf/inch (77 N/mm) in the filling.
 3. Service Temperature: Minus 50 to plus 250 deg F (Minus 45 to plus 121 deg C).
- G. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.
1. Minimum Weight: 16 oz./sq. yd. (542 g/sq. m).
 2. Tensile Strength: 285 lbf/inch (50 N/mm) in the warp and 185 lbf/inch (32 N/mm) in the filling.
 3. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).
- H. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.
1. Minimum Weight: 14 oz./sq. yd. (474 g/sq. m).
 2. Tensile Strength: 450 lbf/inch (79 N/mm) in the warp and 340 lbf/inch (60 N/mm) in the filling.
 3. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).
- I. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.
1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.
 2. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
 3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
 4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
 6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
 7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch (6-mm) movement at start and stop.

2.25 FLEXIBLE DUCTS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Flexmaster U.S.A., Inc.](#)
 2. [McGill AirFlow LLC.](#)
 3. [Ward Industries, Inc.; a division of Hart & Cooley, Inc.](#)
 4. **<Insert manufacturer's name>.**
 5. or approved equal.

- B. Noninsulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire.
1. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 10 to plus 160 deg F (Minus 23 to plus 71 deg C).
- C. Noninsulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire.
1. Pressure Rating: 4-inch wg (1000 Pa) positive and 0.5-inch wg (125 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 20 to plus 175 deg F (Minus 29 to plus 79 deg C).
- D. Noninsulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire.
1. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
- E. Noninsulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire.
1. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
- F. Noninsulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil.
1. Pressure Rating: 8-inch wg (2280 Pa) positive or negative.
 2. Maximum Air Velocity: 5000 fpm (25 m/s).
 3. Temperature Range: Minus 100 to plus 435 deg F (Minus 73 to plus 224 deg C).
- G. Insulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.
1. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 10 to plus 160 deg F (Minus 23 to plus 71 deg C).
 4. Insulation R-value: [Comply with ASHRAE/IESNA 90.1] <Insert value>.
- H. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; [polyethylene] [aluminized] vapor-barrier film.

1. Pressure Rating: 4-inch wg (1000 Pa) positive and 0.5-inch wg (125 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 20 to plus 175 deg F (Minus 29 to plus 79 deg C).
 4. Insulation R-Value: **[Comply with ASHRAE/IESNA 90.1] <Insert value>**.
- I. Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire; fibrous-glass insulation; **[polyethylene] [aluminized]** vapor-barrier film.
1. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
 4. Insulation R-value: **[Comply with ASHRAE/IESNA 90.1] <Insert value>**.
- J. Insulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire; fibrous-glass insulation; **[polyethylene] [aluminized]** vapor-barrier film.
1. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
 2. Maximum Air Velocity: 4000 fpm (20 m/s).
 3. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
 4. Insulation R-value: **[Comply with ASHRAE/IESNA 90.1] <Insert value>**.
- K. Insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil; fibrous-glass insulation; **[polyethylene] [aluminized]** vapor-barrier film.
1. Pressure Rating: 8-inch wg (2280 Pa) positive or negative.
 2. Maximum Air Velocity: 5000 fpm (25 m/s).
 3. Temperature Range: Minus 20 to plus 250 deg F (Minus 29 to plus 121 deg C).
 4. Insulation R-value: **[Comply with ASHRAE/IESNA 90.1] <Insert value>**.
- L. Flexible Duct Connectors:
1. Clamps: **[Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action] [Nylon strap]** in sizes 3 through 18 inches (75 through 460 mm), to suit duct size.
 2. Non-Clamp Connectors: **[Adhesive] [Liquid adhesive plus tape] [Adhesive plus sheet metal screws]**.
- 2.26 DUCT SECURITY BARS
- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Carnes](#).
 2. [KEES, Inc.](#)
 3. [Lloyd Industries, Inc.](#)

4. [Metal Form Manufacturing, Inc.](#)
 5. [Price Industries.](#)
 6. **<Insert manufacturer's name>.**
 7. or approved equal.
- B. Description: **[Field-fabricated] [Factory-fabricated and field-installed] [Field- or factory-fabricated and field-installed]** duct security bars.
- C. Configuration:
1. Frame: **[2 by 1/4 inch (51 by 6 mm) flat frame] [2-1/2 by 2-1/2 by 1/4 inch (64 by 64 by 6 mm) angle] <Insert values>.**
 2. Sleeve: **[0.1345-inch (3.4-mm)] [3/16-inch (4.8-mm)] <Insert size>, [continuously welded] [bent] steel frames with [1-by-1-by-3/16-inch (25-by-25-by-4.8-mm)] [1-1/2-by-1-1/2-by-1/8-inch (38-by-38-by-3.2-mm)] <Insert size> angle frame [factory welded to 1 end] [furnished loose for field welding on other end].** To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
 3. Horizontal Bars: **[1/2 inch (13 mm)] [2 by 1/4 inch (50 by 6 mm)] <Insert values>.**
 4. Vertical Bars: **[1/2 inch (13 mm)] [3/4 inch (19 mm)] [1 inch (25 mm)] [2 by 1/4 inch (51 by 6 mm)] <Insert value>.**
 5. Bar Spacing: **[6 inches (150 mm)] <Insert value>.**
 6. Mounting: **[Metal deck or roofing] [Bolted or welded] [Bolted or welded with masonry anchors] [Ductwork or other framing] [Poured in place or set with concrete block] [Welded or bolted to one wall (one side only)] [Bar extends 6 inches (150 mm) into wall].**

2.27 DUCT ACCESSORY HARDWARE

- A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.
- B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

2.28 END SWITCHES

- A. Coordinate requirements for end switches on modulating dampers (control, fire/smoke, etc) with the Division 26 contractors. End switches shall be provided by the Division 26 Contractor and installed by the Division 26 Contractor.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Verify that electric power is available and of the correct characteristics.

3.2 INSTALLATION

- A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.
- B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.
- C. Install [**backdraft**] [**control**] dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.
- D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.
 - 1. Install steel volume dampers in steel ducts.
 - 2. Install aluminum volume dampers in aluminum ducts.
- E. Set dampers to fully open position before testing, adjusting, and balancing.
- F. Install test holes at fan inlets and outlets and elsewhere as indicated.
- G. Install fire[**and smoke**] dampers according to UL listing and as follows:
 - 1. Provide fire dampers [, **combination fire and smoke dampers**] [**and smoke dampers**] at locations indicated, where ducts and outlets pass through fire rated components [, **and where required by authorities having jurisdiction**]. Install with required perimeter mounting angles, sleeves, breakaway duct connections, corrosion resistant springs, bearings, bushings, and hinges.
 - 2. Install smoke dampers and combination smoke and fire dampers in accordance with NFPA 92A and 92B, as applicable.
 - 3. Demonstrate re-setting of fire dampers to DEN Project Manager's representative.
 - 4. Install dampers in accordance with manufacturer's UL Installation Instructions, labeling, and NFPA 90A at locations indicated on the drawings or required by Authority Having Jurisdiction. Any damper installation that is not in accordance with the manufacturer's UL Installation Instructions must be approved prior to installation.
 - a. Dampers must be accessible to allow inspection, adjustment, and replacement of components. The Contractor shall furnish any access doors in ductwork or plenums required to provide this access, and arrange for any access doors required in walls, ceilings, or other general building construction.
 - b. Install dampers square and free from racking.
 - c. The Contractor shall provide and install bracing for multiple section assemblies to support assembly weight and to hold against system pressure.

- d. Do not compress or stretch the damper frame into the duct or opening.
 - e. Attach multiple damper section assemblies together in accordance with manufacturer's instructions. Install support mullions as reinforcement between assemblies as required.
 - f. Handle dampers using the frame or sleeve. Do not lift or move dampers using blades, actuator, or jackshaft.
 - g. Install connections to actuators.
 - h. Attach multiple damper section assemblies together in accordance with manufacturer's instructions. Install support mullions as reinforcement between assemblies as required.
- H. Provide balancing dampers at points on supply, return, and exhaust systems where branches are taken from larger ducts as required for air balancing. Install minimum 2 duct widths from duct take-off.
- I. Use splitter dampers only where indicated.
- J. Provide balancing dampers on high velocity systems where indicated. Refer to Section 233600 "Air Terminal Units".
- K. Provide balancing dampers on duct take-off to diffusers, grilles, and registers, regardless of whether dampers are specified as part of the diffuser, grille, or register assembly.
- L. Install duct security bars. Construct duct security bars from 0.164-inch (4.18-mm) steel sleeve, continuously welded at all joints and 1/2-inch- (13-mm-) diameter steel bars, 6 inches (150 mm) o.c. in each direction in center of sleeve. Weld each bar to steel sleeve and each crossing bar. Weld 2-1/2-by-2-1/2-by-1/4-inch (63-by-63-by-6-mm) steel angle to 4 sides and both ends of sleeve. Connect duct security bars to ducts with flexible connections. Provide 12-by-12-inch (300-by-300-mm) hinged access panel with cam lock in duct in each side of sleeve.
- M. Install duct silencers in accordance with manufacturer's instructions.
- 1. Support duct silencers [**independent of**] [**rigidly to**] ductwork [.] [**with flexible duct connections, lagged with loaded vinyl sheet on inlet and outlet.**] Refer to Section 233113 "Metal Ductwork" and Section 233116 "Nonmetal Ductwork".
 - 2. Install cross-talk silencers in wall. Caulk wall penetrations; refer to Division 1 requirements.
 - 3. Lag ductwork, where indicated by wrapping with insulation and covering. Apply covering to be airtight. Do not attach covering rigidly to ductwork.
 - 4. Attach ductwork to acoustic louvers with flexible duct connections.
- N. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:
- 1. On both sides of duct coils.
 - 2. Upstream[**and downstream**] from duct filters.
 - 3. At outdoor-air intakes and mixed-air plenums.
 - 4. At drain pans and seals.

5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
 6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
 7. At each change in direction and at maximum **50-foot (15-m)** spacing.
 8. Upstream[**and downstream**] from turning vanes.
 9. Upstream or downstream from duct silencers.
 10. Control devices requiring inspection.
 11. **[Provide for cleaning kitchen exhaust ductwork in accordance with NFPA 96.]**
 12. Elsewhere as indicated.
- O. Install access doors with swing against duct static pressure.
- P. Access Door Sizes:
1. One-Hand or Inspection Access: **8 by 8 inches** (200 by 200 mm).
 2. Two-Hand Access: **12 by 8 inches** (300 by 200 mm).
 3. Head and Hand Access: **18 by 10 inches** (460 by 250 mm).
 4. Head and Shoulders Access: **21 by 14 inches** (530 by 355 mm).
 5. Body Access: **25 by 14 inches** (635 by 355 mm).
 6. Body plus Ladder Access: **25 by 17 inches** (635 by 430 mm).
- Q. Label access doors according to Section 230553 "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.
- R. Install flexible connectors to connect ducts to equipment.
- S. For fans developing static pressures of **5-inch wg** (1250 Pa) and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.
- T. Connect terminal units to supply ducts[**directly or**] with maximum [**12-inch (300-mm)**] **<Insert value>** lengths of flexible duct. Do not use flexible ducts to change directions.
- U. Connect diffusers or light troffer boots to ducts[**directly or**] with maximum [**60-inch (1500-mm)**] **<Insert value>** lengths of flexible duct clamped or strapped in place.
- V. Connect flexible ducts to metal ducts with [**adhesive**] [**liquid adhesive plus tape**] [**draw bands**] [**adhesive plus sheet metal screws**].
- W. Install duct test holes where required for testing and balancing purposes.
- X. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of **1/4-inch (6-mm)** movement during start and stop of fans.

3.3 LABELING

- A. Provide identification and access labels for all fire dampers, smoke dampers and combination fire smoke dampers.
- B. Labels shall be plastic with pressure-sensitive, permanent-type, self-adhesive back. Font shall be Arial, with a minimum text height of half an inch. Font color shall be red and background color shall be white.
- C. Identification labels shall be located on the damper sleeve or frame on both side of the damper. The label shall indicate "FIRE DAMPER", "SMOKE DAMPER" and/or "COMBINATION FIRE/SMOKE DAMPER".
- D. Access labels shall be provided to indicate locations for access to reset and maintain the damper. The label shall indicate "FIRE DAMPER ACCESS", "SMOKE DAMPER ACCESS" and/or "COMBINATION FIRE/SMOKE DAMPER ACCESS".
 - 1. Access label location shall be as follows:
 - a. Damper in continuous duct with duct access with 12 inches of the damper:
 - 1) Locate label on duct access door.
 - 2) Locate label on suspended ceiling tile
 - 3) Locate label on access door in hard ceiling.
 - b. Damper with removable grille/register on one side:
 - 1) Locate label on face of grille/register.
 - c. Damper in wall with no duct connection:
 - 1) Locate label on suspended ceiling tile
 - 2) Locate label on access door in hard ceiling.

3.4 FIELD QUALITY CONTROL

- A. Tests and Inspections:
 - 1. Operate dampers to verify full range of movement.
 - 2. Inspect locations of access doors and verify that purpose of access door can be performed.
 - 3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
 - 4. Inspect turning vanes for proper and secure installation.
 - 5. Operate remote damper operators to verify full range of movement of operator and damper.
- B. MANUFACTURER'S FIELD SERVICES FOR DUCT SILENCERS
- C. Prepare and place systems into service.

- D. Inspect installation periodically.
- E. Lag ductwork, where indicated by wrapping with insulation and covering. Apply covering to be air tight. Do not attach covering rigidly to ductwork.
- F. Attach ductwork to acoustic louvers with flexible duct connections. Refer to Section 15910 - Ductwork Accessories.
- G. Provide services of [AABC] [NEBB] testing agency to take noise measurement. Use meters meeting requirements of ASA 47 (ANSI S1.4).
- H. After start-up, final corrections and balancing of systems take octave band sound measurements over full audio frequency range in areas adjacent to mechanical equipment rooms, duct and pipe shafts, and other critical locations, as directed.
- I. Provide one-third octave band measurements of artificial sound sources in areas indicated as having critical requirements.
- J. Submit complete report of test results including sound curves.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233300

SECTION 233413 - AXIAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Tubeaxial fans.
 - 2. Vaneaxial fans.
 - 3. Mixed-flow fans.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, furnished specialties, and accessories for each fan.
 - 2. Certified fan performance curves with system operating conditions indicated.
 - 3. Certified fan sound-power ratings.
 - 4. Motor ratings and electrical characteristics, plus motor and electrical accessories.
 - 5. Material thickness and finishes, including color charts.
 - 6. Dampers, including housings, linkages, and operators.
 - 7. Fan speed controllers.
 - 8. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
 - a. Differentiate between manufacturer-installed and field-installed wiring.
 - 4. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.

5. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.
- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For axial fans to include in emergency, operation, and maintenance manuals.
 1. Include instructions for lubrication, motor and drive replacement, spare parts list, and wiring diagrams.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.
- C. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.
- C. Disassemble and reassemble units, as required for moving to final locations, according to manufacturer's written instructions.

- D. Lift and support units with manufacturer's designated lifting or supporting points.
- E. Protect motors, shafts, and bearings from weather and construction dust.

1.8 COORDINATION

- A. Coordinate size and location of structural-steel support members.
- B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.
- C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 7.

1.9 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Belts: [**One (1)**] <Insert number> set(s) for each belt-driven unit.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. AMCA Compliance:
 - 1. Comply with AMCA performance and sound rating requirements and bear the AMCA-Certified Ratings Seal.
 - 2. Operating Limits: Classify according to AMCA 99.
- B. Unusual Service Conditions:
 - 1. Ambient Temperature: <Insert deg F>.
 - 2. Altitude: [**5,500 ft**]<Insert feet (m)> above sea level.
 - 3. High humidity.
 - 4. <Insert conditions>.

- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Capacities and Characteristics:
1. Airflow: **<Insert cfm (L/s)>**.
 2. External Static Pressure: **<Insert inches wg (Pa)>**.
 3. Fan Diameter: **<Insert inches (mm)>**.
 4. Brake Horsepower: **<Insert value>**.
 5. Drive Type: **[Direct] [Belt]**.
 6. Fan Rpm: **<Insert value>**.
 7. Motor:
 - a. Motor Enclosure: **[Open, dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over] [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine]**.
 - b. Enclosure Materials: **[Cast iron] [Cast aluminum] [Rolled steel]**.
 - c. Motor Bearings: **<Insert requirements>**.
 - d. Efficiency: Premium efficient.
 - e. NEMA Design: **<Insert designation>**.
 - f. Service Factor: **<Insert value>**.
 - g. Electrical Characteristics:
 - 1) Motor Size: **<Insert horsepower>**.
 - 2) Motor Rpm: **<Insert value>**.
 - 3) Volts: **[120] [208] [230] [460] <Insert value>**.
 - 4) Phase: **[Single] [Poly]**.
 - 5) Hertz: 60.
 - 6) Full-Load Amperes: **<Insert value>**.
 - 7) Minimum Circuit Ampacity: **<Insert value>**.
 - 8) Maximum Overcurrent Protection: **<Insert amperage>**.
 8. Sound Power:
 - a. 1st Octave: **<Insert dB>**.
 - b. 2nd Octave: **<Insert dB>**.
 - c. 3rd Octave: **<Insert dB>**.
 - d. 4th Octave: **<Insert dB>**.
 - e. 5th Octave: **<Insert dB>**.
 - f. 6th Octave: **<Insert dB>**.
 - g. 7th Octave: **<Insert dB>**.
 - h. 8th Octave: **<Insert dB>**.
 9. Vibration Isolators: **[Spring] [Restrained spring] <Insert type>** isolators having a static deflection of **[1 inch (25 mm)] <Insert deflection>**.

2.2 TUBEAXIAL FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Acme Engineering & Mfg. Corp.](#)
 2. [Aerovent; a Twin City Fan company.](#)
 3. [Airmaster Fan Company.](#)
 4. [American Coolair Corporation.](#)
 5. [American Fan Company; part of Flakt Woods Americas.](#)
 6. [Breidert Air Products.](#)
 7. [Carnes Company.](#)
 8. [Chicago Blower Corporation.](#)
 9. [Cincinnati Fan.](#)
 10. [CML Northern Blower Inc.](#)
 11. [Greenheck Fan Corporation.](#)
 12. [Hartzell Fan Incorporated.](#)
 13. [Howden Buffalo Inc.](#)
 14. [Howden Buffalo Inc.; New Philadelphia Division.](#)
 15. [Lau Industries.](#)
 16. [Loren Cook Company.](#)
 17. [Madison Manufacturing.](#)
 18. [New York Blower Company \(The\).](#)
 19. [PennBarry.](#)
 20. [Strobic Air Corporation.](#)
 21. [Trane Inc.; a subsidiary of Ingersoll-Rand company.](#)
 22. **<Insert manufacturer's name>.**
 23. or approved equal.
- B. Description: Fan wheel and housing, factory-mounted motor with **[belt]** **[or]** **[direct]** drive, an inlet cone section, and accessories.
- C. Hub and Impeller:
1. Airfoil Impeller Blades: Adjustable die cast aluminum alloy **[or glass reinforced polyester resin]** **[or welded steel die formed blades with belt drive]**.
 2. Hub: Die cast aluminum alloy or cast iron hub **[or with belt drive of spun, welded steel]**, bored and keyed to shaft; to facilitate indexing of blade angle with **[manual]** **[automatic]** adjustment stops.
 3. Controllable Pitch Assemblies: Incorporate ball bearing counterbalanced blade and variable pitch assembly into hub with mechanical link to casing exterior mounted actuator, or pneumatic or electric actuator incorporated within hub.
 4. Cast Components: X-ray components after fabrication and statically and dynamically balance assembly before attachment to motor or shaft.
- D. Housings: **[Steel]** **[Galvanized steel]** with flanged inlet and outlet connections.
1. Fabricate casing of **[1/4]** **<Insert number>** inch steel for fans **[40]** **[50]** **<Insert number>** inch in diameter and smaller and **[3/8]** **<Insert number>** inch steel for larger fans.

2. Continuously weld, with inlet and outlet flange connections, and motor or shaft supports. Incorporate flow straightening guide vanes for fans specified for static pressures greater than **[one] [1.5] [2] <Insert number>** in wg.
- E. Bearings:
1. Bearings: ABMA 11 **[L-10 life at 120,000 hours] [L-50 life at 400,000 hours]** pillow block type, self-aligning, grease-lubricated roller bearings.
 2. Shafts: Hot rolled steel, ground and polished, with key- way; protectively coated with lubricating oil.
 3. Lubrication: Extend lubrication fittings to outside of casing.
- F. Wheel Assemblies: Cast or extruded aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.
- G. Wheel Assemblies: Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless-steel shaft.
- H. Wheel Assemblies: Cast aluminum, machined and fitted to shaft.
- I. Belt Drives:
1. Cast iron or steel sheaves, dynamically balanced, keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
 2. Factory mounted, with adjustable alignment and belt tensioning.
 3. Service Factor Based on Fan Motor Size: **[1.2] [1.3] [1.4] [1.5]**.
 4. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
 5. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
 6. Motor Pulleys: Adjustable pitch for use with motors through **[5] <Insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
 7. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
 8. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet. Fabricate to SMACNA Standards; of 12 gage, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
 9. Motor Mount: Adjustable base.
 10. Shaft Bearings: Radial, self-aligning bearings.
 - a. Ball-Bearing Rating Life: ABMA 9, **[L10 of 50,000 hours] <Insert life>**.
 - b. Roller-Bearing Rating Life: ABMA 11, **[L10 of 50,000 hours] <Insert life>**.
 - c. Extend lubrication lines to outside of casing and terminate with grease fittings.

J. Accessories:

1. Companion Flanges: Rolled flanges of same material as housing.
2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
3. Propeller Access Section Door: Short duct section bolted to fan **[inlet] [and] [outlet]** allowing access to internal parts of fan for inspection and cleaning, of same material as housing, with quick opening latches and gaskets.
4. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
5. Mounting Clips: **[Horizontal ceiling] [Vertical mounting]** clips welded to fan housing, of same material as housing.
6. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
7. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.
8. Inlet Screen: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
9. Outlet Screen: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
10. Backdraft Dampers: Butterfly style, for bolting to the discharge of fan or outlet cone, of same material as housing.
11. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to **300 deg F (149 deg C)**.
12. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
13. Guide Vanes: Welded steel construction with airfoil vanes and casing flanges, finished to match casing.
14. Dampers: Welded steel construction, consisting of two semi-circular vanes pivoted on oil-retaining bearings in short casing section, finished **[with one coat enamel.] [by hot dip galvanizing.]** Provide **[airstream operation closing blades by reverse airflow and gravity.] [hand operation with handwheel control of screw and link mechanism.] [motor actuation.]**
15. Blade Pitch Actuator: Factory mounted and calibrated, **[electric actuator requiring single phase power and accepting electric input.] [electric actuator requiring single phase power and accepting pneumatic control input signal.] [pneumatic actuator requiring [25 psi] main supply pressure and accepting pneumatic control input signal.]**
16. Stall Alarm Probe: Factory installed sensing probe to detect fan operation in stall. Refer to other Division 23 sections for control equipment.
17. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
18. Inlet Bell: Curved inlet for when fan is not attached to duct, **[of same material as housing] [aluminum]**.
19. Inlet Cone: Round-to-round transition of same material as housing.
20. Outlet Cone: Round-to-round transition, of same material as housing. Fabricated of steel with flanges, outlet area/inlet area ratio of **[1.5/1.0] <Insert number>**, with center pod as recommended by manufacturer.
21. Inlet Screens: Galvanized steel welded grid to fit inlet bell.

22. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.
23. Direct-Driven Units: Encase motor in housing outside of airstream[, **factory wired to disconnect switch located on outside of fan housing**]. Extend lubrication lines to outside of casing and terminate with grease fittings.
24. Vibration Detector: Factory installed vibration switch to stop fan [**with extra set of contacts**]. Refer to other Division 23 sections for control equipment.
25. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge:	64	57	51	47	42	39	38	37
Inlet:	64	57	51	47	42	39	38	37

K. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: [**Thermoplastic vinyl**] [**Epoxy**] [**Zinc**] [**Synthetic resin**] [**Phenolic**] [**Color-match enamel**] [**Polytetrafluoroethylene**] [**Vinyl ester**] [**Hot-dip galvanized**] [**Powder-baked enamel**]; <Insert manufacturer's name and trade name>
 - a. Apply to finished housings.
 - b. Apply to fan wheels.

2.3 VANEAXIAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Mfg. Corp.](#)
2. [Aerovent; a Twin City Fan company.](#)
3. [Airmaster Fan Company.](#)
4. [American Coolair Corporation.](#)
5. [American Fan Company; part of Flakt Woods Americas.](#)
6. [Breidert Air Products.](#)
7. [Carnes Company.](#)
8. [Chicago Blower Corporation.](#)
9. [Cincinnati Fan.](#)
10. [CML Northern Blower Inc.](#)
11. [Greenheck Fan Corporation.](#)
12. [Hartzell Fan Incorporated.](#)
13. [Howden Buffalo Inc.](#)
14. [Howden Buffalo Inc.; New Philadelphia Division.](#)
15. [Lau Industries.](#)
16. [Loren Cook Company.](#)
17. [Madison Manufacturing.](#)

18. [New York Blower Company \(The\)](#).
 19. [PennBarry](#).
 20. [Strobic Air Corporation](#).
 21. [Trane Inc.: a subsidiary of Ingersoll-Rand company](#).
 22. **<Insert manufacturer's name>**.
 23. or approved equal.
- B. Description: Fan wheel and housing, straightening vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.
1. Variable-Pitch Fans: Internally mounted [**pneumatic**] [**electric**] [**electronic**] actuator, externally-mounted positive positioner, and mechanical-blade-pitch indicator.
- C. Hub and Impeller:
1. Airfoil Impeller Blades: Adjustable die cast aluminum alloy [**or glass reinforced polyester resin**] [**or welded steel die formed blades with belt drive**].
 2. Hub: Die cast aluminum alloy or cast iron hub [**or with belt drive of spun, welded steel**], bored and keyed to shaft; to facilitate indexing of blade angle with [**manual**] [**automatic**] adjustment stops.
 3. Controllable Pitch Assemblies: Incorporate ball bearing counterbalanced blade and variable pitch assembly into hub with mechanical link to casing exterior mounted actuator, or pneumatic or electric actuator incorporated within hub.
 4. Cast Components: X-ray components after fabrication and statically and dynamically balance assembly before attachment to motor or shaft.
- D. Housings: [**Steel**] [**Galvanized steel**].
1. Inlet and Outlet Connections: Flanges.
 2. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
 3. Sound-Trap Housing: Housing incorporating perforated steel inner liner, **2 inch (50 mm)** fiberglass duct liner sandwiched between the inner and outer shell, and steel bands sealing the insulated cavity.
 4. Fabricate casing of [**1/4**] **<Insert number>** inch steel for fans [**40**] [**50**] **<Insert number>** inch in diameter and smaller and [**3/8**] [**<Insert number>**] inch steel for larger fans.
 5. Continuously weld, with inlet and outlet flange connections, and motor or shaft supports. Incorporate flow straightening guide vanes for fans specified for static pressures greater than [**one**] [**1.5**] [**2**] **<Insert number>** in wg.
- E. Bearings:
1. Bearings: ABMA 11 [**L-10 life at 120,000 hours**] [**L-50 life at 400,000 hours**] pillow block type, self-aligning, grease-lubricated roller bearings.
 2. Shafts: Hot rolled steel, ground and polished, with key- way; protectively coated with lubricating oil.
 3. Lubrication: Extend lubrication fittings to outside of casing.

- F. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.
- G. Wheel Assemblies: Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless-steel shaft.
- H. Wheel Assemblies: Cast-aluminum hub assembly, machined and fitted with threaded bearing wells to receive blade-bearing assemblies with replaceable, cast-aluminum blades; factory mounted and balanced.
- I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.
1. Cast iron or steel sheaves, dynamically balanced, keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
 2. Service Factor Based on Fan Motor Size: **[1.2] [1.3] [1.4] [1.5]**.
 3. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
 4. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
 5. Motor Pulleys: Adjustable pitch for use with motors through **[5] <Insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
 6. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
 7. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet. Fabricate to SMACNA Standards; of 12 gage, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
 8. Motor Mount: Adjustable base.
 9. Shaft Bearings: Radial, self-aligning bearings.
 - a. Ball-Bearing Rating Life: ABMA 9, **[L10 of 100,000 hours] <Insert life>**.
 - b. Roller-Bearing Rating Life: ABMA 11, **[L10 of 100,000 hours] <Insert life>**.
 - c. Extend lubrication lines to outside of casing and terminate with grease fittings.
- J. Accessories:
1. Companion Flanges: Rolled flanges of same material as housing.
 2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
 3. Propeller Access Section Door: Short duct section bolted to fan **[inlet] [and] [outlet]** allowing access to internal parts of fan for inspection and cleaning, of same material as housing.

4. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
5. Mounting Clips: [**Horizontal ceiling**] [**Vertical mounting**] clips welded to fan housing, of same material as housing.
6. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
7. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.
8. Inlet Screen: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
9. Outlet Screen: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
10. Backdraft Dampers: Butterfly style, for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section, of same material as housing.
11. Stall Alarm Probe: Sensing probe capable of detecting fan operation in stall and signaling control devices. Control devices and sequence of operation are specified in Section 230923.23 "Pressure Instruments" and Section 230993.11 "Sequence of Operations for HVAC DDC."
12. Flow Measurement Port: Pressure measurement taps installed in the inlet of fan to detect and signal airflow readings to temperature-control systems. Control devices and sequence of operation are specified in Section 230923.14 "Flow Instruments" and Section 230993.11 "Sequence of Operations for HVAC DDC."
13. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 300 deg F (148 deg C).
14. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
15. Guide Vanes: Welded steel construction with airfoil vanes and casing flanges, finished to match casing.
16. Dampers: Welded steel construction, consisting of two semi-circular vanes pivoted on oil-retaining bearings in short casing section, finished [**with one coat enamel.**] [**by hot dip galvanizing.**] Provide [**airstream operation closing blades by reverse airflow and gravity.**] [**hand operation with handwheel control of screw and link mechanism.**] [**motor actuation.**]
17. Access Doors: Shaped to conform to casing with quick opening latches and gaskets.
18. Blade Pitch Actuator: Factory mounted and calibrated, [**electric actuator requiring single phase power and accepting electric input.**] [**electric actuator requiring single phase power and accepting pneumatic control input signal.**] [**pneumatic actuator requiring [25 psi] main supply pressure and accepting pneumatic control input signal.**]
19. Stall Alarm Probe: Factory installed sensing probe to detect fan operation in stall. Refer to other Division 23 sections for control equipment.
20. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation, of same material as housing.
21. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
22. Inlet Cone: Round-to-round transition, of same material as housing.

23. Outlet Cone: Round-to-round transition, of same material as housing. Fabricated of steel with flanges, outlet area/inlet area ratio of [1.5/1.0] <Insert number>, with center pod as recommended by manufacturer.
24. Inlet Screens: Galvanized steel welded grid to fit inlet bell.
25. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.
26. Direct-Driven Units: Encase motor in housing outside of airstream[, **factory wired to disconnect switch located on outside of fan housing**]. Extend lubrication lines to outside of casing and terminate with grease fittings.
27. Vibration Detector: Factory installed vibration switch to stop fan [**with extra set of contacts**]. Refer to other Division 23 sections for control equipment.
28. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge:	64	57	51	47	42	39	38	37
Inlet:	64	57	51	47	42	39	38	37

K. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Color-match enamel] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name and trade name>.ol style="list-style-type: none;">- a. Apply to finished housings.
- b. Apply to fan wheels.

2.4 MIXED-FLOW FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Greenheck Fan Corporation](#).
2. [Howden Buffalo Inc.](#)
3. [Howden Buffalo Inc.; New Philadelphia Division](#).
4. [Loren Cook Company](#).
5. <Insert manufacturer's name>.
6. or approved equal.

- B. Description: Fan wheel and housing, [**straightening vane section**,] factory-mounted motor with belt drive, and accessories.

C. Hub and Impeller:

1. Mixed Flow impeller blades: Fixed welded steel die formed blades with belt drive.

2. Hub: Welded steel, bored and keyed to shaft.

D. Housings: **[Steel]** **[Galvanized steel]**.

1. Inlet and Outlet Connections: Outer mounting frame and companion flanges.
2. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
3. Mixed-Flow Outlet Connection: **[One]** **[Two]** flanged discharge(s) perpendicular to fan inlet.
4. Fabricate casing of **[14 ga]** **[1/4]** **<Insert number>** inch steel for fans **[40]** **[50]** **<Insert number>** inch in diameter and smaller and **[3/8]** **<Insert number inch>** steel for larger fans.
5. Continuously weld, with inlet and outlet flange connections, and motor or shaft supports. Incorporate flow straightening guide vanes for fans specified for static pressures greater than **[one]** **[1.5]** **[2]** **<Insert number>** in wg.

E. Bearings:

1. Bearings: ABMA 11 L-50 life at 400,000 hours pillow block type, self-aligning, grease-lubricated roller bearings.
2. Shafts: Hot rolled steel, ground and polished, with key- way; protectively coated with lubricating oil.
3. Lubrication: Extend lubrication fittings to outside of casing.

F. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.

G. Belt Drives:

1. Cast iron or steel sheaves, dynamically balanced, keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
2. Factory mounted, with final alignment and belt adjustment made after installation.
3. Service Factor Based on Fan Motor Size: **[1.2]** **[1.3]** **[1.4]** **[1.5]**.
4. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
5. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
6. Motor Pulleys: Adjustable pitch for use with motors through **[5]** **<Insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
7. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
8. Belt Guards: Fabricate to SMACNA Standards; of 12 gage, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

9. Motor Mount: Adjustable base.
10. Shaft Bearings: Radial, self-aligning bearings.
 - a. Ball-Bearing Rating Life: ABMA 9, [**L10 of 100,000 hours**] <Insert life>.
 - b. Roller-Bearing Rating Life: ABMA 11, [**L10 of 100,000 hours**] <Insert life>.
 - c. Extend lubrication lines to outside of casing and terminate with grease fittings.

H. Accessories:

1. Mounting Clips: [**Horizontal ceiling**] [**Vertical mounting**] clips welded to fan housing, of same material as housing.
2. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
3. Backdraft Dampers: Butterfly style, for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section, of same material as housing.
4. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
5. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
6. Inlet Cones: Round-to-round transition, of same material as housing.
7. Outlet Cones: Round-to-round transition, of same material as housing.
8. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.
9. Direct-Driven Units: Encase motor in housing outside of airstream[, **factory wired to disconnect switch located on outside of fan housing**].
10. Inlet Bell: Bell mouth inlet fabricated of [steel] [aluminum] with flange.
11. Outlet Cones: Fabricated of steel with flanges, outlet area/inlet area ratio of [**1.5/1.0**] <Insert number>, with center pod as recommended by manufacturer.
12. Inlet Screens: Galvanized steel welded grid to fit inlet bell.
13. Dampers: Welded steel construction, consisting of two semi-circular vanes pivoted on oil-retaining bearings in short casing section, finished [**with one coat enamel.**] [**by hot dip galvanizing.**] Provide [**airstream operation closing blades by reverse airflow and gravity.**] [**hand operation with handwheel control of screw and link mechanism.**] [**motor actuation**].
14. Access Doors: Shaped to conform to casing with quick opening latches and gaskets.
15. Vibration Detector: Factory installed vibration switch to stop fan [with extra set of contacts].
16. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge:	64	57	51	47	42	39	38	37
Inlet:	64	57	51	47	42	39	38	37

I. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.

2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: [**Thermoplastic vinyl**] [**Epoxy**] [**Zinc**] [**Synthetic resin**] [**Phenolic**] [**Color-match enamel**] [**Polytetrafluoroethylene**] [**Vinyl ester**] [**Hot-dip galvanized**] [**Powder-baked enamel**]; <Insert manufacturer's name and trade name>.ol style="list-style-type: none;">- a. Apply to finished housings.
- b. Apply to fan wheels.

2.5 PROPELLER FANS

- A. Manufacturers: Subject to conformance with specified requirements, provide products by one of the following:
 1. Acme.
 2. Bayley.
 3. Greenheck.
 4. Loren Cook.
 5. Penn Ventilator.
 6. or approved equal.
- B. Impeller: Shaped steel or steel reinforced aluminum blade with heavy hubs, statically and dynamically balanced, [**keyed and**] locked to shaft, directly connected to motor [**or provided with V-belt drive.**]
- C. Electrical Characteristics and Components:
 1. Electrical Characteristics: As indicated on the Drawings.
 2. Motor: Self-aligning pre-lubricated ball or sleeve bearings affixed to mounting plate [**permitting belt tensioning**], neoprene vibration isolation between fan assembly and mounting plate.
 3. Wiring Terminations: Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated. Enclose terminal lugs in terminal box sized to NFPA 70.
- D. Frame: One piece, square steel with die formed venturi orifice, mounting flanges and supports, with baked enamel finish.
- E. Backdraft Damper: Multiple blade with offset hinge pin, blades linked.
- F. Safety Screens: One inch galvanized wire over inlet, motor, and drive [**and backdraft damper for separate mounting on outlet**].

2.6 ROOF CURB

- A. Roof Curb: [**14**] [**16**] [**20**] [**24**] <Insert number> inch high (top of finish roof to top of curb) [**self flashing**] of [**galvanized steel**] [**aluminum**] with continuously welded

seams, **[built in cant strips] [one inch insulation and curb bottom] [interior baffle with acoustic insulation, curb bottom] [ventilated double wall] [hinged curb adapter]**, and factory installed nailer strip.

2.7 DUCT SILENCERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Mfg. Corp.](#)
2. [Aerovent; a Twin City Fan company.](#)
3. [Airmaster Fan Company.](#)
4. [American Coolair Corporation.](#)
5. [American Fan Company; part of Flakt Woods Americas.](#)
6. [Carnes Company.](#)
7. [Chicago Blower Corporation.](#)
8. [Cincinnati Fan.](#)
9. [CML Northern Blower Inc.](#)
10. [Greenheck Fan Corporation.](#)
11. [Hartzell Fan Incorporated.](#)
12. [Howden Buffalo Inc.](#)
13. [Howden Buffalo Inc.; New Philadelphia Division.](#)
14. [Lau Industries.](#)
15. [Loren Cook Company.](#)
16. [Madison Manufacturing.](#)
17. [New York Blower Company \(The\).](#)
18. [PennBarry.](#)
19. [Strobic Air Corporation.](#)
20. [Trane Inc.; a subsidiary of Ingersoll-Rand company.](#)
21. **<Insert manufacturer's name>.**
22. or approved equal.

B. Description: Tubular **[with center cone]** silencers consisting of a shell with fill material.

C. Housings: **[Steel] [Galvanized steel] [Aluminum] [Fiberglass-reinforced plastic] [Stainless steel]** with flanged inlet and outlet connections matching fan or cone sizes.

1. Inner Shell: **[Steel] [Galvanized steel] [Aluminum] [Fiberglass-reinforced plastic] [Stainless steel]**.
2. Liner: Duct liner.

D. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: **[Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Color-match enamel] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]**; **<Insert manufacturer's name and trade name>** applied to finished housings.

E. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. Static Pressure Drop: <Insert inches wg (Pa)>.
3. Diameter: <Insert inches (mm)>.
4. Sound Attenuation (Insertion Loss):
 - a. 1st Octave: <Insert dB>.
 - b. 2nd Octave: <Insert dB>.
 - c. 3rd Octave: <Insert dB>.
 - d. 4th Octave: <Insert dB>.
 - e. 5th Octave: <Insert dB>.
 - f. 6th Octave: <Insert dB>.
 - g. 7th Octave: <Insert dB>.
 - h. 8th Octave: <Insert dB>.
5. Vibration Isolators: [Spring] [Restrained spring] <Insert type> isolators having a static deflection of [1 inch (25 mm)] <Insert deflection>.

2.8 SOURCE QUALITY CONTROL

- A. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.
- B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210/ASHRAE 51, "Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating."

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install axial fans level and plumb.
- C. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.
- D. Lift and support units with manufacturer's designated lifting or supporting points.
- E. Equipment Mounting:
 1. Install fans on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [Section 033000

"Cast-in-Place Concrete." [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

- a. Support floor-mounting units using **[spring isolators] [restrained spring isolators]** <Insert item> having a static deflection of **[1 inch (25 mm)]** <Insert number>.
 - 1) Secure vibration controls to concrete bases using anchor bolts cast in concrete base.
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - a. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction.
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- F. Support suspended units from structure using threaded steel rods and **[spring hangers]** <Insert item>.
- G. Do not operate fans for any purpose until ductwork is clean, filters in place, bearings lubricated, and fan has been test run under observation.
- H. Install flexible connections specified in Section 233300 "Air Duct Accessories" between axial fan inlet and discharge ductwork. Ensure metal bands of connectors are parallel with minimum one inch flex between ductwork and axial fan while running.
- I. Provide **[fixed]** sheaves required for final air balance.
- J. Provide safety screen where inlet or outlet is exposed.
- K. Provide backdraft dampers on discharge of exhaust fans and as indicated.
- L. Provide access to adjustable blade axial fan wheels for varying blade angle setting. Adjust blades for varying range of volume and pressure.
- M. Install units with clearances for service and maintenance.
- N. Label fans according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."
- 3.2 CONNECTIONS
- A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300 "Air Duct Accessories."

- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.3 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Verify that shipping, blocking, and bracing are removed.
 - 2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
 - 3. Verify that cleaning and adjusting are complete.
 - 4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
 - 5. Adjust belt tension.
 - 6. Adjust damper linkages for proper damper operation.
 - 7. Verify lubrication for bearings and other moving parts.
 - 8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
 - 9. Disable automatic temperature-control operators, energize motor, and confirm proper motor rotation and unit operation, adjust fan to indicated rpm, and measure and record motor voltage and amperage.
 - 10. Shut unit down and reconnect automatic temperature-control operators.
 - 11. Remove and replace malfunctioning units and retest as specified above.
- D. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.
- E. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections. Replace damaged and malfunctioning controls and equipment.

- F. Shut unit down and reconnect automatic temperature-control operators.
- G. Refer to Section 230593 "Testing, Adjusting and Balancing for HVAC", adjusting, and balancing procedures.
- H. Replace fan and motor pulleys as required to achieve design airflow.
- I. Repair or replace malfunctioning units. Retest as specified above after repairs or replacements are made.
- J. Prepare test and inspection reports.

3.4 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Adjust belt tension.
- C. Lubricate bearings.

3.5 CLEANING

- A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.
- B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain axial fans.
- B. Train DEN maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
- C. Review data in maintenance manuals. Refer to Section 230400 "Basic HVAC Requirements".
- D. Schedule training with DEN Project Manager, with at least seven (7) days' advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233413

SECTION 233423 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Utility set fans.
 - 2. Centrifugal roof ventilators.
 - 3. Axial roof ventilators.
 - 4. Upblast propeller roof exhaust fans.
 - 5. Centrifugal wall ventilators.
 - 6. Ceiling-mounted ventilators.
 - 7. In-line centrifugal fans.
 - 8. Propeller fans.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Project Altitude: Base fan-performance ratings on 5,500 feet above sea level. .
- B. Operating Limits: Classify according to AMCA 99.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Also include the following:
 - 1. Certified fan performance curves with system operating conditions indicated.
 - 2. Certified fan sound-power ratings.
 - 3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
 - 4. Material thickness, gages and finishes, including color charts.
 - 5. Dampers, including housings, linkages, and operators.
 - 6. Roof curbs.
 - 7. Fan speed controllers.
 - 8. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring Diagrams: For power, signal, and control wiring.
 - a. Differentiate between manufacturer-installed and field-installed wiring.
 3. **[Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.]**
- C. Delegated-Design Submittal: For unit hangars and supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
1. Roof framing and support members relative to duct penetrations.
 2. Ceiling suspension assembly members.
 3. Size and location of initial access modules for acoustical tile.
 4. Ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
- B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- 1. Belts: [**One (1)**] <Insert number> set(s) for each belt-driven unit.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. AMCA Compliance: Fans shall have AMCA-Certified performance ratings and shall bear the AMCA-Certified Ratings Seal.
- C. UL Standards: Power ventilators shall comply with UL 705. Power ventilators for use for restaurant kitchen exhaust shall also comply with UL 762.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver fans as factory-assembled unit, to the extent allowable by shipping limitations, with protective crating and covering.
- B. Disassemble and reassemble units, as required for moving to final location, according to manufacturer's written instructions.
- C. Lift and support units with manufacturer's designated lifting or supporting points.

1.10 COORDINATION

- A. Coordinate size and location of structural-steel support members.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 UTILITY SET FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
 2. [American Coolair Corporation.](#)
 3. [Ammerman; Millennium Equipment.](#)
 4. [Braidert Air Products.](#)
 5. [Carnes Company.](#)
 6. [Delhi Industries Inc.](#)
 7. [Hartzell Fan Incorporated.](#)
 8. [JencoFan.](#)
 9. [Loren Cook Company.](#)
 10. [Madison Manufacturing.](#)
 11. [New York Blower Company \(The\).](#)
 12. [PennBarry.](#)
 13. [Quietaire Inc.](#)
 14. [Trane; a business of American Standard Companies.](#)
 15. **<Insert manufacturer's name>.**
 16. or approved equal.
- B. Housing: Fabricated of [**galvanized**] steel with side sheets fastened with a deep lock seam or welded to scroll sheets.
1. Housing Discharge Arrangement: Adjustable to eight standard positions.
- C. Fan Wheels: Single-width, single inlet; welded to cast-iron or cast-steel hub and spun-steel inlet cone, with hub keyed to shaft.
1. Blade Materials: [**Steel**] [**Aluminum**].
 2. Blade Type: [**Backward inclined**] [**Forward curved**] [**Airfoil**].
 3. Spark-Resistant Construction: AMCA 99, Type [**A**] [**B**] [**C**].
- D. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
- E. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, [**L₅₀ of 200,000 hours**] [**L₁₀ of 80,000 hours**] **<Insert life>**.
1. Extend grease fitting to accessible location outside of unit.
- F. Belt Drives:
1. Factory mounted, with final alignment and belt adjustment made after installation
 2. Service Factor Based on Fan Motor Size: [**1.5**] [**1.4**] [**1.3**] [**1.2**].
 3. Motor Pulleys: Adjustable pitch for use with motors through [**5**] **<Insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

G. Accessories:

1. Inlet and Outlet: Flanged.
2. Companion Flanges: Rolled flanges for duct connections of same material as housing.
3. Backdraft Dampers: Gravity actuated with counterweight and interlocking aluminum blades with felt edges in steel frame installed on fan discharge.
4. Access Door: Gasketed door in scroll with latch-type handles.
5. Scroll Dampers: Single-blade damper installed at fan scroll top with adjustable linkage.
6. Inlet Screens: Removable wire mesh.
7. Drain Connections: **NPS 3/4 (DN 20)** threaded coupling drain connection installed at lowest point of housing.
8. Weather Hoods: Weather resistant with stamped vents over motor and drive compartment.
9. Discharge Dampers: Assembly with [**parallel**] [**opposed**] blades constructed of two plates formed around and to shaft, channel frame, sealed ball bearings, with blades linked outside of airstream to single control lever of same material as housing.
10. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
11. Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.

H. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. External Static Pressure: <Insert inches wg (Pa)>.
3. Fan Diameter: <Insert inches (mm)>.
4. Wheel Type: [**Backward inclined**] [**Forward curved**] [**Airfoil**].
5. Class: [**I**] [**II**] [**III**].
6. Drive Arrangement: [**Direct**] [**Belt**].
7. Fan rpm: <Insert value>.
8. Outlet Velocity: <Insert fpm (m/s)>.
9. Brake Horsepower: <Insert value>.
10. Motor Size: <Insert value> hp.
11. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
12. Vibration Isolators:
 - a. Type: [**Spring isolators**] [**Restrained spring isolators**] <Insert type>.

b. Static Deflection: <Insert inches (mm)>.

13. Spark Arrestance Class: [A] [B] [C].

2.2 CENTRIFUGAL ROOF VENTILATORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [American Coolair Corporation.](#)
4. [Ammerman; Millennium Equipment.](#)
5. [Braidert Air Products.](#)
6. [Broan-NuTone LLC.](#)
7. [Broan-NuTone LLC; NuTone Inc.](#)
8. [Carnes Company.](#)
9. [Central Blower Company.](#)
10. [Delhi Industries Inc.](#)
11. [Greenheck Fan Corporation.](#)
12. [Hartzell Fan Incorporated.](#)
13. [JencoFan.](#)
14. [Loren Cook Company.](#)
15. [PennBarry.](#)
16. [Quietaire Inc.](#)
17. [W.W. Grainger, Inc.; Dayton Products.](#)
18. <Insert manufacturer's name>.
19. or approved equal.

B. Housing: Removable, [**spun-aluminum, dome top and outlet baffle**] [**extruded-aluminum, rectangular top**] [**galvanized steel, mushroom-domed top**]; square, one-piece, aluminum base with venturi inlet cone.

1. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains[**and grease collector**].
2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

C. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

D. Belt Drives:

1. Resiliently mounted to housing.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
5. Fan and motor isolated from exhaust airstream.

E. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted **[inside]** **[outside]** fan housing, factory wired through an internal aluminum conduit.
3. Bird Screens: Removable, **1/2-inch** (13-mm) mesh, aluminum or brass wire.
4. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
5. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

F. Roof Curbs: Galvanized steel; mitered and welded corners; **1-1/2-inch-** (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and **1-1/2-inch** (40-mm) wood nailer. Size as required to suit roof opening and fan base.

1. Configuration: **[Self-flashing without a cant strip, with mounting flange]** **[Built-in cant and mounting flange]** **[Built-in raised cant and mounting flange]**.
2. Overall Height: **[8 inches** (200 mm)] **[9-1/2 inches** (240 mm)] **[12 inches** (300 mm)] **[16 inches** (400 mm)] **[18 inches** (450 mm)].
3. Sound Curb: Curb with sound-absorbing insulation.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Galvanized steel.
6. Burglar Bars: **[1/2-inch-** (13-mm-)] **[5/8-inch-** (16-mm-)] **[3/4-inch-** (19-mm-)] thick steel bars welded in place to form **6-inch** (150-mm) squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.
8. Vented Curb: Unlined with louvered vents in vertical sides.

G. Capacities and Characteristics:

1. Airflow: **<Insert cfm (L/s)>**.
2. External Static Pressure: **<Insert inches wg (Pa)>**.
3. Fan Diameter: **<Insert inches (mm)>**.
4. Drive Arrangement: **[Direct]** **[Belt drive]**.
5. Fan rpm: **<Insert value>**.
6. Tip Speed: **<Insert fpm (m/s)>**.
7. Sound: **<Insert sone>**.
8. Curb Size: **<Insert inches by inches (mm by mm)>**.
9. Curb Height: **<Insert inches (mm)>**.
10. Damper: **[Yes]** **[No]**.
11. Damper Size: **<Insert inches by inches (mm by mm)>**.
12. Brake Horsepower: **<Insert value>**.
13. Motor Size: **<Insert value>** hp.
14. Motor rpm: **<Insert value>**.
15. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.

c. Hertz: **<Insert value>**.

2.3 AXIAL ROOF VENTILATORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [American Coolair Corporation.](#)
4. [Ammerman; Millennium Equipment.](#)
5. [Breidert Air Products.](#)
6. [Broan-NuTone LLC.](#)
7. [Carnes Company.](#)
8. [FloAire.](#)
9. [Greenheck Fan Corporation.](#)
10. [Hartzell Fan Incorporated.](#)
11. [JencoFan.](#)
12. [Loren Cook Company.](#)
13. [New York Blower Company \(The\).](#)
14. [PennBarry.](#)
15. [Stanley Fans.](#)
16. **<Insert manufacturer's name>**.
17. or approved equal.

B. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; square, one-piece, hinged, aluminum base.

1. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

C. Fan Wheel: [**Aluminum**] [**Steel**] hub and blades.

D. Belt Drives:

1. Resiliently mounted to housing.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.

E. Accessories:

1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted [**inside**] [**outside**] fan housing, factory wired through an internal aluminum conduit.
2. Bird Screens: Removable, **1/2-inch** (13-mm) mesh, aluminum or brass wire.
3. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.

4. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.
- F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch (40-mm) wood nailer. Size as required to suit roof opening and fan base.
1. Configuration: [Self-flashing without a cant strip, with mounting flange] [Built-in cant and mounting flange] [Built-in raised cant and mounting flange].
 2. Overall Height: [8 inches (200 mm)] [9-1/2 inches (240 mm)] [12 inches (300 mm)] [16 inches (400 mm)] [18 inches (450 mm)].
 3. Sound Curb: Curb with sound-absorbing insulation.
 4. Pitch Mounting: Manufacture curb for roof slope.
 5. Metal Liner: Galvanized steel.
 6. Burglar Bars: [1/2-inch- (13-mm-)] [5/8-inch- (16-mm-)] [3/4-inch- (19-mm-)] thick steel bars welded in place to form 6-inch (150-mm) squares.
 7. Mounting Pedestal: Galvanized steel with removable access panel.
- G. Capacities and Characteristics:
1. Airflow: <Insert cfm (L/s)>.
 2. External Static Pressure: <Insert inches wg (Pa)>.
 3. Fan Diameter: <Insert inches (mm)>.
 4. Drive Arrangement: [Direct] [Belt drive].
 5. Fan rpm: <Insert value>.
 6. Tip Speed: <Insert fpm (m/s)>.
 7. Sound: <Insert sone>.
 8. Curb Size: <Insert inches by inches (mm by mm)>.
 9. Curb Height: <Insert inches (mm)>.
 10. Damper: [Yes] [No].
 11. Damper Size: <Insert inches by inches (mm by mm)>.
 12. Brake Horsepower: <Insert value>.
 13. Motor Size: <Insert value> hp.
 14. Motor rpm: <Insert value>.
 15. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.

2.4 UPBLAST PROPELLER ROOF EXHAUST FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Acme Engineering & Manufacturing Corporation.](#)
 2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
 3. [American Coolair Corporation.](#)

4. [Ammerman; Millennium Equipment.](#)
 5. [Breidert Air Products.](#)
 6. [Carnes Company.](#)
 7. [Cincinnati Fan.](#)
 8. [Greenheck Fan Corporation.](#)
 9. [Hartzell Fan Incorporated.](#)
 10. [JencoFan.](#)
 11. [Loren Cook Company.](#)
 12. [Madison Manufacturing.](#)
 13. [New York Blower Company \(The\).](#)
 14. [PennBarry.](#)
 15. [Quietaire Inc.](#)
 16. [Stanley Fans.](#)
 17. **<Insert manufacturer's name>.**
 18. or approved equal.
- B. Wind Band, Fan Housing, and Base: Reinforced and braced [**galvanized steel**] [**aluminum**], containing [**galvanized-steel**] [**aluminum**] butterfly dampers and rain trough, motor and drive assembly, and fan wheel.
1. Damper Rods: Steel with [**bronze**] [**nylon**] bearings.
 2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.
- C. Fan Wheel: Replaceable, [**cast**] [**extruded**]-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.
- D. Belt Drives:
1. Resiliently mounted to housing.
 2. Weatherproof housing of same material as fan housing.
 3. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 4. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings.
 5. Pulleys: Cast-iron, adjustable-pitch motor pulley.
 6. Motor Mount: On outside of fan cabinet, adjustable base for belt tensioning.
- E. Roof Curbs: Galvanized steel; mitered and welded corners; **1-1/2-inch-** (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and **1-1/2-inch** (40-mm) wood nailer. Size as required to suit roof opening and fan base.
1. Configuration: [**Self-flashing without a cant strip, with mounting flange**] [**Built-in cant and mounting flange**] [**Built-in raised cant and mounting flange**].
 2. Overall Height: [**8 inches** (200 mm)] [**9-1/2 inches** (240 mm)] [**12 inches** (300 mm)] [**16 inches** (400 mm)] [**18 inches** (450 mm)].
 3. Sound Curb: Curb with sound-absorbing insulation.
 4. Pitch Mounting: Manufacture curb for roof slope.
 5. Metal Liner: Galvanized steel.

6. Burglar Bars: [1/2-inch- (13-mm-)] [5/8-inch- (16-mm-)] [3/4-inch- (19-mm-)] thick steel bars welded in place to form 6-inch (150-mm) squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.

F. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. External Static Pressure: <Insert inches wg (Pa)>.
3. Fan Diameter: <Insert inches (mm)>.
4. Drive Arrangement: [Direct] [Belt drive].
5. Fan rpm: <Insert value>.
6. Tip Speed: <Insert fpm (m/s)>.
7. Sound: <Insert sone>.
8. Curb Size: <Insert inches by inches (mm by mm)>.
9. Curb Height: <Insert inches (mm)>.
10. Damper: [Yes] [No].
11. Damper Size: <Insert inches by inches (mm by mm)>.
12. Brake Horsepower: <Insert value>.
13. Motor Size: <Insert value> hp.
14. Motor rpm: <Insert value>.
15. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.

2.5 CENTRIFUGAL WALL VENTILATORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [American Coolair Corporation.](#)
4. [Ammerman; Millennium Equipment.](#)
5. [Braidert Air Products.](#)
6. [Broan-NuTone LLC.](#)
7. [Broan-NuTone LLC; NuTone Inc.](#)
8. [Carnes Company.](#)
9. [Greenheck Fan Corporation.](#)
10. [Hartzell Fan Incorporated.](#)
11. [JencoFan.](#)
12. [Loren Cook Company.](#)
13. [PennBarry.](#)
14. [W.W. Grainger, Inc.; Dayton Products.](#)
15. <Insert manufacturer's name>.
16. or approved equal.

- B. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.
- C. Fan Wheel: Aluminum hub and wheel with backward-inclined blades.
- D. Belt Drives:
1. Resiliently mounted to housing.
 2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
 4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
 5. Fan and motor isolated from exhaust airstream.
- E. Accessories:
1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through internal aluminum conduit.
 3. Bird Screens: Removable, 1/2-inch (13-mm) mesh, aluminum or brass wire.
 4. Wall Grille: Ring type for flush mounting.
 5. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
 6. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.
- F. Capacities and Characteristics:
1. Airflow: <Insert cfm (L/s)>.
 2. External Static Pressure: <Insert inches wg (Pa)>.
 3. Fan Diameter: <Insert inches (mm)>.
 4. Drive Arrangement: [Direct] [Belt drive].
 5. Fan rpm: <Insert value>.
 6. Tip Speed: <Insert fpm (m/s)>.
 7. Sound: <Insert sone>.
 8. Damper: [Yes] [No].
 9. Damper Size: <Insert inches by inches (mm by mm)>.
 10. Brake Horsepower: <Insert value>.
 11. Motor Size: <Insert value> hp.
 12. Motor rpm: <Insert value>.
 13. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.

2.6 CEILING-MOUNTED VENTILATORS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [American Coolair Corporation](#).
 2. [Ammerman; Millennium Equipment](#).
 3. [Breidert Air Products](#).
 4. [Broan-NuTone LLC](#).
 5. [Broan-NuTone LLC; NuTone Inc](#).
 6. [Carnes Company](#).
 7. [FloAire](#).
 8. [Greenheck Fan Corporation](#).
 9. [JencoFan](#).
 10. [Loren Cook Company](#).
 11. [PennBarry](#).
 12. [W.W. Grainger, Inc.; Dayton Products](#).
 13. **<Insert manufacturer's name>**.
 14. or approved equal.
- B. Housing: Steel, lined with acoustical insulation.
- C. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.
- D. Grille: **[Plastic] [Stainless steel] [Aluminum] [Painted aluminum]**, louvered grille with flange on intake and thumbscrew attachment to fan housing.
- E. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.
- F. Accessories:
1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Manual Starter Switch: Single-pole rocker switch assembly with cover and pilot light.
 3. Time-Delay Switch: Assembly with single-pole rocker switch, timer, and cover plate.
 4. Motion Sensor: Motion detector with adjustable shutoff timer.
 5. Ceiling Radiation Damper: Fire-rated assembly with ceramic blanket, stainless-steel springs, and fusible link.
 6. Filter: Washable aluminum to fit between fan and grille.
 7. Isolation: Rubber-in-shear vibration isolators.
 8. Manufacturer's standard roof jack or wall cap, and transition fittings.
- G. Capacities and Characteristics:
1. Airflow: **<Insert cfm (L/s)>**.
 2. External Static Pressure: **<Insert inches wg (Pa)>**.

3. Sound: **<Insert sone>**.
4. Motor Size: **<Insert value>** hp.
5. Motor rpm: **<Insert value>**.
6. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.

2.7 IN-LINE CENTRIFUGAL FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Acme Engineering & Manufacturing Corporation](#).
 2. [American Coolair Corporation](#).
 3. [Ammerman; Millennium Equipment](#).
 4. [Breidert Air Products](#).
 5. [Carnes Company](#).
 6. [FloAire](#).
 7. [Greenheck Fan Corporation](#).
 8. [Hartzell Fan Incorporated](#).
 9. [JencoFan](#).
 10. [Loren Cook Company](#).
 11. [Madison Manufacturing](#).
 12. [PennBarry](#).
 13. [Quietaire Inc.](#)
 14. **<Insert manufacturer's name>**.
 15. or approved equal.
- B. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, sidewall, or ceiling mounting.
- C. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing[; **with wheel, inlet cone, and motor on swing-out service door**].
- D. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.
- E. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.
- F. Accessories:
1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.

3. Companion Flanges: For inlet and outlet duct connections.
4. Fan Guards: **1/2- by 1-inch** (13- by 25-mm) mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
5. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

G. Capacities and Characteristics:

1. Airflow: **<Insert cfm (L/s)>**.
2. External Static Pressure: **<Insert inches wg (Pa)>**.
3. Fan Diameter: **<Insert inches (mm)>**.
4. Wheel Type: **[Backward inclined] [Forward curved] [Airfoil]**.
5. Class: **[I] [II] [III]**.
6. Drive Arrangement: **<Insert AMCA number>**.
7. Fan rpm: **<Insert value>**.
8. Outlet Velocity: **<Insert fpm (m/s)>**.
9. Brake Horsepower: **<Insert value>**.
10. Motor Size: **<Insert value>** hp.
11. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
12. Vibration Isolators:
 - a. Type: **[Elastomeric hangers] <Insert type>**.
 - b. Static Deflection: **[1 inch (25 mm)] <Insert value>**.
13. Spark Arrestance Class: **[A] [B] [C]**.

2.8 PROPELLER FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [Airmaster Fan Company.](#)
4. [American Coolair Corporation.](#)
5. [Ammerman; Millennium Equipment.](#)
6. [Breidert Air Products.](#)
7. [Broan-NuTone LLC; NuTone Inc.](#)
8. [Carnes Company.](#)
9. [Chicago Blower Corporation.](#)
10. [Cincinnati Fan.](#)
11. [Hartzell Fan Incorporated.](#)
12. [Howden Buffalo Inc.](#)
13. [JencoFan.](#)
14. [King Company; part of Mestek, Inc.](#)

15. [Loren Cook Company](#).
 16. [Madison Manufacturing](#).
 17. [Moffitt Corporation Inc.](#)
 18. [New York Blower Company \(The\)](#).
 19. [PennBarry](#).
 20. [Quietaire Inc.](#)
 21. [Stanley Fans](#).
 22. [W.W. Grainger, Inc.; Dayton Products](#).
 23. **<Insert manufacturer's name>**.
 24. or approved equal.
- B. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.
- C. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.
- D. Fan Wheel: Replaceable, **[cast]** **[extruded]**-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.
- E. Fan Drive: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing.
- F. Fan Drive:
1. Resiliently mounted to housing.
 2. Statically and dynamically balanced.
 3. Selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
 4. Extend grease fitting to accessible location outside of unit.
 5. Service Factor Based on Fan Motor Size: 1.4.
 6. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 7. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
 - a. Ball-Bearing Rating Life: ABMA 9, **[L₁₀ of 100,000 hours]** **<Insert life>**.
 8. Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
 9. Motor Pulleys: Adjustable pitch for use with motors through **[5]** **<insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
 10. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
 11. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
- G. Accessories:
1. Gravity Shutters: Aluminum blades in aluminum frame; interlocked blades with nylon bearings.

2. Motor-Side Back Guard: Galvanized steel, complying with OSHA specifications, removable for maintenance.
3. Wall Sleeve: Galvanized steel to match fan and accessory size.
4. Weathershield Hood: Galvanized steel to match fan and accessory size.
5. Weathershield Front Guard: Galvanized steel with expanded metal screen.
6. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
7. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.

H. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. Fan Diameter: <Insert inches (mm)>.
3. Fan rpm: <Insert value>.
4. Brake Horsepower: <Insert value>.
5. Motor Size: <Insert value> hp.
6. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
7. Vibration Isolators:
 - a. Type: [Elastomeric hangers] [Spring isolators] [Restrained spring isolators] <Insert type>.
 - b. Static Deflection: [1 inch (25 mm)] <Insert value>.
8. Spark Arrestance Class: [A] [B] [C].

2.9 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- B. Enclosure Type: Totally enclosed, fan cooled.

2.10 SOURCE QUALITY CONTROL

- A. Certify sound-power level ratings according to AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

- B. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge:	64	57	51	47	42	39	38	37
Inlet:	64	57	51	47	42	39	38	37

- C. Certify fan performance ratings, including flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating." Label fans with the AMCA-Certified Ratings Seal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install power ventilators level and plumb.
- C. Equipment Mounting:
1. Install power ventilators on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - a. Support units using [**spring isolators**] [**restrained spring isolators**] <Insert item> having a static deflection of [**1 inch (25 mm)**] <Insert number>.
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Secure roof-mounted fans to roof curbs with cadmium-plated hardware. See Section 077200 "Roof Accessories" for installation of roof curbs.
- E. Ceiling Units: Suspend units from structure; use steel wire or metal straps.
- F. Support suspended units from structure using threaded steel rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stops**] <Insert device> having a static deflection of [**1 inch (25 mm)**] <Insert deflection>. Vibration-control devices are specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]
- G. Install units with clearances for service and maintenance.

- H. Extend ducts to **[roof] [wall]** exhausters into **[roof curb] [structure]**. Counterflash duct to **[roof] [wall]** opening.
- I. Provide sheaves required for final air balance.
- J. Install flexible connections specified in Section 233300 "Air Duct Accessories" between fan inlet and ductwork. Ensure metal bands of connectors are parallel with minimum one inch flex between ductwork and fan while running.
- K. Do not operate fans for any purpose until ductwork is clean, filters in place, bearings lubricated, and fan has been test run under observation.
- L. Label units according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

- A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300 "Air Duct Accessories."
- B. Install ducts adjacent to power ventilators to allow service and maintenance.
- C. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- E. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.3 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. Verify that shipping, blocking, and bracing are removed.
 - 2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
 - 3. Verify that cleaning and adjusting are complete.

4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
 5. Adjust belt tension.
 6. Adjust damper linkages for proper damper operation.
 7. Verify lubrication for bearings and other moving parts.
 8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
 9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
 10. Shut unit down and reconnect automatic temperature-control operators.
 11. Remove and replace malfunctioning units and retest as specified above.
- C. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.
- D. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections. Replace damaged and malfunctioning controls and equipment.
- E. Shut unit down and reconnect automatic temperature-control operators.
- F. Refer to Section 230593 "Testing, Adjusting and Balancing for HVAC", adjusting, and balancing procedures.
- G. Replace fan and motor pulleys as required to achieve design airflow.
- H. Repair or replace malfunctioning units. Retest as specified above after repairs or replacements are made.
- I. Prepare test and inspection reports.
- 3.4 ADJUSTING
- A. Adjust damper linkages for proper damper operation.
 - B. Adjust belt tension.
 - C. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.
 - D. Replace fan and motor pulleys as required to achieve design airflow.
 - E. Lubricate bearings.

3.5 CLEANING

- A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.
- B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain power ventilators.
- B. Train DEN maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
- C. Review data in maintenance manuals. Refer to Section 230400 "Basic HVAC Requirements".
- D. Schedule training with DEN Project Manager, with at least seven (7) days' advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233423

SECTION 233423 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Utility set fans.
 - 2. Centrifugal roof ventilators.
 - 3. Axial roof ventilators.
 - 4. Upblast propeller roof exhaust fans.
 - 5. Centrifugal wall ventilators.
 - 6. Ceiling-mounted ventilators.
 - 7. In-line centrifugal fans.
 - 8. Propeller fans.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Project Altitude: Base fan-performance ratings on 5,500 feet above sea level. .
- B. Operating Limits: Classify according to AMCA 99.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Also include the following:
 - 1. Certified fan performance curves with system operating conditions indicated.
 - 2. Certified fan sound-power ratings.
 - 3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
 - 4. Material thickness, gages and finishes, including color charts.
 - 5. Dampers, including housings, linkages, and operators.
 - 6. Roof curbs.
 - 7. Fan speed controllers.
 - 8. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring Diagrams: For power, signal, and control wiring.
 - a. Differentiate between manufacturer-installed and field-installed wiring.
 3. **[Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.]**
- C. Delegated-Design Submittal: For unit hangars and supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
1. Roof framing and support members relative to duct penetrations.
 2. Ceiling suspension assembly members.
 3. Size and location of initial access modules for acoustical tile.
 4. Ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
- B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- 1. Belts: [**One (1)**] <Insert number> set(s) for each belt-driven unit.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. AMCA Compliance: Fans shall have AMCA-Certified performance ratings and shall bear the AMCA-Certified Ratings Seal.
- C. UL Standards: Power ventilators shall comply with UL 705. Power ventilators for use for restaurant kitchen exhaust shall also comply with UL 762.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver fans as factory-assembled unit, to the extent allowable by shipping limitations, with protective crating and covering.
- B. Disassemble and reassemble units, as required for moving to final location, according to manufacturer's written instructions.
- C. Lift and support units with manufacturer's designated lifting or supporting points.

1.10 COORDINATION

- A. Coordinate size and location of structural-steel support members.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 UTILITY SET FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
 2. [American Coolair Corporation.](#)
 3. [Ammerman; Millennium Equipment.](#)
 4. [Braidert Air Products.](#)
 5. [Carnes Company.](#)
 6. [Delhi Industries Inc.](#)
 7. [Hartzell Fan Incorporated.](#)
 8. [JencoFan.](#)
 9. [Loren Cook Company.](#)
 10. [Madison Manufacturing.](#)
 11. [New York Blower Company \(The\).](#)
 12. [PennBarry.](#)
 13. [Quietaire Inc.](#)
 14. [Trane; a business of American Standard Companies.](#)
 15. **<Insert manufacturer's name>.**
 16. or approved equal.
- B. Housing: Fabricated of [**galvanized**] steel with side sheets fastened with a deep lock seam or welded to scroll sheets.
1. Housing Discharge Arrangement: Adjustable to eight standard positions.
- C. Fan Wheels: Single-width, single inlet; welded to cast-iron or cast-steel hub and spun-steel inlet cone, with hub keyed to shaft.
1. Blade Materials: [**Steel**] [**Aluminum**].
 2. Blade Type: [**Backward inclined**] [**Forward curved**] [**Airfoil**].
 3. Spark-Resistant Construction: AMCA 99, Type [**A**] [**B**] [**C**].
- D. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
- E. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, [**L₅₀ of 200,000 hours**] [**L₁₀ of 80,000 hours**] **<Insert life>**.
1. Extend grease fitting to accessible location outside of unit.
- F. Belt Drives:
1. Factory mounted, with final alignment and belt adjustment made after installation
 2. Service Factor Based on Fan Motor Size: [**1.5**] [**1.4**] [**1.3**] [**1.2**].
 3. Motor Pulleys: Adjustable pitch for use with motors through [**5**] **<Insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

G. Accessories:

1. Inlet and Outlet: Flanged.
2. Companion Flanges: Rolled flanges for duct connections of same material as housing.
3. Backdraft Dampers: Gravity actuated with counterweight and interlocking aluminum blades with felt edges in steel frame installed on fan discharge.
4. Access Door: Gasketed door in scroll with latch-type handles.
5. Scroll Dampers: Single-blade damper installed at fan scroll top with adjustable linkage.
6. Inlet Screens: Removable wire mesh.
7. Drain Connections: **NPS 3/4 (DN 20)** threaded coupling drain connection installed at lowest point of housing.
8. Weather Hoods: Weather resistant with stamped vents over motor and drive compartment.
9. Discharge Dampers: Assembly with [**parallel**] [**opposed**] blades constructed of two plates formed around and to shaft, channel frame, sealed ball bearings, with blades linked outside of airstream to single control lever of same material as housing.
10. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
11. Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.

H. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. External Static Pressure: <Insert inches wg (Pa)>.
3. Fan Diameter: <Insert inches (mm)>.
4. Wheel Type: [**Backward inclined**] [**Forward curved**] [**Airfoil**].
5. Class: [**I**] [**II**] [**III**].
6. Drive Arrangement: [**Direct**] [**Belt**].
7. Fan rpm: <Insert value>.
8. Outlet Velocity: <Insert fpm (m/s)>.
9. Brake Horsepower: <Insert value>.
10. Motor Size: <Insert value> hp.
11. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
12. Vibration Isolators:
 - a. Type: [**Spring isolators**] [**Restrained spring isolators**] <Insert type>.

b. Static Deflection: <Insert inches (mm)>.

13. Spark Arrestance Class: [A] [B] [C].

2.2 CENTRIFUGAL ROOF VENTILATORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [American Coolair Corporation.](#)
4. [Ammerman; Millennium Equipment.](#)
5. [Braidert Air Products.](#)
6. [Broan-NuTone LLC.](#)
7. [Broan-NuTone LLC; NuTone Inc.](#)
8. [Carnes Company.](#)
9. [Central Blower Company.](#)
10. [Delhi Industries Inc.](#)
11. [Greenheck Fan Corporation.](#)
12. [Hartzell Fan Incorporated.](#)
13. [JencoFan.](#)
14. [Loren Cook Company.](#)
15. [PennBarry.](#)
16. [Quietaire Inc.](#)
17. [W.W. Grainger, Inc.; Dayton Products.](#)
18. <Insert manufacturer's name>.
19. or approved equal.

B. Housing: Removable, [**spun-aluminum, dome top and outlet baffle**] [**extruded-aluminum, rectangular top**] [**galvanized steel, mushroom-domed top**]; square, one-piece, aluminum base with venturi inlet cone.

1. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains[**and grease collector**].
2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

C. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

D. Belt Drives:

1. Resiliently mounted to housing.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
5. Fan and motor isolated from exhaust airstream.

E. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted **[inside]** **[outside]** fan housing, factory wired through an internal aluminum conduit.
3. Bird Screens: Removable, **1/2-inch** (13-mm) mesh, aluminum or brass wire.
4. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
5. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

F. Roof Curbs: Galvanized steel; mitered and welded corners; **1-1/2-inch-** (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and **1-1/2-inch** (40-mm) wood nailer. Size as required to suit roof opening and fan base.

1. Configuration: **[Self-flashing without a cant strip, with mounting flange]** **[Built-in cant and mounting flange]** **[Built-in raised cant and mounting flange]**.
2. Overall Height: **[8 inches** (200 mm)] **[9-1/2 inches** (240 mm)] **[12 inches** (300 mm)] **[16 inches** (400 mm)] **[18 inches** (450 mm)].
3. Sound Curb: Curb with sound-absorbing insulation.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Galvanized steel.
6. Burglar Bars: **[1/2-inch-** (13-mm-)] **[5/8-inch-** (16-mm-)] **[3/4-inch-** (19-mm-)] thick steel bars welded in place to form **6-inch** (150-mm) squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.
8. Vented Curb: Unlined with louvered vents in vertical sides.

G. Capacities and Characteristics:

1. Airflow: **<Insert cfm (L/s)>**.
2. External Static Pressure: **<Insert inches wg (Pa)>**.
3. Fan Diameter: **<Insert inches (mm)>**.
4. Drive Arrangement: **[Direct]** **[Belt drive]**.
5. Fan rpm: **<Insert value>**.
6. Tip Speed: **<Insert fpm (m/s)>**.
7. Sound: **<Insert sone>**.
8. Curb Size: **<Insert inches by inches (mm by mm)>**.
9. Curb Height: **<Insert inches (mm)>**.
10. Damper: **[Yes]** **[No]**.
11. Damper Size: **<Insert inches by inches (mm by mm)>**.
12. Brake Horsepower: **<Insert value>**.
13. Motor Size: **<Insert value>** hp.
14. Motor rpm: **<Insert value>**.
15. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.

c. Hertz: <Insert value>.

2.3 AXIAL ROOF VENTILATORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [American Coolair Corporation.](#)
4. [Ammerman; Millennium Equipment.](#)
5. [Breidert Air Products.](#)
6. [Broan-NuTone LLC.](#)
7. [Carnes Company.](#)
8. [FloAire.](#)
9. [Greenheck Fan Corporation.](#)
10. [Hartzell Fan Incorporated.](#)
11. [JencoFan.](#)
12. [Loren Cook Company.](#)
13. [New York Blower Company \(The\).](#)
14. [PennBarry.](#)
15. [Stanley Fans.](#)
16. <Insert manufacturer's name>.
17. or approved equal.

B. **Housing:** Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; square, one-piece, hinged, aluminum base.

1. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

C. **Fan Wheel:** [**Aluminum**] [**Steel**] hub and blades.

D. **Belt Drives:**

1. Resiliently mounted to housing.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.

E. **Accessories:**

1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted [**inside**] [**outside**] fan housing, factory wired through an internal aluminum conduit.
2. Bird Screens: Removable, 1/2-inch (13-mm) mesh, aluminum or brass wire.
3. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.

4. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.
- F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch (40-mm) wood nailer. Size as required to suit roof opening and fan base.
1. Configuration: [Self-flashing without a cant strip, with mounting flange] [Built-in cant and mounting flange] [Built-in raised cant and mounting flange].
 2. Overall Height: [8 inches (200 mm)] [9-1/2 inches (240 mm)] [12 inches (300 mm)] [16 inches (400 mm)] [18 inches (450 mm)].
 3. Sound Curb: Curb with sound-absorbing insulation.
 4. Pitch Mounting: Manufacture curb for roof slope.
 5. Metal Liner: Galvanized steel.
 6. Burglar Bars: [1/2-inch- (13-mm-)] [5/8-inch- (16-mm-)] [3/4-inch- (19-mm-)] thick steel bars welded in place to form 6-inch (150-mm) squares.
 7. Mounting Pedestal: Galvanized steel with removable access panel.
- G. Capacities and Characteristics:
1. Airflow: <Insert cfm (L/s)>.
 2. External Static Pressure: <Insert inches wg (Pa)>.
 3. Fan Diameter: <Insert inches (mm)>.
 4. Drive Arrangement: [Direct] [Belt drive].
 5. Fan rpm: <Insert value>.
 6. Tip Speed: <Insert fpm (m/s)>.
 7. Sound: <Insert sone>.
 8. Curb Size: <Insert inches by inches (mm by mm)>.
 9. Curb Height: <Insert inches (mm)>.
 10. Damper: [Yes] [No].
 11. Damper Size: <Insert inches by inches (mm by mm)>.
 12. Brake Horsepower: <Insert value>.
 13. Motor Size: <Insert value> hp.
 14. Motor rpm: <Insert value>.
 15. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.

2.4 UPBLAST PROPELLER ROOF EXHAUST FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Acme Engineering & Manufacturing Corporation.](#)
 2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
 3. [American Coolair Corporation.](#)

4. [Ammerman; Millennium Equipment.](#)
 5. [Breidert Air Products.](#)
 6. [Carnes Company.](#)
 7. [Cincinnati Fan.](#)
 8. [Greenheck Fan Corporation.](#)
 9. [Hartzell Fan Incorporated.](#)
 10. [JencoFan.](#)
 11. [Loren Cook Company.](#)
 12. [Madison Manufacturing.](#)
 13. [New York Blower Company \(The\).](#)
 14. [PennBarry.](#)
 15. [Quietaire Inc.](#)
 16. [Stanley Fans.](#)
 17. **<Insert manufacturer's name>.**
 18. or approved equal.
- B. Wind Band, Fan Housing, and Base: Reinforced and braced [**galvanized steel**] [**aluminum**], containing [**galvanized-steel**] [**aluminum**] butterfly dampers and rain trough, motor and drive assembly, and fan wheel.
1. Damper Rods: Steel with [**bronze**] [**nylon**] bearings.
 2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.
- C. Fan Wheel: Replaceable, [**cast**] [**extruded**]-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.
- D. Belt Drives:
1. Resiliently mounted to housing.
 2. Weatherproof housing of same material as fan housing.
 3. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 4. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings.
 5. Pulleys: Cast-iron, adjustable-pitch motor pulley.
 6. Motor Mount: On outside of fan cabinet, adjustable base for belt tensioning.
- E. Roof Curbs: Galvanized steel; mitered and welded corners; **1-1/2-inch-** (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and **1-1/2-inch** (40-mm) wood nailer. Size as required to suit roof opening and fan base.
1. Configuration: [**Self-flashing without a cant strip, with mounting flange**] [**Built-in cant and mounting flange**] [**Built-in raised cant and mounting flange**].
 2. Overall Height: [**8 inches** (200 mm)] [**9-1/2 inches** (240 mm)] [**12 inches** (300 mm)] [**16 inches** (400 mm)] [**18 inches** (450 mm)].
 3. Sound Curb: Curb with sound-absorbing insulation.
 4. Pitch Mounting: Manufacture curb for roof slope.
 5. Metal Liner: Galvanized steel.

6. Burglar Bars: [1/2-inch- (13-mm-)] [5/8-inch- (16-mm-)] [3/4-inch- (19-mm-)] thick steel bars welded in place to form 6-inch (150-mm) squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.

F. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. External Static Pressure: <Insert inches wg (Pa)>.
3. Fan Diameter: <Insert inches (mm)>.
4. Drive Arrangement: [Direct] [Belt drive].
5. Fan rpm: <Insert value>.
6. Tip Speed: <Insert fpm (m/s)>.
7. Sound: <Insert sone>.
8. Curb Size: <Insert inches by inches (mm by mm)>.
9. Curb Height: <Insert inches (mm)>.
10. Damper: [Yes] [No].
11. Damper Size: <Insert inches by inches (mm by mm)>.
12. Brake Horsepower: <Insert value>.
13. Motor Size: <Insert value> hp.
14. Motor rpm: <Insert value>.
15. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.

2.5 CENTRIFUGAL WALL VENTILATORS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [American Coolair Corporation.](#)
4. [Ammerman; Millennium Equipment.](#)
5. [Braidert Air Products.](#)
6. [Broan-NuTone LLC.](#)
7. [Broan-NuTone LLC; NuTone Inc.](#)
8. [Carnes Company.](#)
9. [Greenheck Fan Corporation.](#)
10. [Hartzell Fan Incorporated.](#)
11. [JencoFan.](#)
12. [Loren Cook Company.](#)
13. [PennBarry.](#)
14. [W.W. Grainger, Inc.; Dayton Products.](#)
15. <Insert manufacturer's name>.
16. or approved equal.

- B. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.
- C. Fan Wheel: Aluminum hub and wheel with backward-inclined blades.
- D. Belt Drives:
1. Resiliently mounted to housing.
 2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
 4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
 5. Fan and motor isolated from exhaust airstream.
- E. Accessories:
1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through internal aluminum conduit.
 3. Bird Screens: Removable, 1/2-inch (13-mm) mesh, aluminum or brass wire.
 4. Wall Grille: Ring type for flush mounting.
 5. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
 6. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.
- F. Capacities and Characteristics:
1. Airflow: <Insert cfm (L/s)>.
 2. External Static Pressure: <Insert inches wg (Pa)>.
 3. Fan Diameter: <Insert inches (mm)>.
 4. Drive Arrangement: [Direct] [Belt drive].
 5. Fan rpm: <Insert value>.
 6. Tip Speed: <Insert fpm (m/s)>.
 7. Sound: <Insert sone>.
 8. Damper: [Yes] [No].
 9. Damper Size: <Insert inches by inches (mm by mm)>.
 10. Brake Horsepower: <Insert value>.
 11. Motor Size: <Insert value> hp.
 12. Motor rpm: <Insert value>.
 13. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.

2.6 CEILING-MOUNTED VENTILATORS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [American Coolair Corporation](#).
 2. [Ammerman; Millennium Equipment](#).
 3. [Breidert Air Products](#).
 4. [Broan-NuTone LLC](#).
 5. [Broan-NuTone LLC; NuTone Inc](#).
 6. [Carnes Company](#).
 7. [FloAire](#).
 8. [Greenheck Fan Corporation](#).
 9. [JencoFan](#).
 10. [Loren Cook Company](#).
 11. [PennBarry](#).
 12. [W.W. Grainger, Inc.; Dayton Products](#).
 13. **<Insert manufacturer's name>**.
 14. or approved equal.
- B. Housing: Steel, lined with acoustical insulation.
- C. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.
- D. Grille: **[Plastic] [Stainless steel] [Aluminum] [Painted aluminum]**, louvered grille with flange on intake and thumbscrew attachment to fan housing.
- E. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.
- F. Accessories:
1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Manual Starter Switch: Single-pole rocker switch assembly with cover and pilot light.
 3. Time-Delay Switch: Assembly with single-pole rocker switch, timer, and cover plate.
 4. Motion Sensor: Motion detector with adjustable shutoff timer.
 5. Ceiling Radiation Damper: Fire-rated assembly with ceramic blanket, stainless-steel springs, and fusible link.
 6. Filter: Washable aluminum to fit between fan and grille.
 7. Isolation: Rubber-in-shear vibration isolators.
 8. Manufacturer's standard roof jack or wall cap, and transition fittings.
- G. Capacities and Characteristics:
1. Airflow: **<Insert cfm (L/s)>**.
 2. External Static Pressure: **<Insert inches wg (Pa)>**.

3. Sound: **<Insert sone>**.
4. Motor Size: **<Insert value>** hp.
5. Motor rpm: **<Insert value>**.
6. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.

2.7 IN-LINE CENTRIFUGAL FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Acme Engineering & Manufacturing Corporation.](#)
 2. [American Coolair Corporation.](#)
 3. [Ammerman; Millennium Equipment.](#)
 4. [Breidert Air Products.](#)
 5. [Carnes Company.](#)
 6. [FloAire.](#)
 7. [Greenheck Fan Corporation.](#)
 8. [Hartzell Fan Incorporated.](#)
 9. [JencoFan.](#)
 10. [Loren Cook Company.](#)
 11. [Madison Manufacturing.](#)
 12. [PennBarry.](#)
 13. [Quietaire Inc.](#)
 14. **<Insert manufacturer's name>**.
 15. or approved equal.
- B. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, sidewall, or ceiling mounting.
- C. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing[; **with wheel, inlet cone, and motor on swing-out service door**].
- D. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.
- E. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.
- F. Accessories:
1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.

3. Companion Flanges: For inlet and outlet duct connections.
4. Fan Guards: **1/2- by 1-inch** (13- by 25-mm) mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
5. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

G. Capacities and Characteristics:

1. Airflow: **<Insert cfm (L/s)>**.
2. External Static Pressure: **<Insert inches wg (Pa)>**.
3. Fan Diameter: **<Insert inches (mm)>**.
4. Wheel Type: **[Backward inclined] [Forward curved] [Airfoil]**.
5. Class: **[I] [II] [III]**.
6. Drive Arrangement: **<Insert AMCA number>**.
7. Fan rpm: **<Insert value>**.
8. Outlet Velocity: **<Insert fpm (m/s)>**.
9. Brake Horsepower: **<Insert value>**.
10. Motor Size: **<Insert value>** hp.
11. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
12. Vibration Isolators:
 - a. Type: **[Elastomeric hangers] <Insert type>**.
 - b. Static Deflection: **[1 inch (25 mm)] <Insert value>**.
13. Spark Arrestance Class: **[A] [B] [C]**.

2.8 PROPELLER FANS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Manufacturing Corporation.](#)
2. [Aerovent; a division of Twin City Fan Companies, Ltd.](#)
3. [Airmaster Fan Company.](#)
4. [American Coolair Corporation.](#)
5. [Ammerman; Millennium Equipment.](#)
6. [Breidert Air Products.](#)
7. [Broan-NuTone LLC; NuTone Inc.](#)
8. [Carnes Company.](#)
9. [Chicago Blower Corporation.](#)
10. [Cincinnati Fan.](#)
11. [Hartzell Fan Incorporated.](#)
12. [Howden Buffalo Inc.](#)
13. [JencoFan.](#)
14. [King Company; part of Mestek, Inc.](#)

15. [Loren Cook Company](#).
 16. [Madison Manufacturing](#).
 17. [Moffitt Corporation Inc.](#)
 18. [New York Blower Company \(The\)](#).
 19. [PennBarry](#).
 20. [Quietaire Inc.](#)
 21. [Stanley Fans](#).
 22. [W.W. Grainger, Inc.; Dayton Products](#).
 23. **<Insert manufacturer's name>**.
 24. or approved equal.
- B. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.
- C. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.
- D. Fan Wheel: Replaceable, [**cast**] [**extruded**]-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.
- E. Fan Drive: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing.
- F. Fan Drive:
1. Resiliently mounted to housing.
 2. Statically and dynamically balanced.
 3. Selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
 4. Extend grease fitting to accessible location outside of unit.
 5. Service Factor Based on Fan Motor Size: 1.4.
 6. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 7. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
 - a. Ball-Bearing Rating Life: ABMA 9, [**L₁₀ of 100,000 hours**] **<Insert life>**.
 8. Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
 9. Motor Pulleys: Adjustable pitch for use with motors through [**5**] **<insert value>** hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
 10. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
 11. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
- G. Accessories:
1. Gravity Shutters: Aluminum blades in aluminum frame; interlocked blades with nylon bearings.

2. Motor-Side Back Guard: Galvanized steel, complying with OSHA specifications, removable for maintenance.
3. Wall Sleeve: Galvanized steel to match fan and accessory size.
4. Weathershield Hood: Galvanized steel to match fan and accessory size.
5. Weathershield Front Guard: Galvanized steel with expanded metal screen.
6. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
7. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.

H. Capacities and Characteristics:

1. Airflow: <Insert cfm (L/s)>.
2. Fan Diameter: <Insert inches (mm)>.
3. Fan rpm: <Insert value>.
4. Brake Horsepower: <Insert value>.
5. Motor Size: <Insert value> hp.
6. Electrical Characteristics:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
7. Vibration Isolators:
 - a. Type: [Elastomeric hangers] [Spring isolators] [Restrained spring isolators] <Insert type>.
 - b. Static Deflection: [1 inch (25 mm)] <Insert value>.
8. Spark Arrestance Class: [A] [B] [C].

2.9 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- B. Enclosure Type: Totally enclosed, fan cooled.

2.10 SOURCE QUALITY CONTROL

- A. Certify sound-power level ratings according to AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

- B. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge:	64	57	51	47	42	39	38	37
Inlet:	64	57	51	47	42	39	38	37

- C. Certify fan performance ratings, including flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating." Label fans with the AMCA-Certified Ratings Seal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install power ventilators level and plumb.
- C. Equipment Mounting:
1. Install power ventilators on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - a. Support units using [**spring isolators**] [**restrained spring isolators**] <Insert item> having a static deflection of [**1 inch (25 mm)**] <Insert number>.
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Secure roof-mounted fans to roof curbs with cadmium-plated hardware. See Section 077200 "Roof Accessories" for installation of roof curbs.
- E. Ceiling Units: Suspend units from structure; use steel wire or metal straps.
- F. Support suspended units from structure using threaded steel rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stops**] <Insert device> having a static deflection of [**1 inch (25 mm)**] <Insert deflection>. Vibration-control devices are specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]
- G. Install units with clearances for service and maintenance.

- H. Extend ducts to **[roof] [wall]** exhausters into **[roof curb] [structure]**. Counterflash duct to **[roof] [wall]** opening.
- I. Provide sheaves required for final air balance.
- J. Install flexible connections specified in Section Section 233300 "Air Duct Accessories" between fan inlet and ductwork. Ensure metal bands of connectors are parallel with minimum one inch flex between ductwork and fan while running.
- K. Do not operate fans for any purpose until ductwork is clean, filters in place, bearings lubricated, and fan has been test run under observation.
- L. Label units according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

- A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300 "Air Duct Accessories."
- B. Install ducts adjacent to power ventilators to allow service and maintenance.
- C. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- E. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.3 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. Verify that shipping, blocking, and bracing are removed.
 - 2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
 - 3. Verify that cleaning and adjusting are complete.

4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
 5. Adjust belt tension.
 6. Adjust damper linkages for proper damper operation.
 7. Verify lubrication for bearings and other moving parts.
 8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
 9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
 10. Shut unit down and reconnect automatic temperature-control operators.
 11. Remove and replace malfunctioning units and retest as specified above.
- C. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.
- D. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections. Replace damaged and malfunctioning controls and equipment.
- E. Shut unit down and reconnect automatic temperature-control operators.
- F. Refer to Section 230593 "Testing, Adjusting and Balancing for HVAC", adjusting, and balancing procedures.
- G. Replace fan and motor pulleys as required to achieve design airflow.
- H. Repair or replace malfunctioning units. Retest as specified above after repairs or replacements are made.
- I. Prepare test and inspection reports.
- 3.4 ADJUSTING
- A. Adjust damper linkages for proper damper operation.
 - B. Adjust belt tension.
 - C. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.
 - D. Replace fan and motor pulleys as required to achieve design airflow.
 - E. Lubricate bearings.

3.5 CLEANING

- A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.
- B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain power ventilators.
- B. Train DEN maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
- C. Review data in maintenance manuals. Refer to Section 230400 "Basic HVAC Requirements".
- D. Schedule training with DEN Project Manager, with at least seven (7) days' advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233423

SECTION 233433 - AIR CURTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes air curtains [**with**] [**hot-water heat**] [**steam heat**] [**electric heat**] [**gas-fired heater**].
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties, and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For air curtains. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.
- C. Delegated-Design Submittal: For air curtains indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 - 1. Detail fabrication and assembly of air-curtain mounting assemblies.
 - 2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**].
- D. Coordination Drawings: Plans and details drawn to scale and coordinating penetrations of exterior walls.
- E. Samples for Initial Selection: For units with factory-applied color finishes.

1.4 INFORMATIONAL SUBMITTALS

- A. Warranties: Sample of special warranties.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air curtains to include in maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Furnish one (1) set of filters for each unit.
 2. Furnish one (1) set of fan belts for each unit.

1.7 QUALITY ASSURANCE

- A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air curtains and are based on the specific product indicated. Refer to Division 1.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.
- C. Comply with AMCA 220, "Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings," for airflow, outlet velocity, and power consumption.
- D. Comply with ARI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating.
1. Certify coils according to ARI 410.
- E. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."

1.8 COORDINATION

- A. Coordinate layout and installation of air curtains and suspension system components with other construction, including light fixtures, fire-suppression-system components, and partition assemblies.
- B. Coordinate installation of wall penetrations and louvers.

1.9 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air curtains that fail in materials or workmanship within specified warranty period.
1. Warranty Period (Nonheating Units): Minimum [**Five years**] [**Two years**] [**One year**] <Insert period>
 2. Warranty Period (Water or Steam Heating Units): Minimum [**Five years**] [**Two years**] [**One year**] <Insert period>
 3. Warranty Period (Gas Heating Units): Minimum [**Five years**] [**Two years**] [**One year**] <Insert period> months.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 AIR-CURTAIN UNIT<Insert drawing designation>

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Air Economy Corporation](#).
 2. [Berner International](#).
 3. [Biddle Air Systems Limited](#).
 4. [Cambridge Engineering, Inc.](#)
 5. [Disco Engineering, Inc.](#)
 6. [Fantech](#).
 7. [King Company; a company of Mestek, Inc.](#)
 8. [Loren Cook Company](#).
 9. [Marley Engineered Products](#).
 10. [Mars Air Doors; Mars Air System](#).
 11. [Mestek, Inc.; L. J. Wing Division](#).
 12. [Miniveil Air Systems](#).
 13. [Powered Aire, Inc.](#)
 14. [TMI, LLC; Curtron Products Division](#).
 15. <Insert manufacturer's name>.
 16. or approved equal.
- B. Housing:
1. Materials: Galvanized steel with electrostatically-applied epoxy-enamel finish over powdered mirror.
 2. Materials: One-piece, molded, high-impact, white polymer material.

3. Materials: Heavy-gage, electroplated-zinc steel with welded construction and polyester-coated finish.
 4. Materials: Heavy-gage, aluminum construction.
 - a. Anodized Finish: Match finish and color of adjacent architectural metals. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - b. Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.
 - 1) Class II, Clear Anodic Finish: AA-M12C22A31 (Mechanical Finish: Nonspecular as fabricated; Chemical Finish: Etched, medium matte; Anodic Coating: Architectural Class II, clear coating 0.010 mm or thicker) complying with AAMA 611.
 - 2) Class II, Color Anodic Finish: AA-M12C22A32/A34 (Mechanical Finish: Nonspecular as fabricated; Chemical Finish: Etched, medium matte; Anodic Coating: Architectural Class II, integrally colored or electrolytically deposited color coating 0.010 mm or thicker).
 5. Materials: Stainless steel.
 6. Discharge Nozzle: Integral part of the housing, containing fixed air-directional vanes.
 7. Discharge Nozzle: Integral part of the housing, containing adjustable air-directional vanes with **[40] [20] [15] <Insert number>**-degree sweep front to back.
 8. Discharge Nozzle: Integral part of the housing, containing air-directional vanes adjustable in 5-degree increments through a 45-degree sweep front to back.
- C. Mounting Brackets: Steel, for **[wall] [ceiling]** mounting.
- D. Air-Intake Louvers: Comply with requirements in Section 089000 "Louvers and Vents."
- E. Air-Intake **[Louvers] [Grille]**:
1. Louvers: Integral part of and same material as the housing, mechanically field adjustable and capable of reducing air-outlet velocity by **[60] <Insert number>** percent with louver in totally closed position.
 2. Grille: Integral part of and same material as the housing.
 3. Insect Screen: **[Aluminum] [Stainless steel]**, removable.
- F. Fans:
1. **[Centrifugal, forward curved, double width, double inlet] [Vane axial]**.
 2. **[Galvanized steel] [Painted steel] [Aluminum]**.
 3. Statically and dynamically balanced.
 4. **[Direct drive] [Belt drive and equipped with belt guards and adjustable sheaves and pulleys]**.

- G. Motors: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. **[Single speed] [Two speed] [Multispeed]**.
 3. Resiliently mounted.
 4. Continuous duty.
 5. **[Totally enclosed, air over] [Totally enclosed, fan cooled] [Open, dripproof] [Explosion proof]**.
 6. Integral thermal-overload protection.
 7. Bearings: Permanently sealed, lifetime, prelubricated, ball bearings.
 8. Disconnect: Internal power cord with plug and receptacle.
- H. Water Coils:
1. Type: **[Continuous-circuit] [Self-draining] [Cleanable]**.
 2. Piping Connections: Threaded on **[same end] [opposite ends]**.
 3. Tube Material: Copper, complying with **ASTM B 75** (ASTM B 75M).
 - a. Tube Diameter: **0.625 inch** (15.9 mm).
 4. Fins: **[Aluminum] [Copper]** with fin spacing **[0.167 inch (4.23 mm)] [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)]**.
 5. Fin and Tube Joint: **[Mechanical bond] [Silver brazed]**.
 6. Headers: **[Cast iron with drain and air vent tappings] [Cast iron with cleaning plugs, and drain and air vent tappings] [Seamless copper tube with brazed joints, prime coated] [Fabricated steel with brazed joints, prime coated]**.
 7. Frames: Galvanized-steel channel frame, **[0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] [0.0625 inch (1.59 mm)]**.
 8. Ratings: According to ASHRAE 33.
 9. Working-Pressure Ratings: **200 psig** (1380 kPa), **325 deg F** (163 deg C).
- I. Steam Coils: **[Distribution-header] [Single-tube]** coil, with threaded steam supply and condensate connections.
1. Piping Connections: **[Same end] [Opposite ends] [Steam supply on both ends; condensate on one end]**.
 2. Tube Material: Copper, complying with **ASTM B 75** (ASTM B 75M).
 3. Tube Diameter: **0.625 inch** (15.9 mm).
 4. Fins: **[Aluminum] [Copper]** with fin spacing **[0.167 inch (4.23 mm)] [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)]**.
 5. Fin and Tube Joint: **[Mechanical bond] [Silver brazed]**.
 6. Headers: **[Cast iron with drain and air vent tappings] [Cast iron with cleaning plugs, and drain and air vent tappings] [Seamless copper tube]**

with brazed joints, prime coated] [Fabricated steel with brazed joints, prime coated].

7. Frames: Galvanized-steel channel frame, [0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] [0.0625 inch (1.59 mm)].
8. Pressure and Temperature Ratings: 100 psig (690 kPa), 400 deg F (205 deg C) according to ASHRAE 33.

J. Electric-Resistance Coils:

1. Coil Assembly: Comply with UL 1995.
2. Frame: Galvanized-steel frame.
3. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
4. Heating Elements: Open-coil resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
5. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or unit.
 - a. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
6. Control Panel: [Unit] [Remote] mounted with disconnecting means and overcurrent protection. Include the following controls:
 - a. Magnetic contactor.
 - b. Mercury contactor.
 - c. Solid-state stepless pulse controller.
 - d. Toggle switches; one per step.
 - e. Step controller.
 - f. Time-delay relay.
 - g. Pilot lights; one per step.
 - h. Airflow-proving switch.

K. Gas-Fired Heaters:

1. Comply with ANSI Z83.8/CSA 2.6, "Gas Unit Heaters and Gas-Fired Duct Furnaces."
 - a. CSA Approval: Bear CSA label.
 - b. Type of Gas: [Natural] [LP].
2. Assembly and Wiring: Heaters factory assembled, piped, wired, and tested for 120-V ac.
3. Housing: Steel, with integral draft hood and inserts for suspension-mounted rods.

4. External Casings and Cabinets: Baked enamel over corrosion-resistant-treated surface.
5. Heat Exchanger: **[Aluminized]** **[Stainless]** steel.
6. Burners: Cast iron or aluminized steel with stainless-steel inserts.
7. Gravity vent.
8. Power Venter: 120-V ac, with stainless-steel shaft.
9. Automatic Gas Control: **[Single]** **[Two]**-stage, 24-V ac valve.
10. Ignition: **[Standing pilot]** **[Electronically controlled spark with flame sensor]**.

L. Filters:

1. Disposable Panel Filters: Factory-fabricated, viscous-coated, flat-panel-type, disposable air filters with glass-fiber media sprayed with nonflammable adhesive in **[cardboard]** **[galvanized-steel]** frame.
2. Washable Panel Filters: Removable, stainless-steel, baffle-type filters with spring-loaded fastening; with minimum **0.0781-inch-** (1.984-mm-) thick, stainless-steel filter frame.
3. Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.

M. Controls:

1. **[Built-in]** **[Field-Installed]** Thermostat: Line voltage, factory installed and wired to the **[junction box on air curtain]** **[motor-control panel]**.
2. Automatic Door Switch: **[Roller type]** **[Combination roller-plunger type]** **[Plunger type]** installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.
3. Start-Stop, Push-Button Switch: Manually activates and deactivates air curtain.
4. Three-Speed Switch: Manually activates, deactivates, and controls air-curtain fan speed.
5. Time-Delay Relay: Factory installed and adjustable to allow air curtain to operate from 0.5 seconds to 10 hours.
6. Motor-Control Panel: Complete with motor starter, 115-V ac transformer with primary and secondary fuses, terminal strip, and NEMA 250, **[Type 1]** **[Type 12]** enclosure**[with door-mounted hands-off-auto switch]**.

N. Accessories:

1. Mounting Brackets: Adjustable mounting brackets for drum-type roll-up doors.
2. Discharge Extension Neck: For ceiling-recessed installation.

O. Capacities and Characteristics:

1. Application: **[Thermal barrier]** **[Wind resistance]** **[Interior separation]** **[Fly and insect control]**.
2. Mounting Type: **[Suspension]** **[Wall brackets]** **[Keyhole wall mount]**.
3. Discharge Direction: **[Horizontal]** **[Vertical]**.
4. Door Type: **[Exterior]** **[Interior]**.
5. Door Height: <Insert inches (mm)>.
6. Door Width: <Insert inches (mm)>.

7. Unit Length: <Insert inches (mm)>.
8. Net Weight: <Insert lb (kg)>.
9. Nozzle Velocity: [1000 fpm (5 m/s)] <Insert fpm (m/s)>.
10. Airflow: <Insert cfm (L/s)>.
11. Intake: [Internal] [External].
12. Number of Fan(s): [1] [2] [3] <Insert number>.
13. Fan Motor:
 - a. Electrical Characteristics:
 - 1) Horsepower: [0.5] [1] [2] [3] <Insert value>.
 - 2) Volts: [120] [208] [230] [460] <Insert value>.
 - 3) Phase: [Single] [Poly].
 - 4) Hertz: 60.
 - 5) Speed: [1750] <Insert number> rpm.
 - 6) Full-Load Amperes: <Insert value>.
 - 7) Minimum Circuit Ampacity: <Insert value>.
 - 8) Maximum Overcurrent Protection: <Insert amperage>.
14. Sound Level Measured 10 feet (3 m) from Nozzle: <Insert number> dBA.
15. Hot-Water Coil:
 - a. Entering-Water Temperature: <Insert deg F (deg C)>.
 - b. Leaving-Water Temperature: <Insert deg F (deg C)>.
 - c. Water Flow: <Insert gpm (L/s)>.
 - d. Water Pressure Drop: <Insert feet of head (kPa)>.
 - e. Air-Temperature Rise: <Insert deg F (deg C)>.
 - f. Number of Coil Row(s): [1] [2] <Insert number>.
16. Steam Coil:
 - a. Capacity: <Insert MBh (kW)>.
 - b. Air-Temperature Rise: <Insert deg F (deg C)>.
 - c. Number of Coil Row(s): [1] [2] <Insert number>.
 - d. Inlet Pressure: <Insert psig (kPa)>.
 - e. Condensing Capacity: <Insert lb/h (g/s)>.
17. Electric Heater:
 - a. Capacity: <Insert kW>.
 - b. Air-Temperature Rise: <Insert deg F (deg C)>.
 - c. Volts: [120] [208] [230] [460] <Insert value>.
 - d. Phase: [Single] [Poly].
 - e. Hertz: 60.
 - f. Minimum Circuit Ampacity: <Insert value>.
 - g. Maximum Overcurrent Protection: <Insert amperage>.
 - h. Control Step(s): [One] [Two] [Three] <Insert value>.
18. Gas-Fired Heaters:

- a. Capacity: <Insert Btu/h (W)> at <Insert wg (Pa)> gas pressure.
- b. Air-Temperature Rise: <Insert deg F (deg C)>.

2.2 SOURCE QUALITY CONTROL

- A. Source Quality Control: Test to **300 psig** (2070 kPa) and to **200 psig** (1380 kPa) underwater.
- B. Testing: Test and inspect steam coils according to ASHRAE 33.
- C. Steam coils will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance.
- B. Examine roughing-in for [**hot-water**] [**steam**] [**gas**] piping systems to verify actual locations of piping connections before air-curtain installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install air curtains with clearance for equipment service and maintenance.
- B. Equipment Installation: Install air curtains[**with seismic-restraint devices**]. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- C. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

3.3 CONNECTIONS

- A. Comply with requirements for heating hot water piping specified in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements for steam piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

- C. Comply with requirements for natural gas piping specified in Section 231123 "Facility Natural-Gas Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- D. Comply with requirements for LP gas piping specified in Section 231126 "Facility Liquefied-Petroleum Gas Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- E. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
- F. Breeching: Comply with applicable requirements in Section 235116 "Fabricated Breechings and Accessories." Connect breeching to full size at flue outlet.
- G. Ground equipment according to Division 26.
- H. Connect wiring according to Division 26.

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. After installing air curtains completely, perform visual and mechanical check of individual components.
 - 2. After electrical circuitry has been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.
 - 3. Inspect for water leaks.
 - 4. Test gas train and verify that there are no gas leaks.
 - 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Air-curtain unit will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Adjust belt tension.
- B. Adjust motor and fan speed to achieve specified airflow.
- C. Adjust discharge louver and dampers to regulate airflow.

- D. Adjust air-directional vanes.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air curtains.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233433

SECTION 233600 - AIR TERMINAL UNITS

IT INCLUDES DUAL DUCT UNITS INCORPORATING DIFFUSERS, AND UNITS SUPPLIED FOR FIELD INSTALLATION OF CONTROLS BY A CONTROLS CONTRACTOR. AIR OUTLETS AND INLETS ARE NOT INCLUDED IN THIS SECTION.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Bypass, single-duct air terminal units.
 - 2. Dual-duct air terminal units.
 - 3. Fan-powered air terminal units.
 - 4. Induction air terminal units.
 - 5. Shutoff, single-duct air terminal units.
 - 6. Diffuser-type air terminal units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following products, including configuration, general assembly, materials used in fabrication. Include catalog performance ratings that indicate airflow, static pressure, and NC designation. Include rated capacities, electrical characteristics and connection requirements, furnished specialties, sound-power ratings, and accessories.
 - 1. Air terminal units.
 - 2. Liners and adhesives.
 - 3. Sealants and gaskets.

4. Seismic-restraint devices.
5. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Shop Drawings: For air terminal units. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.
3. Hangers and supports, including methods for duct and building attachment[, **seismic restraints,**] and vibration isolation.

D. Delegated-Design Submittal:

1. Materials, fabrication, assembly, and spacing of hangers and supports.
2. Design Calculations: Calculations[, **including analysis data signed and sealed by the qualified professional engineer responsible for their preparation**] for selecting hangers and supports[**and seismic restraints**].

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Ceiling suspension assembly members.
2. Size and location of initial access modules for acoustic tile.
3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

B. Copies of required warranties.

C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals. Include manufacturer's descriptive literature, operating instructions, maintenance and repair data, and parts lists. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

1. Instructions for resetting minimum and maximum air volumes.

2. Instructions for adjusting software set points.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual locations of [units] [, controls components] <Insert item>.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fan-Powered-Unit Filters: Furnish [one (1)] <Insert number> spare filter(s) for each filter installed.

2. Provide [two (2)] <Insert number> additional electric motors of each size on Project.

1.7 QUALITY ASSURANCE

A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

B. Base performance on tests conducted in accordance with ADC 1062.

C. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

E. NFPA Compliance: Install air terminal units according to NFPA 90A.

1.8 WARRANTY

A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements".

B. Provide [five (5)] <Insert number> year warranty for [system powered control systems.] [operating controls.] [electric motors.]

1.9 CONSTRUCTION WASTE MANAGEMENT

A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to

satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Structural Performance: Hangers and supports[**and seismic restraints**] shall withstand the effects of gravity[**and seismic**] loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" [and] [ASCE/SEI 7] [SMACNA's "**Seismic Restraint Manual: Guidelines for Mechanical Systems**"] <Insert document>.
1. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
 2. Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
 3. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.

2.2 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 BYPASS, SINGLE-DUCT AIR TERMINAL UNITS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Carnes](#).
 2. [Carrier Corporation](#).
 3. [Titus](#).
 4. <Insert manufacturer's name>.
 5. or approved equal.
- B. Configuration: Diverting-damper assembly inside unit casing with control components inside a protective metal shroud.
- C. Casing: [0.034-inch (0.85-mm) **steel**] [0.032-inch (0.8-mm) **aluminum**], [**single**] [**double**] wall.
1. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.

2. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Air Inlet: Round stub connection for duct attachment.
 4. Air Outlet: S-slip and drive connections.
 5. Access: Removable panels for access to diverting damper and other parts requiring service, adjustment, or maintenance; with airtight gasket.
 6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Diverter Assembly: [**Galvanized-steel gate, with polyethylene linear bearings**] [**Aluminum blade, with nylon-fitted pivot points**].
- E. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <Insert number> [6-inch- (150-mm-)] [8-inch- (200-mm-)] [10-inch- (250-mm-)] diameter collars, each with locking butterfly balancing damper.
- F. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
- G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
1. Access door interlocked disconnect switch.
 2. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
 3. Nickel chrome 80/20 heating elements.
 4. Airflow switch for proof of airflow.
 5. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
 6. Mercury contactors.
 7. Pneumatic-electric switches and relays.
 8. Magnetic contactor for each step of control (for three-phase coils).
- H. Electric Controls: Damper actuator and thermostat.
1. Damper Actuator: 24 V, powered closed, powered open[**with microswitch to energize heating control circuit**].
 2. Thermostat: Wall-mounted electric type with temperature display in Fahrenheit and Celsius, and space temperature set point.
 3. Changeover Thermostat: Duct-mounted, field-adjustable, electric type reverses action of zone thermostat when air temperature reaches 70 deg F (21 deg C).

- I. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat. Control devices shall be compatible with temperature controls and shall have the following features:
 1. Damper Actuator: 24 V, powered closed, powered open.
 2. Thermostat: Wall-mounted electronic type with the following features:
 - a. Temperature set-point display in Fahrenheit and Celsius.
 - b. Auxiliary switch to energize heating control circuit.
 - c. Changeover thermistor to reverse action.

2.4 DUAL-DUCT AIR TERMINAL UNITS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Anemostat Products; a Mestek Company.](#)
 2. [Carnes.](#)
 3. [Krueger.](#)
 4. [METALAIRE, Inc.](#)
 5. [Nailor Industries Inc.](#)
 6. [Price Industries.](#)
 7. [Titus.](#)
 8. [Trane; a business of American Standard Companies.](#)
 9. [Tuttle & Bailey.](#)
 10. **<Insert manufacturer's name>.**
 11. or approved equal.
- B. Configuration: Two volume dampers inside unit casing with mixing attenuator section and control components inside a protective metal shroud [**with a third primary air inlet with volume damper**].
- C. Casing: [**0.034-inch (0.85-mm) steel**] [**0.032-inch (0.8-mm) aluminum**], [**single**] [**double**] wall.
 1. Casing Lining: Adhesive attached, [**1/2-inch- (13-mm-)**] [**3/4-inch- (19-mm-)**] [**1-inch- (25-mm-)**] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Casing Lining: Adhesive attached, [**1/2-inch- (13-mm-)**] [**3/4-inch- (19-mm-)**] [**1-inch- (25-mm-)**] thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

3. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
 4. Air Outlet: S-slip and drive connections.
 5. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
 6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
1. Maximum Damper Leakage: ARI 880 rated, 3 percent of nominal airflow at [3-inch wg (750-Pa)] [6-inch wg (1500-Pa)] inlet static pressure.
- E. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.
- F. Attenuator Section: [0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum] sheet.
1. Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- G. Multioutlet Attenuator Section: With [two] [three] [four] <Insert number> [6-inch- (150-mm-)] [8-inch- (200-mm-)] [10-inch- (250-mm-)] [12-inch- (300-mm-)] diameter collars, each with locking butterfly balancing damper.
- H. Pneumatic Controls: Damper operator, velocity controllers, and thermostat. Control devices shall be compatible with temperature controls and shall have the following features:
1. Pneumatic Damper Operator: [0- to 13-psig (0- to 90-kPa)] <Insert range> spring range.
 2. Velocity Controllers: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor.

- Locate velocity sensors in [**cold- and hot-deck**] [**cold-, hot-, and ventilation-deck**] [**cold-deck**] air inlets and supply air outlets.
3. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.
- I. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls and shall have the following features:
 1. Damper Actuator: 24 V, powered closed, [**spring return open**] [**powered open**].
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to **4-inch wg** (1000 Pa); and shall have a multipoint velocity sensor. Locate velocity sensors in cold-deck air inlets and air outlets.
 3. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit[**and Celsius**].
 - J. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
 - K. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and shall have the following features:
 1. Damper Actuators: 24 V, powered closed, [**spring return open**] [**powered open**].
 2. Terminal Unit Controller: Pressure-independent, [**variable-air**] [**constant**]-volume controller with electronic airflow transducers factory calibrated to minimum and maximum air volumes, and having the following features:
 - a. Occupied and unoccupied operating mode.
 - b. Remote reset of airflow or temperature set points.
 - c. Adjusting and monitoring with portable terminal.
 - d. Communication with temperature-control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
 3. Room Sensor: Wall mounted with temperature set-point adjustment and access for connection of portable operator terminal.
 - L. Control Sequence:
 1. Modulate cold-air damper to maintain room temperature.
 2. Modulate warm-air damper to maintain constant airflow.
- 2.5 PARALLEL FAN-POWERED AIR TERMINAL UNITS
- A. **Manufacturers**: Subject to compliance with requirements, provide products by one of the following:

1. [Anemostat Products; a Mestek Company.](#)
 2. [Carnes.](#)
 3. [Environmental Technologies, Inc.](#)
 4. [Krueger.](#)
 5. [METALAIRE, Inc.](#)
 6. [Nailor Industries Inc.](#)
 7. [Price Industries.](#)
 8. [Titus.](#)
 9. [Trane; a business of American Standard Companies.](#)
 10. [Tuttle & Bailey.](#)
 11. **<Insert manufacturer's name>.**
 12. or approved equal.
- B. Configuration: Volume-damper assembly and fan in parallel arrangement inside unit casing with control components inside a protective metal shroud.
- C. Casing: [0.034-inch (0.85-mm) **steel**] [0.032-inch (0.8-mm) **aluminum**], [**single**] [**double**] wall.
1. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
 4. Air Outlet: S-slip and drive connections.
 5. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
 6. Fan: Forward-curved centrifugal, located at plenum air inlet.
 7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.
1. Maximum Damper Leakage: ARI 880 rated, [2] [3] percent of nominal airflow at [3-inch wg (750-Pa)] [6-inch wg (1500-Pa)] inlet static pressure.
 2. Damper Position: Normally [**open**] [**closed**].

- E. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.
- F. Motor:
1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Type: [**Permanent-split capacitor with SCR for speed adjustment**] [**Electronically commutated motor**].
 3. Fan-Motor Assembly Isolation: Rubber isolators.
 4. Enclosure: [**Open dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 5. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 6. Motor Bearings: <Insert special requirements>.
 7. Unusual Service Conditions:
 - a. Ambient Temperature: <Insert deg F (deg C)>.
 - b. Altitude: <Insert feet (m)> above sea level.
 - c. High humidity.
 - d. <Insert conditions>.
 8. Efficiency: Premium efficient.
 9. NEMA Design: <Insert designation>.
 10. Service Factor: <Insert value>.
 11. Motor Speed: [**Single speed**] [**Multispeed**].
 - a. Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.
 12. Electrical Characteristics:
 - a. Horsepower: <Insert value>.
 - b. Volts: [**120**] [**208**] [**230**] [**460**] <Insert value>.
 - c. Phase: [**Single**] [**Poly**].
 - d. Hz: 60.
 - e. Full-Load Amperes: <Insert value>.
 - f. Minimum Circuit Ampacity: <Insert value>.
 - g. Maximum Overcurrent Protection: <Insert amperage>.
- G. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
1. Material: Polyurethane foam having 70 percent arrestance and 3 MERV.
 2. Material: Glass fiber treated with adhesive; having 80 percent arrestance and 5 MERV.
 3. Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.
 4. Thickness: [**2 inches (50 mm)**] [**1 inch (25 mm)**].

- H. Attenuator Section: [0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum] sheet.
1. Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- I. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
1. Location: Plenum air inlet.
- J. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
1. Location: Plenum air inlet.
 2. Stage(s): [1] [2] [3].
 3. Access door interlocked disconnect switch.
 4. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
 5. Nickel chrome 80/20 heating elements.
 6. Airflow switch for proof of airflow.
 7. Fan interlock contacts.
 8. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
 9. Mercury contactors.
 10. Pneumatic-electric switches and relays.
 11. Magnetic contactor for each step of control (for three-phase coils).
- K. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
 2. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
 3. Disconnect Switch: Factory-mounted, fuse type.
- L. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.
- M. Electric Controls: 24-V damper actuator with wall-mounted electric thermostat and appropriate mounting hardware.
- N. Pneumatic Controls: Damper operator, velocity controller, and thermostat. Control devices shall be compatible with temperature controls and shall have the following features:
1. Pneumatic Damper Operator: [0- to 13-psig (0- to 90-kPa)] **<Insert range>** spring range.
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while pressure independent up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
 3. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.
- O. Electronic Controls: Bidirectional damper operator and microprocessor-based controller with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls and shall have the following features:
1. Occupied and unoccupied operating mode.
 2. Remote reset of airflow or temperature set points.
 3. Adjusting and monitoring with portable terminal.
 4. Communication with temperature-control system.
- P. Control Sequence:
1. Occupied (Primary Airflow On):
 - a. Operate as throttling control for cooling.
 - b. As cooling requirement decreases, control valve throttles toward minimum airflow.
 - c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**].
 2. Unoccupied (Primary Airflow Off):
 - a. When pressure at primary inlet is zero or less, fan is de-energized.
 - b. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**].

Q. Acoustical Performance - Fan Powered Parallel VAV Units

1. All sound data shall be compiled in an independent ADC certified laboratory and in accordance with the latest version of ARI 880. All units shall be ARI certified and bear the ARI certification label.
2. Unit maximum radiated and discharge sound power levels with fan only and 0.25 in. w.g. (63 Pa) discharge static pressure shall not exceed the values in Tables 1 and 2 at the specified airflow. No credit shall in any way be considered for room, plenum, ceiling, and/or similar item effects.
3. VAV units provided for this Project shall perform so as not to exceed sound power levels shown in Tables 1 and 2.

**Table 1 - Maximum Radiated Sound Power Levels (dB)
 (Heating Cycle - Fan Only)**

Unit Size	Airflow CFM	L/sec	Sound Power Octave Band and Center Frequency					
			2 125	3 250	4 500	5 1000	6 2000	7 4000
2	450	189	71	63	61	56	51	47
3	600	284	70	62	62	57	51	46
4	750	355	71	63	63	58	52	47
5	950	449	73	65	62	58	54	49
6	1450	685	73	69	64	59	58	52

**Table 1 - Maximum Discharge Sound Power Levels (dB)
 (Heating Cycle - Fan Only)**

Unit Size	Airflow CFM	L/sec	Sound Power Octave Band and Center Frequency					
			2 125	3 250	4 500	5 1000	6 2000	7 4000
2	450	189	68	67	63	56	53	50
3	600	284	65	64	61	54	50	47
4	750	355	66	66	62	55	52	48
5	950	449	69	65	61	54	54	51
6	1450	685	69	66	63	57	56	54

4. Unit maximum radiated and discharge sound power levels with 100% primary air at 1.0 in. w.g. (250 Pa) inlet pressure and 0.25 in. w.g. (63 Pa) discharge static pressure shall not exceed the values in Tables 3 and 4 at the specified airflow. No credit shall in any way be considered for room, plenum, ceiling, and/or similar item effects.

**Table 1 - Maximum Radiated Sound Power Levels (dB)
 (Full Cooling - 100% Primary Air and Fan Off)**

Unit Size	Airflow CFM	L/sec	Sound Power Octave Band and Center Frequency					
			2 125	3 250	4 500	5 1000	6 2000	7 4000
2	700	331	62	58	50	43	36	27
3	1100	520	65	56	52	47	37	27

4	1600	756	59	59	56	48	40	31
5	2100	993	67	59	53	46	43	37
6	2800	1324	71	60	52	47	43	32

2.6 SERIES FAN-POWERED AIR TERMINAL UNITS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Anemostat Products: a Mestek Company.](#)
2. [Carnes.](#)
3. [Environmental Technologies, Inc.](#)
4. [Krueger.](#)
5. [METALAIRE, Inc.](#)
6. [Nailor Industries Inc.](#)
7. [Price Industries.](#)
8. [Titus.](#)
9. [Trane: a business of American Standard Companies.](#)
10. [Tuttle & Bailey.](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

B. Configuration: Volume-damper assembly and fan in series arrangement inside unit casing with control components inside a protective metal shroud **[for installation above a ceiling] [and] [within a raised access floor].**

C. Casing: **[0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum], [single] [double] wall.**

1. Casing Lining: Adhesive attached, **[1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)]** thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
2. Casing Lining: Adhesive attached, **[1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)]** thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
3. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
4. Air Outlet: S-slip and drive connections.
5. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
6. Fan: Forward-curved centrifugal.

7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.
 1. Maximum Damper Leakage: ARI 880 rated, [2] [3] percent of nominal airflow at [3-inch wg (750-Pa)] [6-inch wg (1500-Pa)] inlet static pressure.
 2. Damper Position: Normally [open] [closed].
- E. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.
- F. Motor:
 1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Type: [Permanent-split capacitor with SCR for speed adjustment] [Electronically commutated motor].
 3. Fan-Motor Assembly Isolation: Rubber isolators.
 4. Enclosure: [Open dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over] [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine].
 5. Enclosure Materials: [Cast iron] [Cast aluminum] [Rolled steel].
 6. Motor Bearings: <Insert special requirements>.
 7. Unusual Service Conditions:
 - a. Ambient Temperature: <Insert deg F (deg C)>.
 - b. Altitude: <Insert feet (m)> above sea level.
 - c. High humidity.
 - d. <Insert conditions>.
 8. Efficiency: Premium efficient.
 9. NEMA Design: <Insert designation>.
 10. Service Factor: <Insert value>.
 11. Motor Speed: [Single speed] [Multispeed].
 - a. Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.
 12. Electrical Characteristics:
 - a. Horsepower: <Insert value>.
 - b. Volts: [120] [208] [230] [460] <Insert value>.
 - c. Phase: [Single] [Poly].
 - d. Hz: 60.
 - e. Full-Load Amperes: <Insert value>.
 - f. Minimum Circuit Ampacity: <Insert value>.
 - g. Maximum Overcurrent Protection: <Insert amperage>.

- G. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
1. Material: Polyurethane foam having 70 percent arrestance and 3 MERV.
 2. Material: Glass fiber treated with adhesive; having 80 percent arrestance and 5 MERV.
 3. Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.
 4. Thickness: [2 inches (50 mm)] [1 inch (25 mm)].
- H. Attenuator Section: [0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum] sheet.
1. Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- I. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
- J. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
1. Stage(s): [1] [2] [3].
 2. Access door interlocked disconnect switch.
 3. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
 4. Nickel chrome 80/20 heating elements.
 5. Airflow switch for proof of airflow.
 6. Fan interlock contacts.
 7. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
 8. Mercury contactors.
 9. Pneumatic-electric switches and relays.

10. Magnetic contactor for each step of control (for three-phase coils).
- K. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.
 1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
 2. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
 3. Disconnect Switch: Factory-mounted, fuse type.
- L. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.
- M. Electric Controls: 24-V damper actuator with wall-mounted electric thermostat and appropriate mounting hardware.
- N. Pneumatic Controls: Damper operator, velocity controller, and thermostat. Control devices shall be compatible with temperature controls and shall have the following features:
 1. Pneumatic Damper Operator: [0- to 13-psig (0- to 90-kPa)] <Insert range> spring range.
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while pressure independent up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
 3. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.
- O. Electronic Controls: Bidirectional damper operator and microprocessor-based controller with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls and shall have the following features:
 1. Occupied and unoccupied operating mode.
 2. Remote reset of airflow or temperature set points.
 3. Adjusting and monitoring with portable terminal.
 4. Communication with temperature-control system.
- P. Control Sequence:
 1. Occupied (Primary Airflow On):
 - a. When pressure at inlet is at least 1.2-inch wg (300 Pa).
 - b. As cooling requirement decreases, control valve throttles toward minimum airflow.
 2. Unoccupied (Primary Airflow Off):
 - a. When pressure at primary inlet is zero or less, fan is de-energized.

Q. Acoustical Performance - Fan powered Series VAV Units

1. All sound data shall be compiled in an independent ADC certified laboratory and in accordance with the latest version of ARI 880. All units shall be ARI certified and bear the ARI certification label.
2. Unit maximum radiated sound power levels at 1.0 in. w.g. (250 Pa) inlet pressure and 0.25 in. w.g. (63 Pa) discharge static pressure shall not exceed the values in Tables 1 and 2 at the specified airflow. No credit shall in any way be considered for room, plenum, ceiling, and/or similar item effects.

**Table 2 - Maximum Radiated Sound Power Levels (dB)
 (Full Heating - Fan Only)**

Unit Size	Airflow		Sound Power Octave Band and Center Frequency						
	CFM	L/sec	2	3	4	5	6	7	
			125	250	500	1000	2000	4000	
2	450	212	62	58	53	46	40	35	
3	900	425	64	61	61	60	51	39	
4	1300	614	68	64	60	55	48	42	
5	1700	802	70	65	61	59	53	48	
6	2000	944	70	67	61	58	52	47	

3. Unit maximum discharge sound power levels at 1.0 in. w.g. (250 Pa) inlet pressure and 0.25 in. w.g. (63 Pa) discharge static pressure shall not exceed, by more than 2 dB, the values in Table 3 at the specified airflow. No credit shall in any way be considered for room, plenum, ceiling, and/or similar item effects.

**Table 3 - Maximum Discharge Sound Power Levels (dB)
 (Full Cooling - Fan On and 100% Primary Air)**

Unit Size	Airflow		Sound Power Octave Band and Center Frequency						
	CFM	L/sec	2	3	4	5	6	7	
			125	250	500	1000	2000	4000	
2	450	212	72	67	63	61	61	50	
3	900	425	69	63	61	57	57	55	
4	1300	614	73	74	65	62	65	61	
5	1700	802	77	70	71	68	68	65	
6	2000	944	77	68	69	67	65	64	

2.7 INDUCTION AIR TERMINAL UNITS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Price Industries.
 2. Tuttle & Bailey.
 3. **<Insert manufacturer's name>.**
 4. or approved equal.

- B. Configuration: Volume-damper assembly inside unit casing with mechanical induction damper mounted on casing and control components inside a protective metal shroud.
- C. Casing: [0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum], [single] [double] wall.
1. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Air Inlet: Round stub connection for duct attachment.
 4. Air Outlet: S-slip and drive connections[, **size matching inlet size**].
 5. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
 6. Fan: Forward-curved centrifugal.
 7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
1. Maximum Damper Leakage: ARI 880 rated, [2] [3] percent of nominal airflow at [3-inch wg (750-Pa)] [6-inch wg (1500-Pa)] inlet static pressure.
 2. Damper Position: Normally [**open**] [**closed**].
- E. Induction Damper: Galvanized-steel, multiblade assembly with self-lubricating bearings.
- F. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
- G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
1. Access door interlocked disconnect switch.

2. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
 3. Nickel chrome 80/20 heating elements.
 4. Airflow switch for proof of airflow.
 5. Fan interlock contacts.
 6. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
 7. Mercury contactors.
 8. Pneumatic-electric switches and relays.
 9. Magnetic contactor for each step of control (for three-phase coils).
- H. Pneumatic Controls: Damper operator, velocity controller, and induction damper operator. Control devices shall be compatible with temperature controls and shall have the following features:
1. Damper Operator: Pneumatic, [0- to 13-psig (0- to 90-kPa)] <Insert range> spring range.
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
 3. Induction Damper Operator: Pneumatic, spring range matching reset range of controller.
 4. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.
- I. Electronic Controls: Pneumatic damper operators, electronic controller integral airflow transducer, and electronic thermostat. Control devices shall be compatible with temperature controls and shall have the following features:
1. Damper Actuator: Pneumatic, [0- to 13-psig (0- to 90-kPa)] <Insert range> spring range.
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
 3. Induction Damper Operator: Pneumatic, spring range matching reset range of controller.
 4. Thermostat: Wall-mounted electronic type with the following features:
 - a. Proportional, plus integral control of room temperature.
 - b. Time-proportional reheat-coil control.
 - c. Temperature set-point display in Fahrenheit and Celsius.

2.8 SHUTOFF, SINGLE-DUCT AIR TERMINAL UNITS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Anemostat Products; a Mestek Company.](#)
 2. [Carnes.](#)
 3. [Environmental Technologies, Inc.](#)
 4. [Krueger.](#)
 5. [METALAIRE, Inc.](#)
 6. [Nailor Industries Inc.](#)
 7. [Phoenix Controls Corporation.](#)
 8. [Price Industries.](#)
 9. [Titus.](#)
 10. [Trane; a business of American Standard Companies.](#)
 11. [Trox USA Inc.; a subsidiary of the TROX GROUP.](#)
 12. [Tuttle & Bailey.](#)
 13. [Warren Technology.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.
- C. Casing: [0.034-inch (0.85-mm) **steel**] [0.032-inch (0.8-mm) **aluminum**], [**single**] [**double**] wall.
1. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Casing Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
 4. Air Outlet: S-slip and drive connections[, **size matching inlet size**].
 5. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
 6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Regulator Assembly: System-air-powered bellows section incorporating polypropylene bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from 0 to 140 deg F (minus 18 to plus 60 deg C), shall be impervious to moisture and fungus, shall be suitable for 10-inch wg (2500-Pa) static pressure, and shall be factory tested for leaks.

- E. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
1. Maximum Damper Leakage: ARI 880 rated, [2] [3] percent of nominal airflow at [3-inch wg (750-Pa)] [6-inch wg (1500-Pa)] inlet static pressure.
 2. Damper Position: Normally [open] [closed].
- F. Attenuator Section: [0.034-inch (0.85-mm) steel] [0.032-inch (0.8-mm) aluminum] sheet.
1. Lining: Adhesive attached, [1/2-inch- (13-mm-)] [3/4-inch- (19-mm-)] [1-inch- (25-mm-)] thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 - a. Cover liner with nonporous foil.
 - b. Cover liner with nonporous foil and perforated metal.
 2. Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
 3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- G. Multioutlet Attenuator Section: With [two] [three] [four] <Insert number> [6-inch- (150-mm-)] [8-inch- (200-mm-)] [10-inch- (250-mm-)] diameter collars, each with locking butterfly balancing damper.
- H. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
- I. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
1. Access door interlocked disconnect switch.
 2. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
 3. Nickel chrome 80/20 heating elements.
 4. Airflow switch for proof of airflow.
 5. Fan interlock contacts.
 6. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
 7. Mercury contactors.
 8. Pneumatic-electric switches and relays.
 9. Magnetic contactor for each step of control (for three-phase coils).

- J. Electric Controls: Damper actuator and thermostat.
1. Damper Actuator: 24 V, powered closed, [**spring return open**] [**powered open**].
 2. Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.
- K. Pneumatic Controls: Damper operator and velocity controller. Control devices shall be compatible with temperature controls and shall have the following features:
1. Pneumatic Damper Operator: [0- to 13-psig (0- to 90-kPa)] <Insert range> spring range.
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
 3. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.
- L. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls and shall have the following features:
1. Damper Actuator: 24 V, powered closed, [**spring return open**] [**powered open**].
 2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
 3. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.
- M. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- N. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and shall have the following features:
1. Damper Actuator: 24 V, powered closed, [**spring return open**] [**powered open**].
 2. Terminal Unit Controller: Pressure-independent, variable-air-volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
 - a. Occupied and unoccupied operating mode.
 - b. Remote reset of airflow or temperature set points.
 - c. Adjusting and monitoring with portable terminal.
 - d. Communication with temperature-control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

3. Room Sensor: Wall mounted with temperature set-point adjustment and access for connection of portable operator terminal.

O. Control Sequence:

1. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg (60- and 750-Pa) inlet static pressure.
2. System-powered, wall-mounted thermostat.

2.9 DIFFUSER-TYPE AIR TERMINAL UNITS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acutherm](#).
2. [Rickard Air Diffusion](#).
3. [Warren Technology](#).
4. **<Insert manufacturer's name>**.
5. or approved equal.

B. Configuration: Volume-damper, diffuser, controller assembly[**and electric heater**] and wall-mounted thermostat[**with master-slave capability**].

C. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Damper Position: Normally [**open**] [**closed**].

D. Diffuser: Galvanized steel with white baked-enamel finish.

E. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls and shall have the following features:

1. Damper Actuator: 24 V, powered closed, [**spring return open**] [**powered open**].
2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
3. Thermostat: Wall-mounted electronic type with the following features:
 - a. Proportional, plus integral control of room temperature.
 - b. Temperature set-point display in Fahrenheit and Celsius.

F. Integral thermally powered actuators control diffusion dampers based on duct and room temperature.

2.10 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Steel Cables: [**Galvanized steel complying with ASTM A 603**] [**Stainless steel complying with ASTM A 492**].
- D. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- E. Air Terminal Unit Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- F. Trapeze and Riser Supports: Steel shapes and plates for units with steel casings; aluminum for units with aluminum casings.

2.11 SEISMIC-RESTRAINT DEVICES

- A. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by [**an evaluation service member of the ICC Evaluation Service**] [**the Office of Statewide Health Planning and Development for the State of California**] [**an agency acceptable to authorities having jurisdiction**].
 - 1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least [**four**] <**Insert number**> times the maximum seismic forces to which they will be subjected.
- B. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.
- C. Restraint Cables: [**ASTM A 603, galvanized**] [**ASTM A 492, stainless**]-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; with an automatic-locking and clamping device or double-cable clips.
- D. Hanger Rod Stiffener: [**Steel tube or steel slotted-support-system sleeve with internally bolted connections**] [**Reinforcing steel angle clamped**] to hanger rod.
- E. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

2.12 SOURCE QUALITY CONTROL

- A. Factory Tests: Test assembled air terminal units according to ARI 880.
 - 1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, **[coil type,]** and ARI certification seal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."
- B. Install in accordance with manufacturer's instructions.
- C. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.
- D. Provide ceiling access doors or locate units above easily removable ceiling components.
- E. Support units individually from structure. Do not support from adjacent ductwork.
- F. Connect to ductwork in accordance with Sections 233113 "Metal Ducts" and 233116 "Nonmetal Ducts".
- G. Provide minimum of **[5] <Insert number>** ft of **[one (1)] [two (2)]** inch thick lined ductwork downstream of units.
- H. Install heating coils in accordance with Section 238216 "Air Coils".
- I. Verify that electric power is available and of the correct characteristics. Coordinate with requirements of Division 26 Sections.
- J. Install wall-mounted thermostats.

3.2 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 - 1. Where practical, install concrete inserts before placing concrete.
 - 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.

3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches (100 mm) thick.
 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches (100 mm) thick.
 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hangers Exposed to View: Threaded rod and angle or channel supports.
- D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.3 SEISMIC-RESTRAINT-DEVICE INSTALLATION

- A. Install hangers and braces designed to support the air terminal units and to restrain against seismic forces required by applicable building codes. Comply with **[SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."]** **[ASCE/SEI 7.]**
- B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install cable restraints on air terminal units that are suspended with vibration isolators.
- E. Install seismic-restraint devices using methods approved by **[an evaluation service member of the ICC Evaluation Service]** **[the Office of Statewide Health Planning and Development for the State of California]** **[an agency acceptable to authorities having jurisdiction]**.
- F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.
- G. Drilling for and Setting Anchors:
1. Identify position of reinforcing steel and other embedded items before drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the DEN Project Manager if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 3. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.
 4. Set anchors to manufacturer's recommended torque, using a torque wrench.

5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.4 CONNECTIONS

- A. Install piping adjacent to air terminal unit to allow service and maintenance.
- B. Hot-Water Piping: In addition to requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties," connect heating coils to supply with shutoff valve, strainer, control valve, and union or flange; and to return with balancing valve and union or flange.
- C. Connect ducts to air terminal units according to **[Section 233113 "Metal Ducts."]**
[Section 233116 "Nonmetal Ducts."]
- D. Connect terminal units (except integral-diffuser air terminal units) to supply ducts using sheet metal ducts. Do not use flexible ducts.
- E. Ground units with electric heating coils according to Division 26.
- F. Connect wiring according to Division 26.
- G. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.5 ADJUSTING

- A. Adjust work to produce specified operation.
- B. Reset volume with damper operator attached to assembly allowing flow range modulation from 100 percent of design flow to **[0] [50] <Insert number>** percent full flow. **[Set units with heating coils for minimum 50 percent full flow.]**

3.6 IDENTIFICATION

- A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

3.7 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Tests and Inspections:
 - 1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
 - 2. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- E. Air terminal unit will be considered defective if it does not pass tests and inspections.
- F. Remove and replace malfunctioning units and retest as specified above.
- G. Prepare test and inspection reports.

3.8 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
 - 3. Verify that controls and control enclosure are accessible.
 - 4. Verify that control connections are complete.
 - 5. Verify that nameplate and identification tag are visible.
 - 6. Verify that controls respond to inputs as specified.
 - 7. **<Insert startup steps if any>**.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233600

SECTION 233713 - DIFFUSERS, REGISTERS, AND GRILLES

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Round ceiling diffusers.
2. Rectangular and square ceiling diffusers.
3. Louver face diffusers.
4. Linear bar diffusers.
5. Linear slot diffusers.
6. Ceiling-integral continuous diffusers.
7. Light troffer diffusers.
8. Round induction diffusers.
9. Linear floor diffuser plenums.
10. Drum louvers.
11. Modular core supply grilles.
12. Continuous tubular diffusers.
13. Adjustable bar [**registers**] [**grilles**] [**registers and grilles**].
14. Security [**registers**] [**grilles**] [**registers and grilles**].
15. Fixed face [**registers**] [**grilles**] [**registers and grilles**].
16. Linear bar grilles.

B. Related Sections:

1. Section 089116 "Operable Wall Louvers" and Section 089119 "Fixed Louvers" for fixed and adjustable louvers and wall vents, whether or not they are connected to ducts.
2. Section 233300 "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to diffusers, registers, and grilles.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated, include the following:
 - 1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
 - 2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.
 - 3. Include data substantiating that materials comply with requirements.
- B. Samples for Initial Selection: For diffusers, registers, and grilles with factory-applied color finishes.
- C. Samples for Verification: For diffusers, registers, and grilles, in manufacturer's standard sizes to verify color selected.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
 - 1. Ceiling suspension assembly members.
 - 2. Method of attaching hangers to building structure.
 - 3. Size and location of initial access modules for acoustical tile.
 - 4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
 - 5. Duct access panels.
- B. Source quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Record actual locations of air outlets and inlets.

1.6 QUALITY ASSURANCE

- A. Test and rate air outlet and inlet performance in accordance with ADC Equipment Test Code 1062 and ASHRAE 70.
- B. Test and rate louver performance in accordance with AMCA 500.

1.7 MOCKUPS

- A. Provide mockup of typical **[exterior]** **[interior]** ceiling module with supply and return air outlets.
- B. Mockup may **[not]** remain as part of the Work.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CEILING DIFFUSERS

- A. Round Ceiling Diffuser **<Insert drawing designation>**:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Anemostat Products; a Mestek company.
 - b. Carnes.
 - c. Hart & Cooley Inc.
 - d. METALAIRE, Inc.
 - e. Nailor Industries Inc.
 - f. Price Industries.
 - g. Titus.
 - h. Tuttle & Bailey.
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
 - 2. Devices shall be specifically designed for variable-air-volume flows.
 - 3. Material: **[Steel]** **[Aluminum]**.
 - 4. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **[Anodized aluminum]** **<Insert finish>**.
 - 5. Face Style: **[Four]** **[Three]** **[Two]** cone.
 - 6. Mounting: Duct connection.
 - 7. Pattern: **[Fully adjustable]** **[Two-position horizontal]**.
 - 8. Dampers: **[Radial opposed blade]** **[Butterfly]** **[Combination damper and grid]**.
 - 9. Accessories:
 - a. Equalizing grid.
 - b. Plaster ring.
 - c. Safety chain.
 - d. Wire guard.
 - e. Sectorizing baffles.

f. Operating rod extension.

B. Rectangular and Square Ceiling Diffusers <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. <Insert manufacturer's name>.
 - l. or approved equal.
2. Devices shall be specifically designed for variable-air-volume flows.
3. Material: [**Steel**] [**Aluminum**].
4. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by DEN Project Manager**] [**Anodized aluminum**] <Insert finish>.
5. Face Size: [**24 by 24 inches** (600 by 600 mm)] [**20 by 20 inches** (500 by 500 mm)] [**12 by 12 inches** (300 by 300 mm)] <Insert dimensions>.
6. Face Style: [**Three cone**] [**Four cone**] [**Plaque**].
7. Mounting: [**Surface**] [**T-bar**] [**Snap in**] [**Spline**] [**Mounting panel**].
8. Pattern: [**Fixed**] [**Two position**] [**Adjustable**].
9. Dampers: [**Radial opposed blade**] [**Butterfly**] [**Combination damper and grid**].
10. Accessories:
 - a. Equalizing grid.
 - b. Plaster ring.
 - c. Safety chain.
 - d. Wire guard.
 - e. Sectorizing baffles.
 - f. Operating rod extension.

C. Louver Face Diffuser <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [METALAIRE, Inc.](#)
 - e. [Nailor Industries Inc.](#)
 - f. [Price Industries.](#)

- g. [Titus](#).
 - h. [Tuttle & Bailey](#).
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
2. Devices shall be specifically designed for variable-air-volume flows.
 3. Material: **[Steel]** **[Aluminum]**.
 4. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **[Anodized aluminum]** **<Insert finish>**.
 5. Face Size: **<Insert inches (mm)>**.
 6. Mounting: **[Surface]** **[Surface with beveled frame]** **[T-bar]** **[Snap in]** **[Spline]** **[Mounting panel]**.
 7. Pattern: **[One-way]** **[Two-way]** **[Two-way corner]** **[Three-way]** **[Four-way]** **[Adjustable]** **<Insert pattern>** core style.
 8. Dampers: **[Radial opposed blade]** **[Butterfly]** **[Combination damper and grid]**.
 9. Accessories:
 - a. Square to round neck adaptor.
 - b. Adjustable pattern vanes.
 - c. Throw reducing vanes.
 - d. Equalizing grid.
 - e. Plaster ring.
 - f. Safety chain.
 - g. Wire guard.
 - h. Sectorizing baffles.
 - i. Operating rod extension.

2.2 CEILING LINEAR SLOT OUTLETS

A. Linear Bar Diffuser **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Dayus Register & Grille Inc.](#)
 - e. [Hart & Cooley Inc.](#)
 - f. [Krueger.](#)
 - g. [METALAIRE, Inc.](#)
 - h. [Nailor Industries Inc.](#)
 - i. [Price Industries.](#)
 - j. [Titus.](#)
 - k. [Tuttle & Bailey.](#)
 - l. **<Insert manufacturer's name>**.
 - m. or approved equal.
2. Devices shall be specifically designed for variable-air-volume flows.

3. Material: **[Steel]** **[Aluminum]** **[Stainless steel]**.
4. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **<Insert finish>**.
5. Narrow Core Spacing Arrangement: **1/8-inch-** (3-mm-) thick blades spaced **1/4 inch** (6 mm) apart, **[zero]** **[15]**-degree deflection.
6. Wide Core Spacing Arrangement: **1/8-inch-** (3-mm-) thick blades spaced **1/2 inch** (13 mm) apart, **[zero]** **[15]**-degree deflection.
7. Wide Core Spacing Arrangement: **3/16-inch-** (5-mm-) thick blades spaced **1/2 inch** (13 mm) apart, **[zero]** **[15]** **[30]**-degree deflection.
8. Pencil-Proof Core Spacing Arrangement: **3/16-inch-** (5-mm-) thick blades spaced **7/16 inch** (11 mm) apart, **[zero]** **[15]** **[30]**-degree deflection.
9. **[One]** **[Two]**-Way Deflection Vanes: Extruded construction fixed louvers with removable core.
10. Frame: **[1-1/4 inches** (32 mm)] **[1 inch** (25 mm)] **[3/4 inch** (19 mm)] **[1/2 inch** (13 mm)] **[3/16 inch** (5 mm)] wide.
11. Mounting Frame: **[Filter]** **<Insert frame size and style>**.
12. Mounting: **[Countersunk screw]** **[Concealed bracket]** **[Spring clip]**.
13. Damper Type: **[Adjustable opposed-blade assembly]** **[Hinged single blade]**.
14. Accessories: **[Plaster frame]** **[Directional vanes]** **[Alignment pins]** **[Core clips]** **[Blank-off strips]**.

B. Linear Slot Diffuser **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. **<Insert manufacturer's name>**.
 - l. or approved equal.
2. Devices shall be specifically designed for variable-air-volume flows.
3. Material - Shell: **[Steel]** **[Aluminum]**, **[insulated]** **[noninsulated]**.
4. Material - Pattern Controller and Tees: Aluminum.
5. Finish - Face and Shell: **[Baked enamel, black]** **<Insert finish>**.
6. Finish - Pattern Controller: **[Baked enamel, black]** **<Insert finish>**.
7. Finish - Tees: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **<Insert finish>**.
8. Slot Width: **[1/2 inch** (13 mm)] **[3/4 inch** (19 mm)] **[1 inch** (25 mm)] **[1-1/2 inches** (38 mm)].
9. Number of Slots: **[One]** **[Two]** **[Three]** **[Four]** **<Insert number>**.

10. Length: [24 inches (600 mm)] [30 inches (750 mm)] [36 inches (900 mm)] [48 inches (1200 mm)] [60 inches (1500 mm)].
11. Accessories: [Plaster frame] [T-bar slot] [Center notch] [T-bar on inlet side] [T-bar on both sides] [T-bar clip on one side] [T-bar clips on both sides].

C. Ceiling-Integral Continuous Diffuser <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. <Insert manufacturer's name>.
 - l. or approved equal.
2. Slot Width: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] [2-1/2 inches (63 mm)] [3 inches (76 mm)].
3. Section Length: [12 feet (3.7 m)] <Insert dimension>.
4. Straight and curved sections as required to accommodate layout.
5. Mitered tees and corners.
6. Pattern Controllers: [24 inches (600 mm)] <Insert dimension> o.c.
7. Material: Aluminum, extruded, heavy wall.
8. Finishes:
 - a. Exterior: Standard white.
 - b. Interior: Standard black.
9. Throw: [Standard] [High].
10. Mounting: [Ceiling] [Sidewall].
11. Plenum: [Noninsulated] [Insulated].
12. Other Features:
 - a. Painted interior.
 - b. Blank-offs.

D. Light Troffer Diffuser <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Anemostat Products; a Mestek company.](#)
 - b. [Carnes.](#)

- c. [Hart & Cooley Inc.](#)
 - d. [Krueger.](#)
 - e. [METALAIRE, Inc.](#)
 - f. [Nailor Industries Inc.](#)
 - g. [Price Industries.](#)
 - h. [Titus.](#)
 - i. [Tuttle & Bailey.](#)
 - j. **<Insert manufacturer's name>.**
 - k. or approved equal.
2. Devices shall be specifically designed for variable-air-volume flows.
 3. Material: Steel[**with external insulation**].
 4. Finish: **[None] [Black enamel on visible surfaces] <Insert finish>.**
 5. Slot Width: **[1/2 inch (13 mm)] [3/4 inch (19 mm)] [1 inch (25 mm)] [1-1/2 inches (38 mm)]**].
 6. Number of Sides: **[One] [Two]**.
 7. Length: **[24 inches (600 mm)] [36 inches (900 mm)] [48 inches (1200 mm)]**.
 8. Pattern: **[Fixed] [Adjustable]**.
 9. Inlet: **[Top] [Side]**.
 10. Inlet Size: **[5 inches (125 mm)] [6 inches (150 mm)] [8 inches (200 mm)]**.

2.3 UNDERFLOOR AIR DISTRIBUTION DIFFUSERS

A. Round Induction Diffusers **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. **<Insert manufacturer's name>.**
 - k. or approved equal.
2. Airflow Principle: Swirl-pattern induction.
3. Material: Plastic, high impact, and resistant to cart and foot traffic.
4. Color: **[Gray] [Black]**.
5. Components:
 - a. Diffuser core.
 - b. Flow regulator.
 - c. Dirt and liquid catch pan.
 - d. Spacer flange.

- e. Gasketed, underfloor compression ring.

B. Linear Floor Diffuser Plenums **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. **<Insert manufacturer's name>**.
 - k. or approved equal.
2. Material: Steel.
3. Finish: White baked acrylic.
4. Deflection: **[Zero] [15]** degrees.
5. Components:
 - a. Aluminum diffuser core.
 - b. Diffuser frame.
 - c. Plenum, **0.034-inch** (0.85-mm) steel.

2.4 HIGH-CAPACITY DIFFUSERS

A. Drum Louver **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. **<Insert manufacturer's name>**.
 - l. or approved equal.
2. Airflow Principle: Extended distance for high airflow rates.

3. Material: Aluminum, heavy gage extruded.
4. Finish: White baked acrylic.
5. Border: **1-1/4-inch** (32-mm) width with countersunk screw holes.
6. Gasket between drum and border.
7. Body: Drum shaped; adjustable vertically.
8. Blades: Individually adjustable horizontally.
9. Mounting: Surface to [**duct**] [**wall**].
10. Inlet Width: [**6 inches** (150 mm)] [**10 inches** (250 mm)] [**12 inches** (300 mm)] [**15 inches** (380 mm)] **<Insert dimension>**.
11. Inlet Length: [**12 inches** (300 mm)] [**24 inches** (600 mm)] [**36 inches** (900 mm)] [**60 inches** (1500 mm)] **<Insert dimension>**.
12. Accessories:
 - a. Opposed-blade steel damper.
 - b. Duct-mounting collars with countersunk screw holes.

B. Modular Core Supply Grilles **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Research Diffuser Products, Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [METALAIRE, Inc.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. **<Insert manufacturer's name>**.
 - l. or approved equal.
2. Throw: Extended distance for airflow rates.
3. Material: Steel.
4. Grilles per Unit: [**One**] [**Two**] [**Three**] [**Four**].
5. Finish: White baked acrylic.
6. Border: **1-1/2-inch** (38-mm) width with countersunk screw holes.
7. Blades:
 - a. Airfoil, individually adjustable horizontally.
 - b. Double deflection.
 - c. Set in modules.
8. Modules: Removable; rotatable.
9. Mounting: Surface.
10. Accessory: Opposed-blade steel damper.

2.5 FLEXIBLE DIFFUSION OUTLETS

A. Continuous Tubular Diffuser <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [Air Distribution Concepts](#).
 - b. [Airmax International](#).
 - c. [DuctSox Corp.](#)
 - d. [Fabric Duct Systems](#).
 - e. [FabricAir Inc.](#)
 - f. <Insert manufacturer's name>.
 - g. or approved equal.
2. Material: [**Flame-retardant, woven polyethylene fabric**] [**Flame-retardant, coated polyester and fiberglass fabric**] [**Flame-retardant, permeable polyester and fiberglass fabric**] [**Polyethylene**].
3. Duct Connection: Round.
4. Duct Connection Size: <Insert inches (mm)>.
5. Diffusion Hole Size: <Insert inches (mm)>.
6. Diffusion Hole Frequency - Number per 100 Feet (30 m): <Insert number>.
7. Accessories:
 - a. Quick-connect joint.
 - b. Snap hooks.
 - c. Cleanout zipper.
 - d. Condensate drain.

2.6 REGISTERS AND GRILLES

A. Adjustable Bar Register <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company](#).
 - c. [Carnes](#).
 - d. [Dayus Register & Grille Inc.](#)
 - e. [Hart & Cooley Inc.](#)
 - f. [Krueger](#).
 - g. [METALAIRE, Inc.](#)
 - h. [Nailor Industries Inc.](#)
 - i. [Price Industries](#).
 - j. [Titus](#).
 - k. [Tuttle & Bailey](#).
 - l. <Insert manufacturer's name>.
 - m. or approved equal.

2. Material: **[Steel]** **[Aluminum]** **[Stainless steel]**.
3. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **<Insert finish>**.
4. Face Blade Arrangement: **[Horizontal]** **[Vertical]** spaced **[3 inches (76 mm)]** **[1-1/2 inches (38 mm)]** **[3/4 inch (19 mm)]** **[1/2 inch (13 mm)]** apart.
5. Core Construction: **[Integral]** **[Removable]**.
6. Rear-Blade Arrangement: **[Horizontal]** **[Vertical]** spaced **[3/4 inch (19 mm)]** **[1/2 inch (13 mm)]** apart.
7. Frame: **[1-1/4 inches (32 mm)]** **[1 inch (25 mm)]** wide.
8. Mounting Frame: **[Filter]** **<Insert frame size and style>**.
9. Mounting: **[Countersunk screw]** **[Concealed]** **[Lay in]**.
10. Damper Type: **[Adjustable opposed blade]** **[NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C)]**.
11. Accessories:
 - a. **[Front]** **[Rear]**-blade gang operator.
 - b. Filter.

B. Adjustable Bar Grille **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products: a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Dayus Register & Grille Inc.](#)
 - e. [Hart & Cooley Inc.](#)
 - f. [Krueger.](#)
 - g. [METALAIRE, Inc.](#)
 - h. [Nailor Industries Inc.](#)
 - i. [Price Industries.](#)
 - j. [Titus.](#)
 - k. [Tuttle & Bailey.](#)
 - l. **<Insert manufacturer's name>**.
 - m. or approved equal.
2. Material: **[Steel]** **[Aluminum]** **[Stainless steel]**.
3. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **<Insert finish>**.
4. Face Blade Arrangement: **[Horizontal]** **[Vertical]** spaced **[3 inches (76 mm)]** **[1-1/2 inches (38 mm)]** **[3/4 inch (19 mm)]** **[1/2 inch (13 mm)]** apart.
5. Core Construction: **[Integral]** **[Removable]**.
6. Rear-Blade Arrangement: **[Horizontal]** **[Vertical]** spaced **[3/4 inch (19 mm)]** **[1/2 inch (13 mm)]** apart.
7. Frame: **[1-1/4 inches (32 mm)]** **[1 inch (25 mm)]** wide.
8. Mounting Frame: **[Filter]** **<Insert frame size and style>**.
9. Mounting: **[Countersunk screw]** **[Concealed]** **[Lay in]**.

C. Security Register **<Insert drawing designation>**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [Nailor Industries Inc.](#)
 - g. [Price Industries.](#)
 - h. [Titus.](#)
 - i. [Tuttle & Bailey.](#)
 - j. <Insert manufacturer's name>.
 - k. or approved equal.
2. Security Level: [Maximum] [Medium] [Minimum] [and suicide deterrent].
3. Application: [Ducted return] [Air transfer] [Barrier].
4. Material: [Steel] [Aluminum].
5. Material Thickness: [0.19 inch (4.8 mm)] <Insert dimension>.
6. Finish: [Baked enamel, white] [Baked enamel, color selected by DEN Project Manager] <Insert finish>.
7. Face Arrangement:
 - a. Shape: [Square] [Rectangular] [Round].
 - b. Design: [Fixed bar] [Perforated] [Lattice].
 - c. Frame: [Yes] [No].
 - d. Deflection: [Zero] [38] degrees.
 - e. Core: [None] [Louvered].
 - f. 3/16-inch- (5-mm-) thick, front lattice plate with 2-by-2-inch- (50-by-50-mm-) square holes and 1-inch (25-mm) frets, 0.135-inch (3.43-mm) wire mesh, and 1/4-inch- (6-mm-) thick backer plate.
 - g. 3/16-inch- (5-mm-) thick, perforated faceplate with 5/16-inch- (8-mm-) diameter holes spaced 7/16 inch (11 mm) o.c., staggered at 60 degrees.
 - h. 1-1/2-inch (38-mm) bars and mandrel tubes and rods with [zero] [15]-degree deflection in 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) angle border.
 - i. 1-3/8-inch (35-mm) bars and double mandrel tubes with [zero] [15]-degree deflection in 1-3/4-inch (45-mm) angle border.
8. Damper Operation: [None] [Face operated] [Rear operated].
9. Damper Type: [Adjustable opposed blade] [NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C)].
10. Wall Sleeve: [3/16 inch (5 mm) welded to face] [1/8 inch (3 mm) welded to face] [Mechanically fastened to border].
11. Mounting: [1-by-1-by-3/16-inch (25-by-25-by-5-mm) retaining angle frame] [1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) retaining angle frame] [1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) cast-in-place frame and tamperproof machine screws].

D. Security Grille <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Hart & Cooley Inc.](#)
 - e. [Krueger.](#)
 - f. [Nailor Industries Inc.](#)
 - g. [Price Industries.](#)
 - h. [Titus.](#)
 - i. [Tuttle & Bailey.](#)
 - j. <Insert manufacturer's name>.
 - k. or approved equal.
 2. Security Level: **[Maximum] [Medium] [Minimum] [and suicide deterrent]**.
 3. Application: **[Ducted return] [Air transfer] [Barrier]**.
 4. Material: **[Steel] [Aluminum]**.
 5. Material Thickness: **[0.19 inch (4.8 mm)] <Insert dimension>**.
 6. Finish: **[Baked enamel, white] [Baked enamel, color selected by DEN Project Manager] <Insert finish>**.
 7. Face Arrangement:
 - a. Shape: **[Square] [Rectangular] [Round]**.
 - b. Design: **[Fixed bar] [Perforated] [Lattice]**.
 - c. Frame: **[Yes] [No]**.
 - d. Deflection: **[Zero] [38] degrees**.
 - e. Core: **[None] [Louvered]**.
 - f. **3/16-inch- (5-mm-) thick, front lattice plate with 2-by-2-inch- (50-by-50-mm-) square holes and 1-inch (25-mm) frets, 0.135-inch (3.43-mm) wire mesh, and 1/4-inch- (6-mm-) thick backer plate.**
 - g. **3/16-inch- (5-mm-) thick perforated faceplate with 5/16-inch- (8-mm-) diameter holes spaced 7/16 inch (11 mm) o.c., staggered at 60 degrees.**
 - h. **1-1/2-inch (38-mm) bars and mandrel tubes and rods with [zero] [15]-degree deflection in 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) angle border.**
 - i. **1-3/8-inch (35-mm) bars and double mandrel tubes with [zero] [15]-degree deflection in 1-3/4-inch (45-mm) angle border.**
 8. Wall Sleeve: **[3/16 inch (5 mm) welded to face] [1/8 inch (3 mm) welded to face] [Mechanically fastened to border]**.
 9. Mounting: **[1-by-1-by-3/16-inch (25-by-25-by-5-mm) retaining angle frame] [1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) retaining angle frame] [1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) cast-in-place frame and tamperproof machine screws]**.
- E. Fixed Face Register <Insert drawing designation>:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Dayus Register & Grille Inc.](#)
 - e. [Hart & Cooley Inc.](#)
 - f. [Krueger.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. **<Insert manufacturer's name>.**
 - l. or approved equal.
2. Material: **[Steel]** **[Aluminum]**.
 3. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **<Insert finish>.**
 4. Face Arrangement: **[1/2-by-1/2-by-1/2-inch (13-by-13-by-13-mm) grid]** **[Perforated]** core.
 5. Core Construction: **[Integral]** **[Removable]**.
 6. Frame: **[1-1/4 inches (32 mm)]** **[1 inch (25 mm)]** wide.
 7. Mounting Frame: **[Filter]** **<Insert frame size and style>.**
 8. Mounting: **[Countersunk screw]** **[Concealed]** **[Lay in]**.
 9. Damper Type: **[Adjustable opposed blade]** **[NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C)].**
 10. Accessory: Filter.
- F. Fixed Face Grille **<Insert drawing designation>:**
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products; a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Dayus Register & Grille Inc.](#)
 - e. [Hart & Cooley Inc.](#)
 - f. [Krueger.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. **<Insert manufacturer's name>.**
 - l. or approved equal.
 2. Material: **[Steel]** **[Aluminum]**.
 3. Finish: **[Baked enamel, white]** **[Baked enamel, color selected by DEN Project Manager]** **<Insert finish>.**
 4. Face Arrangement: **[1/2-by-1/2-by-1/2-inch (13-by-13-by-13-mm) grid]** **[Perforated]** core.
 5. Core Construction: **[Integral]** **[Removable]**.

6. Frame: [1-1/4 inches (32 mm)] [1 inch (25 mm)] wide.
7. Mounting Frame: [Filter] <Insert frame size and style>.
8. Mounting: [Countersunk screw] [Concealed] [Lay in].
9. Accessory: Filter.

G. Linear Bar Grille <Insert drawing designation>:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. [A-J Manufacturing Co., Inc.](#)
 - b. [Anemostat Products: a Mestek company.](#)
 - c. [Carnes.](#)
 - d. [Dayus Register & Grille Inc.](#)
 - e. [Hart & Cooley Inc.](#)
 - f. [Krueger.](#)
 - g. [Nailor Industries Inc.](#)
 - h. [Price Industries.](#)
 - i. [Titus.](#)
 - j. [Tuttle & Bailey.](#)
 - k. <Insert manufacturer's name>.
 - l. or approved equal.
2. Material: [Steel] [Aluminum].
3. Finish: [Baked enamel, white] [Baked enamel, color selected by DEN Project Manager] <Insert finish>.
4. Face Arrangement: [1/2-by-1/2-by-1/2-inch (13-by-13-by-13-mm) grid] [Perforated] core.
5. Distribution plenum.
 - a. Internal insulation.
 - b. Inlet damper.
6. Frame: [1-1/4 inches (32 mm)] [1 inch (25 mm)] wide.
7. Mounting Frame: [Filter] <Insert frame size and style>.
8. Mounting: [Countersunk screw] [Concealed] [Lay in].
9. Damper Type: [Adjustable opposed blade] [NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C)].

2.7 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install diffusers, registers, and grilles level and plumb.
- C. Check location of outlets and inlets and make necessary adjustments in position to conform to architectural features, symmetry, and lighting arrangement.
- D. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify DEN Project Manager for a determination of final location.
- E. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.
- F. Install diffusers to ductwork with airtight connection.
- G. Provide balancing dampers on duct take-off to diffusers, and grilles and registers, despite whether dampers are specified as part of the diffuser, or grille and register assembly.
- H. Paint ductwork visible behind air outlets and inlets matte black. Refer to Division 9.

3.3 ADJUSTING

- A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233713

SECTION 233723 - HVAC GRAVITY VENTILATORS

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Louvered-penthouse ventilators.
 - 2. Roof hoods.
 - 3. Goosenecks.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design ventilators, including comprehensive engineering analysis by a qualified professional engineer, using structural[**and seismic**] performance requirements and design criteria indicated.
- B. Structural Performance: Ventilators shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated without permanent deformation of ventilator components, noise, or metal fatigue caused by ventilator blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act normal to the face of the building.
 - 1. Wind Loads: Determine loads based on pressures as indicated on Drawings.
 - 2. Wind Loads: Determine loads based on a uniform pressure of [20 lbf/sq. ft. (960 Pa)] [30 lbf/sq. ft. (1440 Pa)] <Insert design wind pressure>, acting inward or outward.
 - 3. Wind Loads: Determine loads based on pressures indicated below:
 - a. Corner Zone: Within <Insert distance> of building corners, uniform pressure of <Insert design wind pressure>, acting inward, and <Insert design wind pressure>, acting outward.

- b. Other Than Corner Zone: Uniform pressure of **<Insert design wind pressure>**, acting inward, and **<Insert design wind pressure>**, acting outward.
 - C. Seismic Performance: Ventilators, including attachments to other construction, shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] **<Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
 - D. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes, without buckling, opening of joints, overstressing of components, failure of connections, or other detrimental effects.
 - 1. Temperature Change (Range): [120 deg F (67 deg C), **ambient**; 180 deg F (100 deg C)] **<Insert temperature range>**, material surfaces.
 - E. Water Entrainment: Limit water penetration through unit to comply with ASHRAE 62.1.
- 1.4 ACTION SUBMITTALS
- A. Product Data: For each type of product indicated.[**For louvered-penthouse ventilators specified to bear AMCA seal, include printed catalog pages showing specified models with appropriate AMCA Certified Ratings Seals.**]
 - 1. Include data substantiating that materials comply with requirements.
 - B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
 - C. Shop Drawings: For gravity ventilators. Include plans, elevations, sections, details, ventilator attachments to curbs, and curb attachments to roof structure.
 - 1. Show weep paths, gaskets, flashing, sealant, and other means of preventing water intrusion.
 - D. Samples: For each exposed product and for each color and texture specified.
 - E. Samples for Initial Selection: For units with factory-applied color finishes.
 - F. Samples for Verification: For each type of louvered-penthouse ventilator indicated, in manufacturer's standard size.
 - G. Delegated-Design Submittal: For shop-fabricated ventilators indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Detail fabrication and assembly of shop-fabricated ventilators.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Roof framing plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
 1. Structural members to which roof curbs and ventilators will be attached.
 2. Sizes and locations of roof openings.
- B. Seismic Qualification Certificates: For ventilators, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Welding certificates.

1.6 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Record actual locations of air outlets and inlets.

1.7 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to the following:
 1. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
 2. AWS D1.3, "Structural Welding Code - Sheet Steel."
- B. Test and rate louver performance in accordance with AMCA 500.

1.8 COORDINATION

- A. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Aluminum Extrusions: [ASTM B 221](#) (ASTM B 221M), Alloy 6063-T5 or T-52.
- B. Aluminum Sheet: [ASTM B 209](#) (ASTM B 209M), Alloy 3003 or 5005 with temper as required for forming or as otherwise recommended by metal producer for required finish.
- C. Galvanized-Steel Sheet: ASTM A 653/A 653M, [G90](#) (Z275) zinc coating, mill phosphatized.
- D. Stainless-Steel Sheet: ASTM A 666, Type 304, with No. [4] [6] finish.
- E. Fasteners: Same basic metal and alloy as fastened metal or 300 Series stainless steel unless otherwise indicated. Do not use metals that are incompatible with joined materials.
 - 1. Use types and sizes to suit unit installation conditions.
 - 2. Use [**Phillips flat**] [**hex-head or Phillips pan**]-head screws for exposed fasteners unless otherwise indicated.
- F. Post-Installed Fasteners for Concrete and Masonry: Torque-controlled expansion anchors made from stainless-steel components, with capability to sustain without failure a load equal to 4 times the loads imposed for concrete, or 6 times the load imposed for masonry, as determined by testing per ASTM E 488, conducted by a qualified independent testing agency.
- G. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

2.2 FABRICATION, GENERAL

- A. Factory or shop fabricate gravity ventilators to minimize field splicing and assembly. Disassemble units to the minimum extent as necessary for shipping and handling. Clearly mark units for reassembly and coordinated installation.
- B. Fabricate frames, including integral bases, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

- C. Fabricate units with closely fitted joints and exposed connections accurately located and secured.
- D. Fabricate supports, anchorages, and accessories required for complete assembly.
- E. Perform shop welding by AWS-certified procedures and personnel.

2.3 LOUVERED-PENTHOUSE VENTILATORS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- 1. [Acme Engineering & Mfg. Corporation.](#)
- 2. [Aerovent.](#)
- 3. [Carnes.](#)
- 4. [Greenheck Fan Corporation.](#)
- 5. [JencoFan.](#)
- 6. [Loren Cook Company.](#)
- 7. [PennBarry.](#)
- 8. **<Insert manufacturer's name>.**
- 9. or approved equal.

- B. Construction: All-welded assembly with [4-inch (100-mm)] [6-inch (150-mm)]-deep louvers, mitered corners, and [aluminum] [galvanized-steel] [stainless-steel] sheet roof [with mineral-fiber insulation and vapor barrier].

- C. Frame and Blade Material and Nominal Thickness: Extruded aluminum, of thickness required to comply with structural performance requirements, but not less than 0.080 inch (2.0 mm) for frames and [0.080 inch (2.0 mm)] [0.060 inch (1.5 mm)] for blades [with condensate deflectors].

- 1. Blade Spacing: **<Insert inches (mm)>.**
- 2. Blade Angle: **<Insert number>** degrees.
- 3. AMCA Seal: Mark units with the AMCA Certified Ratings Seal.
- 4. Exterior Corners: Prefabricated corner units with [mitered and welded blades] [mitered blades with concealed close-fitting splices] and with [fully recessed] [semirecessed] mullions at corners.

- D. Frame and Blade Material and Nominal Thickness: Galvanized-steel sheet, of thickness required to comply with structural performance requirements, but not less than 0.052 inch (1.3 mm) for frames and [0.040 inch (1.0 mm)] [0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] for blades [with condensate deflectors].

- 1. Blade Spacing: **<Insert inches (mm)>.**
- 2. Blade Angle: **<Insert number>** degrees.
- 3. AMCA Seal: Mark units with the AMCA Certified Ratings Seal.
- 4. Exterior Corners: Prefabricated corner units with [mitered and welded blades] [mitered blades with concealed close-fitting splices] and with [fully recessed] [semirecessed] mullions at corners.

- E. Frame and Blade Material and Nominal Thickness: Stainless-steel sheet, of thickness required to comply with structural performance requirements, but not less than [0.050 inch (1.27 mm)] [0.062 inch (1.57 mm)], with grain running [parallel] [perpendicular] to length of blades and frame members[**with condensate deflectors**].
1. Blade Spacing: <Insert inches (mm)>.
 2. Blade Angle: <Insert number> degrees.
 3. AMCA Seal: Mark units with the AMCA Certified Ratings Seal.
 4. Exterior Corners: Prefabricated corner units with [mitered and welded blades] [mitered blades with concealed close-fitting splices] and with [fully recessed] [semirecessed] mullions at corners.
- F. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch- (40-mm-) thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch (40-mm) wood nailer. Size as required to fit roof opening and ventilator base.
1. Configuration: [Self-flashing without a cant strip, with] [Built-in cant and] [Built-in raised cant and] mounting flange.
 2. Overall Height: [8 inches (200 mm)] [9-1/2 inches (240 mm)] [12 inches (300 mm)] [16 inches (400 mm)] [18 inches (450 mm)].
- G. Bird Screening: [Galvanized-steel, 1/2-inch- (12.7-mm-) square mesh, 0.041-inch (1.04-mm) wire] [Aluminum, 1/2-inch- (12.7-mm-) square mesh, 0.063-inch (1.6-mm) wire] [Flattened, expanded aluminum, 3/4 by 0.050 inch (19 by 1.27 mm) thick] [Stainless-steel, 1/2-inch- (12.7-mm-) square mesh, 0.047-inch (1.19-mm) wire].
- H. Insect Screening: [Aluminum, 18-by-16 (1.4-by-1.6-mm) mesh, 0.012-inch (0.30-mm)] [Stainless-steel, 18-by-18 (1.4-by-1.4-mm) mesh, 0.009-inch (0.23-mm)] wire.
- I. Galvanized-Steel Sheet Finish:
1. Surface Preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas and repair galvanizing according to ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
 2. Factory Priming for Field-Painted Finish: Where field painting after installation is indicated, apply an air-dried primer immediately after cleaning and pretreating.
 3. Baked-Enamel Finish: Immediately after cleaning and pretreating, apply manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of 1 mil (0.025 mm) for topcoat and an overall minimum dry film thickness of 2 mils (0.05 mm).
 - a. Color and Gloss: [As indicated by manufacturer's designations] [Match DEN Project Manager's sample] [As selected by DEN Project Manager from manufacturer's full range].
- J. Accessories:
1. Dampers:

- a. Location: **[Penthouse neck] [Inside louver face]**.
- b. Control: **[Manual] [Motorized]**.

K. Capacities and Characteristics:

1. Height: **<Insert inches (mm)>**.
2. Width and Depth: **<Insert inches (mm)>** by **<Insert inches (mm)>**.
3. Free Area: Not less than **[5.0 sq. ft. (0.46 sq. m)] [6.0 sq. ft. (0.56 sq. m)] [7.0 sq. ft. (0.65 sq. m)] <Insert free area>** for **48-inch- (1220-mm-)** wide by **48-inch- (1220-mm-)** high louver.
4. Air Performance: Not more than **[0.10-inch wg (25-Pa)] <Insert pressure>** static pressure drop at **[600-fpm (3.0-m/s)] [700-fpm (3.6-m/s)] [800-fpm (4.1-m/s)] <Insert velocity>** free-area **[exhaust] [intake]** velocity.
5. Wind-Driven Rain Performance: Not less than **[99] [95] [80] <Insert number>** percent effectiveness when subjected to a rainfall rate of **[3 inches (75 mm) per hour and a wind speed of 29 mph (13 m/s)] [8 inches (200 mm) per hour and a wind speed of 50 mph (22.4 m/s)]** at a core-area intake velocity of **[300 fpm (1.5 m/s)] [400 fpm (2.0 m/s)] [500 fpm (2.5 m/s)] <Insert velocity>**.

2.4 ROOF HOODS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering & Mfg. Corporation](#).
2. [Aerovent](#).
3. [Carnes](#).
4. [Greenheck Fan Corporation](#).
5. [JencoFan](#).
6. [Loren Cook Company](#).
7. [PennBarry](#).
8. **<Insert manufacturer's name>**.
9. or approved equal.

B. Factory or shop fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figures 6-6 and 6-7.

C. Materials: **[Galvanized-steel sheet, minimum 0.064-inch- (1.62-mm-) thick base and 0.040-inch- (1.0-mm-) thick hood] [Aluminum sheet, minimum 0.063-inch- (1.6-mm-) thick base and 0.050-inch- (1.27-mm-) thick hood]**; suitably reinforced.

D. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; **1-1/2-inch- (40-mm-)** thick, rigid fiberglass insulation adhered to inside walls; and **1-1/2-inch (40-mm)** wood nailer. Size as required to fit roof opening and ventilator base.

1. Configuration: **[Self-flashing without a cant strip, with] [Built-in cant and] [Built-in raised cant and]** mounting flange.
2. Overall Height: **[8 inches (200 mm)] [9-1/2 inches (240 mm)] [12 inches (300 mm)] [16 inches (400 mm)] [18 inches (450 mm)]**.

- E. Bird Screening: **[Galvanized-steel, 1/2-inch- (12.7-mm-) square mesh, 0.041-inch (1.04-mm) wire]** **[Aluminum, 1/2-inch- (12.7-mm-) square mesh, 0.063-inch (1.6-mm) wire]** **[Flattened, expanded aluminum, 3/4 by 0.050 inch (19 by 1.27 mm) thick]** **[Stainless-steel, 1/2-inch- (12.7-mm-) square mesh, 0.047-inch (1.19-mm) wire]**.
- F. Insect Screening: **[Aluminum, 18-by-16 (1.4-by-1.6-mm) mesh, 0.012-inch (0.30-mm)]** **[Stainless-steel, 18-by-18 (1.4-by-1.4-mm) mesh, 0.009-inch (0.23-mm)]** wire.
- G. Galvanized-Steel Sheet Finish:
1. Surface Preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas and repair galvanizing according to ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
 2. Factory Priming for Field-Painted Finish: Where field painting after installation is indicated, apply an air-dried primer immediately after cleaning and pretreating.
 3. Baked-Enamel Finish: Immediately after cleaning and pretreating, apply manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of **1 mil (0.025 mm)** for topcoat and an overall minimum dry film thickness of **2 mils (0.05 mm)**.
 - a. Color and Gloss: **[As indicated by manufacturer's designations]** **[Match DEN Project Manager's sample]** **[As selected by DEN Project Manager from manufacturer's full range]**.
- H. Capacities and Characteristics:
1. Height: **<Insert inches (mm)>**.
 2. Width and Depth: **<Insert inches (mm)>** by **<Insert inches (mm)>**.
 3. Free Area: Not less than **[5.0 sq. ft. (0.46 sq. m)]** **[6.0 sq. ft. (0.56 sq. m)]** **[7.0 sq. ft. (0.65 sq. m)]** **<Insert free area>** for **48-inch- (1220-mm-) wide** by **48-inch- (1220-mm-) high** louver.
 4. Air Performance: Not more than **[0.10-inch wg (25-Pa)]** **<Insert pressure>** static pressure drop at **[600-fpm (3.0-m/s)]** **[700-fpm (3.6-m/s)]** **[800-fpm (4.1-m/s)]** **<Insert velocity>** free-area **[exhaust]** **[intake]** velocity.

2.5 GOOSENECKS

- A. Factory or shop fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 6-5; with a minimum of **0.052-inch- (1.3-mm-)** thick, galvanized-steel sheet.
- B. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; **1-1/2-inch- (40-mm-)** thick, rigid fiberglass insulation adhered to inside walls; and **1-1/2-inch (40-mm)** wood nailer. Size as required to fit roof opening and ventilator base.
1. Configuration: **[Self-flashing without a cant strip, with]** **[Built-in cant and]** **[Built-in raised cant and]** mounting flange.

2. Overall Height: [8 inches (200 mm)] [9-1/2 inches (240 mm)] [12 inches (300 mm)] [16 inches (400 mm)] [18 inches (450 mm)].
- C. Bird Screening: [**Galvanized-steel, 1/2-inch- (12.7-mm-) square mesh, 0.041-inch (1.04-mm) wire**] [**Aluminum, 1/2-inch- (12.7-mm-) square mesh, 0.063-inch (1.6-mm) wire**] [**Flattened, expanded aluminum, 3/4 by 0.050 inch (19 by 1.27 mm) thick**] [**Stainless-steel, 1/2-inch- (12.7-mm-) square mesh, 0.047-inch (1.19-mm) wire**].
- D. Insect Screening: [**Aluminum, 18-by-16 (1.4-by-1.6-mm) mesh, 0.012-inch (0.30-mm)**] [**Stainless-steel, 18-by-18 (1.4-by-1.4-mm) mesh, 0.009-inch (0.23-mm)**] wire.
- E. Galvanized-Steel Sheet Finish:
1. Surface Preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas and repair galvanizing according to ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
 2. Factory Priming for Field-Painted Finish: Where field painting after installation is indicated, apply an air-dried primer immediately after cleaning and pretreating.
 3. Baked-Enamel Finish: Immediately after cleaning and pretreating, apply manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of **1 mil (0.025 mm)** for topcoat and an overall minimum dry film thickness of **2 mils (0.05 mm)**.
 - a. Color and Gloss: [**As indicated by manufacturer's designations**] [**Match DEN Project Manager's sample**] [**As selected by DEN Project Manager from manufacturer's full range**].
- F. Capacities and Characteristics:
1. Height: <Insert inches (mm)>.
 2. Width and Depth: <Insert inches (mm)> by <Insert inches (mm)>.
 3. Free Area: Not less than [5.0 sq. ft. (0.46 sq. m)] [6.0 sq. ft. (0.56 sq. m)] [7.0 sq. ft. (0.65 sq. m)] <Insert free area> for 48-inch- (1220-mm-) wide by 48-inch- (1220-mm-) high louver.
 4. Air Performance: Not more than [0.10-inch wg (25-Pa)] <Insert pressure> static pressure drop at [600-fpm (3.0-m/s)] [700-fpm (3.6-m/s)] [800-fpm (4.1-m/s)] <Insert velocity> free-area [exhaust] [intake] velocity.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas where louvered-penthouse ventilators, roof hoods and goosnecks are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

3.2 Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install gravity ventilators level, plumb, and at indicated alignment with adjacent work.
- C. Install goosenecks on curb base where throat size exceeds [9 by 9 inches (230 by 230 mm)] <Insert measurement>.
- D. Install gravity ventilators with clearances for service and maintenance.
- E. Install perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.
- F. Install concealed gaskets, flashings, joint fillers, and insulation as installation progresses. Comply with Section 079200 "Joint Sealants" for sealants applied during installation.
- G. Label gravity ventilators according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."
- H. Protect galvanized and nonferrous-metal surfaces from corrosion or galvanic action by applying a heavy coating of bituminous paint on surfaces that will be in contact with concrete, masonry, or dissimilar metals.
- I. Repair finishes damaged by cutting, welding, soldering, and grinding. Restore finishes so no evidence remains of corrective work. Return items that cannot be refinished in the field to the factory, make required alterations, and refinish entire unit or provide new units.

3.4 CONNECTIONS

- A. Duct installation and connection requirements are specified in Section 233113 "Metal Ducts" and Section 233116 "Nonmetal Ducts." Drawings indicate general arrangement of ducts and duct accessories.

3.5 ADJUSTING

- A. Adjust damper linkages for proper damper operation.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233723

SECTION 233813 - COMMERCIAL-KITCHEN HOODS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes [**Type I**] [**Type II**] [**Type I and Type II**] commercial kitchen hoods.
- B. Allowances: Furnish commercial kitchen hoods under the allowances indicated as specified in Section 012100 "Allowances."
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Listed Hood: A hood, factory fabricated and tested for compliance with UL 710 by a testing agency acceptable to authorities having jurisdiction.
- B. Standard Hood: A hood, usually field fabricated that complies with design, construction, and performance criteria of applicable national and local codes.
- C. Type I Hood: A hood designed for grease exhaust applications.
- D. Type II Hood: A hood designed for heat and steam removal and for other nongrease applications.
- E. Terminology Standard: Refer to NSF 2, "Food Equipment" or other applicable NSF standards for definitions of equipment and installation terms not otherwise defined in this Section or in other referenced standards.

1.4 ACTION SUBMITTALS

- A. Product Data: Include manufacturer's model number and accessories and requirements for access and maintenance clearances, power, and service-connections including roughing-in dimensions, for the following:
 - 1. Standard hoods.

2. Filters/baffles.
3. Fire-suppression systems.
4. Lighting fixtures.
5. Include data substantiating that materials comply with requirements.

B. Shop Drawings: Signed and sealed by a qualified professional engineer.

1. Shop Drawing Scale: [1/4 inch = 1 foot (1:50)] <Insert scale>.
2. Show plan view, elevation view, sections, roughing-in dimensions, fabrication details, service requirements, duct connection sizes, and attachments to other work.
3. Show cooking equipment plan and elevation to confirm minimum code-required overhang.
4. Indicate performance, exhaust and makeup air airflow, and pressure loss at actual Project-site elevation.
5. Show water-supply and drain piping connections.
6. Show control cabinets.
7. Show fire-protection cylinders, piping, actuation devices, and manual control devices.
8. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
9. Design Calculations: Calculate requirements for selecting seismic restraints.
10. Wiring Diagrams: Power, signal, and control wiring.
 - a. Differentiate between manufacturer-installed and field-installed wiring.
11. Piping Diagrams: Detail fire-suppression piping and components and differentiate between manufacturer-installed and field-installed piping. Include roughing-in requirements for drain connections. Show cooking equipment plan and elevation to illustrate fire-suppression nozzle locations.
 - a. Piping Diagram Scale: [1/4 inch = 1 foot (1:50)] <Insert scale>.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

1. Coordination Drawing Scale: [1/4 inch = 1 foot (1:50)] <Insert scale>.
2. Suspended ceiling assembly components.
3. Structural members to which equipment will be attached.
4. Roof framing and support members for duct penetrations.
5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.

- d. Sprinklers.
 - e. Access panels.
 - f. Moldings on hoods and accessory equipment.
 - g. <Insert item.>
- B. Welding certificates.
- C. Manufacturer Seismic Qualification Certification: Submit certification that commercial kitchen hoods, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
- 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means, "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Operation, maintenance, and parts data for food service equipment to include in the maintenance manuals specified in Division 1.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Installer Qualifications: Engage an experienced installer to perform work of this Section who has specialized in installing kitchen hood equipment, who has completed installations similar in design and extent to that indicated for this Project, and who has a record of successful in-service performance.
- B. Manufacturer Qualifications: Engage a firm experienced in manufacturing kitchen hood equipment similar to that indicated for this Project and with a record of successful in-service performance.

- C. Source Limitations: Obtain each type of equipment through one source from a single manufacturer.
- D. Product Options: Drawings indicate food service equipment based on the specific products indicated. Other manufacturers' equipment with equal size and performance characteristics may be considered. Refer to Division 1 Section "Substitutions."
- E. Engineering Responsibility: Preparation of Shop Drawings and comprehensive engineering analysis by a qualified professional engineer.
- F. Welding: Qualify procedures and personnel according to AWS D1.1/D 1.1M, "Structural Welding Code - Steel," for hangers and supports; and AWS D9.1/D9.1M, "Sheet Metal Welding Code," for joint and seam welding.
- G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- H. Regulatory Requirements: Comply with the following National Fire Protection Association (NFPA) codes:
 - 1. NFPA 17, "Dry Chemical Extinguishing Systems."
 - 2. NFPA 17A, "Wet Chemical Extinguishing Systems."
 - 3. NFPA 96, "Ventilation Control and Fire Protection of Commercial Cooking Operations."
- I. Listing and Labeling: Provide electrically operated equipment or components specified in this Section that are listed and labeled.
 - 1. The Terms "Listed" and "Labeled": As defined in the National Electrical Code, Article 100.
 - 2. Listing and Labeling Agency Qualifications: A "Nationally Recognized Testing Laboratory" (NRTL) as defined in OSHA Regulation 1910.7.
- J. NSF Standards: Comply with applicable NSF International (NSF) standards and criteria and provide NSF Certification Mark on each equipment item, unless otherwise indicated.
- K. SMACNA Standard: Where applicable, fabricate equipment to comply with the Sheet Metal and Air Conditioning Contractors National Association's (SMACNA) "Kitchen Equipment Fabrication Guidelines," unless otherwise indicated.
- L. Seismic Restraints: Provide seismic restraints for food service equipment according to the Sheet Metal and Air Conditioning Contractors National Association's (SMACNA) "Kitchen Equipment Fabrication Guidelines," appendix 1, "Guidelines for Seismic Restraints of Kitchen Equipment," unless otherwise indicated.
- M. Preinstallation Conference: Conduct conference at Project site [**location and time as determined by DEN Project Manager**] to comply with requirements in Section 013100 "Project Management and Coordination."

1. Review access requirements for equipment delivery.
2. Review equipment storage and security requirements.
3. Inspect and discuss condition of substrate and other preparatory work performed by other trades.
4. Review structural loading limitations.
5. Review and finalize construction schedule and verify availability of materials, Installer's personnel, equipment, and facilities needed to make progress and avoid delays.

1.8 PROJECT CONDITIONS

- A. Field Measurements: Verify dimensions of food service equipment installation areas by field measurements before equipment fabrication and indicate measurements on Shop Drawings and Coordination Drawings. Coordinate fabrication schedule with construction progress to avoid delaying the Work.
 1. Established Dimensions: Where field measurements cannot be made without delaying the Work, establish required dimensions and proceed with fabricating equipment without field measurements. Coordinate construction to ensure actual dimensions correspond to established dimensions.

1.9 COORDINATION

- A. Coordinate equipment layout and installation with adjacent Work, including lighting fixtures, HVAC equipment, plumbing, and fire-suppression system components.

1.10 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Furnish **[one (1)]** <Insert number> complete set(s) of grease filters/baffles.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 HOOD MATERIALS

- A. Stainless-Steel Sheet: ASTM A 666, Type 304.
1. Minimum Thickness: [0.037 inch (0.94 mm)] [0.050 inch (1.3 mm)] <Insert thickness>.
 2. Finish: Comply with SSINA's "Finishes for Stainless Steel" for recommendations for applying and designating finishes.
 - a. Finish shall be free from tool and die marks and stretch lines and shall have uniform, directionally textured, polished finish indicated, free of cross scratches. Grain shall run with long dimension of each piece.
 3. Concealed Stainless-Steel Surfaces: ASTM A 480/A 480M, No. 2B finish (bright, cold-rolled, unpolished finish).
 4. Exposed Surfaces: ASTM A 480/A 480M, No. 2B finish (bright, cold-rolled, unpolished).
 5. Exposed Surfaces: ASTM A 480/A 480M, No. 3 finish (intermediate polished surface).
 6. Exposed Surfaces: ASTM A 480/A 480M, No. 4 finish (directional satin).
 7. Exposed Surfaces: ASTM A 480/A 480M, No. 6 finish (dull satin).
 8. Exposed Surfaces: ASTM A 480/A 480M, No. 7 finish (reflective, directional polish).
 9. Exposed Surfaces: ASTM A 480/A 480M, No. 8 finish (mirrorlike reflective, nondirectional polish).
 10. When polishing is completed, passivate and rinse surfaces. Remove embedded foreign matter and leave surfaces chemically clean.
- B. Carbon-Steel Sheets: ASTM A 1008/A 1008M, cold-rolled sheets; commercial quality; with oiled, exposed matte finish.
1. Minimum Thickness: [0.043 inch (1.09 mm)] [0.0478 inch (1.2 mm)] <Insert thickness>.
- C. Galvanized-Steel Sheet: Lock-forming quality; ASTM A 653/A 653M, G90 (Z275) coating designation.
1. Minimum Thickness: [0.052 inch (1.32 mm)] <Insert thickness>.
- D. Zinc-Coated Steel Shapes: ASTM A 36/A 36M, zinc coated according to ASTM A 123/A 123M requirements.
- E. Sealant: ASTM C 920; Type S, Grade NS, Class 25, Use NT. Elastomeric sealant shall be NSF certified for commercial kitchen hood application. Sealants, when cured and washed, shall comply with requirements in 21 CFR, Section 177.2600, for use in areas that come in contact with food.
1. Color: As selected by DEN Project Manager from manufacturer's full range.

2. Backer Rod: Closed-cell polyethylene, in diameter larger than joint width.
- F. Sound Dampening: NSF-certified, nonabsorbent, hard-drying, sound-deadening compound for permanent adhesion to metal in minimum **1/8-inch (3-mm)** thickness that does not chip, flake, or blister.
- G. Gaskets: NSF certified for end-use application indicated; of resilient rubber, neoprene, or PVC that is nontoxic, stable, odorless, nonabsorbent, and unaffected by exposure to foods and cleaning compounds, and that passes testing according to UL 710.

2.2 GENERAL HOOD FABRICATION REQUIREMENTS

- A. Welding: Use welding rod of same composition as metal being welded. Use methods that minimize distortion and develop strength and corrosion resistance of base metal. Make ductile welds free of mechanical imperfections such as gas holes, pits, or cracks.
1. Welded Butt Joints: Full-penetration welds for full-joint length. Make joints flat, continuous, and homogenous with sheet metal without relying on straps under seams, filling in with solder, or spot welding.
 2. Grind exposed welded joints flush with adjoining material and polish to match adjoining surfaces.
 3. Where fasteners are welded to underside of equipment, finish reverse side of weld smooth and flush.
 4. Coat concealed stainless-steel welded joints with metallic-based paint to prevent corrosion.
 5. After zinc-coated steel is welded, clean welds and abraded areas and apply SSPC-Paint 20, high-zinc-dust-content, galvanizing repair paint to comply with ASTM A 780/A 780M.
- B. For metal butt joints, comply with SMACNA's "Kitchen Ventilation Systems & Food Service Equipment Guidelines."
- C. Where stainless steel is joined to a dissimilar metal, use stainless-steel welding material or fastening devices.
- D. Form metal with break bends that are not flaky, scaly, or cracked in appearance; where breaks mar uniform surface appearance of material, remove marks by grinding, polishing, and finishing.
- E. Sheared Metal Edges: Finish free of burrs, fins, and irregular projections.
- F. In food zones, as defined in NSF, fabricate surfaces free from exposed fasteners.
- G. Cap exposed fastener threads, including those inside cabinets, with stainless-steel lock washers and stainless-steel cap (acorn) nuts.
- H. Fabricate pipe slots on equipment with turned-up edges sized to accommodate service and utility lines and mechanical connections.

- I. Fabricate enclosures, including panels, housings, and skirts, to conceal service lines, operating components, and mechanical and electrical devices including those inside cabinets, unless otherwise indicated.
- J. Fabricate seismic restraints according to SMACNA's "Kitchen Ventilation Systems & Food Service Equipment Guidelines," Appendix A, "Seismic Restraint Details."
- K. Fabricate equipment edges and backsplashes according to SMACNA's "Kitchen Ventilation Systems & Food Service Equipment Guidelines."
- L. Fabricate enclosure panels to ceiling and wall as follows:
 1. Fabricate panels on [**one**] [**two**] [**three**] [**four**] [**all exposed**] side(s) with same material as hood, and extend from ceiling to top of hood canopy and from canopy to wall.
 2. Wall Offset Spacer: Minimum of 3 inches (75 mm).
 3. Wall Shelves and Overshelves: Fabricate according to SMACNA's "Kitchen Ventilation Systems & Food Service Equipment Guidelines," with minimum 0.0625-inch- (1.58-mm-) thick, stainless-steel shelf tops.

2.3 TYPE I EXHAUST HOOD FABRICATION

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Aerolator Systems, Inc.](#)
 2. [AHR Metals, Inc.; Air Saver Systems.](#)
 3. [Air Tech; Delfield Company \(The\).](#)
 4. [AyrKing Corporation.](#)
 5. [Captive-Aire Systems.](#)
 6. [Carroll Manufacturing International.](#)
 7. [Duke Manufacturing Company.](#)
 8. [Gaylord Industries, Inc.](#)
 9. [Giles Enterprises, Inc.](#)
 10. [Grease Master; a division of Custom Industries, Inc.](#)
 11. [Greenheck.](#)
 12. [Halton Company.](#)
 13. [LCSystems, Inc.](#)
 14. [Sturdi-Bilt Restaurant Equipment.](#)
 15. [Vent Master; Div. of Garland Commercial Ranges, Ltd.](#)
 16. <Insert manufacturer's name.>
 17. or approved equal.
- B. Weld all joints exposed to grease with continuous welds, and make filters/baffles or grease extractors and makeup air diffusers easily accessible for cleaning.
 1. Fabricate hoods according to NSF 2, "Food Equipment."
 2. Hoods shall be listed and labeled, according to UL 710, by a testing agency acceptable to authorities having jurisdiction.

3. Hoods shall be designed, fabricated, and installed according to NFPA 96.
 4. Include access panels as required for access to fire dampers and fusible links.
 5. Duct Collars: Minimum **0.0598-inch- (1.5-mm-)** thick steel at least **3 inches (75 mm)** long, continuously welded to top of hood and at corners. [**Fabricate a collar with a 0.5-inch- (13-mm-) wide duct flange.**]
 6. Duct-Collar Fire Dampers: Collar and damper shall comply with UL 710 testing and listing required for the entire hood.
 - a. Collar: Minimum **0.0598-inch- (1.5-mm-)** thick stainless steel, at least **3 inches (75 mm)** long, continuously welded to top of hood and at corners. [**Fabricate a collar with a minimum 0.5-inch- (13-mm-) wide duct flange.**]
 - b. Blades: Minimum **0.1046-inch- (2.7-mm-)** thick stainless steel, counterbalanced to remain closed after actuation.
 - c. Blade Pivot and Spring: Stainless steel.
 - d. Fusible Link: Replaceable, **212 deg F (100 deg C)** rated.
 7. Makeup Air Fire Dampers: Labeled, according to UL 555, by a testing agency acceptable to authorities having jurisdiction.
 - a. Fire Rating: 1-1/2 hours.
 - b. Frame: SMACNA [**Type A**] [**Type B**], with blades in airstream; fabricated with roll-formed, [**galvanized**] [**stainless**] steel; with mitered and interlocking corners.
 - c. Blades: Roll-formed, interlocking or folded, minimum **0.034-inch- (0.86-mm-)** thick, galvanized-steel sheet.
 - d. Horizontal Dampers: Include a blade lock and stainless-steel closure spring.
 - e. Fusible Link: Replaceable, [**165 deg F (74 deg C)**] [**212 deg F (100 deg C)**] rated.
- C. Hood Configuration: Exhaust [**only**] [**and makeup air**].
1. Makeup air shall be introduced by [**induction**] [**combination of induction and diffusion**] inside canopy. If makeup air is not heated, insulate interior of makeup air plenum with high-density insulation having maximum flame-spread and smoke-developed indexes of 25 and 50, respectively.
 2. Makeup air shall be introduced through [**front**] [**front and bottom**] [**bottom**] of canopy through [**perforated diffusers**] [**supply-air registers with adjustable guide vanes**].
 3. Makeup air shall be introduced through laminar-flow-type, perforated metal panels on front of hood canopy.
 4. Makeup air shall be introduced through laminar-flow-type, perforated metal diffusers mounted in the ceiling in front of hood canopy. Furnish laminar-flow-type diffusers with baked [**white**] **<Insert color>** enamel finish and volume-control dampers.
 5. Makeup air shall be introduced through plenum at rear of hood, extending down below appliance cooking surfaces.
- D. Hood Style: [**Wall-mounted canopy**] [**Single-island canopy**] [**Double-island canopy**] [**Back shelf**] [**Eyebrow**] [**Pass over**].

- E. Filters/Baffles: Removable, **[stainless-steel] [aluminum]**, **with spring-loaded fastening**. Fabricate stainless steel for filter frame and removable collection cup and pitched trough. Exposed surfaces shall be pitched to drain to collection cup. Filters/baffles shall be tested according to UL 1046, "Grease Filters for Exhaust Ducts," by an NRTL acceptable to authorities having jurisdiction.
- F. Removable Water-Wash Grease Extractor: Stainless steel, tested with hood according to UL 710.
- G. Stationary Water-Wash Grease Extractor: Integral, automatically self-cleaning, spraying hot water and detergent over the entire length of exhaust plenum. Fabricate to supply **140 deg F (60 deg C)** water at **1.25 gpm/ft. (0.26 L/s per m)** of hood length, at **40- to 60-psig (276- to 414-kPa)** inlet pressure.
1. Water Piping: ASTM A 270, Type 304 stainless steel.
 2. Fabricate to drain water and detergent to a collection trough having stainless-steel drain fittings.
 3. Single, **[hood] [wall]**-mounting control panel with a solid-state, programmable controller shall control all hoods on Project. Wash cycle shall be factory set to operate for 10 minutes after fans stop.
 4. Detergent shall be supplied by an adjustable-flow, 120-V ac injection pump from a reservoir with a minimum capacity of **2.5 gal. (9.5 L)**.
- H. Water-mist option shall supply a maximum of **0.1 gpm/ft. (0.02 L/s per m)** of hood length through stainless-steel piping and nozzles.
1. Water Piping: ASTM A 270, Type 304 stainless steel.
- I. Lighting Fixtures: **[Recessed] [Surface-mounted]**, **[fluorescent] [incandescent]** fixtures and lamps with lenses sealed vaportight. Wiring shall be installed in conduit on hood exterior. Number and location of fixtures shall provide a minimum of **70 fc (753 lx)** at **30 inches (762 mm)** above finished floor.
1. Light switches shall be mounted **[on front panel of hood canopy] [on wall adjacent to hood] [in hood control panel]**.
 2. Lighting Fixtures: **[Fluorescent] [Incandescent]** complying with UL 1598.
- J. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for hood controls.
- K. Hood Controls: **[Hood] [Wall]**-mounting control cabinet, **[factory wired to control groups of adjacent hoods, and]**fabricated of stainless steel.
1. Exhaust Fan: On-off switches shall start and stop the exhaust fan. **[Interlock exhaust fan with makeup air supply fan to operate simultaneously.]** Interlock exhaust fan with fire-suppression system to operate fan(s) during fire-suppression-agent release and to remain in operation until manually stopped. Include red pilot light to indicate fan operation. Motor starters shall comply with Section 262913 "Enclosed Controllers."

2. Exhaust Fan Interlock: Factory wire the exhaust fan starters in a single control cabinet for adjacent hoods to operate together.
3. Photocell and Temperature Control: Cycle makeup air and exhaust-air fans on and off, based on temperature at hood discharge and opacity of smoke in hood. Interlock fan control with fire-suppression system to operate during fire-suppression-agent release and to remain in operation until manually stopped. Provide air-purge fan and conduit to photocell and reflector to avoid grease accumulation that will negatively affect performance of system.
4. Photocell and Temperature Control: Change speed (off, low, and high) of makeup air and exhaust-air fans with speed switch, based on temperature at hood discharge and opacity of smoke in hood. Interlock fan control with fire-suppression system to operate at high speed during fire-suppression-agent release and to remain in high-speed operation until manually stopped. Provide air-purge fan and conduit to photocell and reflector to avoid grease accumulation that will negatively affect performance of system. Controller shall limit exhaust-duct velocity between **<Insert minimum velocity>** and **<Insert maximum velocity>**. Controller shall limit supply quantity to **<Insert minimum quantity>** for proper operation of makeup air unit.
5. Photocell and Temperature Control: Vary speed of makeup air and exhaust-air fans with variable-frequency controllers, based on temperature at hood discharge and opacity of smoke in hood. Interlock fan control with fire-suppression system to operate at high speed during fire-suppression-agent release and to remain in high-speed operation until manually stopped. Provide air-purge fan and conduit to photocell and reflector to avoid grease accumulation that will negatively affect performance of system. Controller shall limit exhaust-duct velocity between **<Insert minimum velocity>** and **<Insert maximum velocity>**. Controller shall limit supply quantity to **<Insert minimum quantity>** for proper operation of makeup air unit.
6. High-Temperature Control: Alarm shall sound and cooking equipment shall shut down before hood discharge temperature rises to actuation temperature of fire-suppression system.
7. Water-Wash Timer: **[24-hour clock] [365-day, programmable timer]** shall control sequential wash of multiple hood sections.
8. Water Mist: Solenoid valve interlocked with exhaust fan to open with hood operation.

L. Capacities and Characteristics:

1. Nominal Hood Length: **<Insert inches (mm).>**
2. Nominal Hood Width: **<Insert inches (mm).>**
3. Canopy Height: **<Insert inches (mm).>**
4. Exhaust Airflow: **<Insert cfm (L/s).>**
5. Exhaust-Air Pressure Loss: **<Insert inches wg (kPa).>**
6. Makeup Air Airflow: **<Insert cfm (L/s).>**
7. Makeup Air Pressure Loss: **<Insert inches wg (kPa).>**
8. Water-Supply Connection: **<Insert NPS (DN).>**
9. Washdown Water Flow: **<Insert gpm (L/s).>**
10. Minimum Water Pressure: **<Insert psig (kPa).>**
11. Mist Water Flow: **<Insert gpm (L/s).>**
12. Sanitary Drain Connection: **<Insert NPS DN.>**

2.4 TYPE II EXHAUST HOOD FABRICATION

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Aerolator Systems, Inc.](#)
2. [AHR Metals, Inc.; Air Saver Systems.](#)
3. [Air Tech; Delfield Company \(The\).](#)
4. [AyrKing Corporation.](#)
5. [Captive-Aire Systems.](#)
6. [Carroll Manufacturing International.](#)
7. [Duke Manufacturing Company](#)
8. [Gaylord Industries, Inc.](#)
9. [Giles Enterprises, Inc.](#)
10. [Grease Master; a division of Custom Industries, Inc.](#)
11. [Greenheck.](#)
12. [Halton Company.](#)
13. [LCSystems, Inc.](#)
14. [Sturdi-Bilt Restaurant Equipment.](#)
15. [Vent Master; Div. of Garland Commercial Ranges, Ltd.](#)
16. **<Insert manufacturer's name.>**
17. or approved equal.

B. Fabricate hoods according to NSF 2, "Food Equipment."

C. Fabricate hoods to comply with SMACNA's "HVAC Duct Construction Standards: Metal and Flexible."

D. Hood Configuration: Exhaust [**only**] [**and makeup air**].

1. Makeup air shall be introduced by [**induction**] [**combination of induction and diffusion**] inside canopy. If makeup air is not heated, insulate interior of makeup air plenum with high-density insulation having maximum flame-spread and smoke-developed indexes of 25 and 50, respectively.
2. Makeup air shall be introduced through [**front**] [**front and bottom**] [**bottom**] of canopy through supply-air registers.
3. Makeup air shall be introduced through laminar-flow-type, perforated metal panels on front of hood canopy.
4. Makeup air shall be introduced through plenum at rear of hood, extending down below appliance cooking surfaces.

E. Hood Type: [**Heat and vapor**] [**Condensate**] removal.

F. Hood Style: [**Wall-mounted canopy**] [**Single-island canopy**] [**Double-island canopy**] [**Back shelf**] [**Eyebrow**] [**Pass over**].

G. Condensate Hood Baffles: Removable, stainless-steel baffles to drain into a hood drain trough, and stainless-steel drain piping.

- H. Lighting Fixtures: **[Recessed]** **[Surface-mounted]**, **[fluorescent]** **[incandescent]** fixtures and lamps with lenses sealed vaportight. Wiring shall be installed in stainless-steel conduit on hood exterior. Number and location of fixtures shall provide a minimum of **70 fc (753 lx)** at **30 inches (762 mm)** above finished floor.
1. Light switches shall be mounted **[on front panel of hood canopy]** **[on wall adjacent to hood]** **[in hood control panel]**.
 2. Lighting Fixtures: **[Fluorescent]** **[Incandescent]** complying with UL 1598.
- I. Capacities and Characteristics:
1. Nominal Hood Length: **<Insert inches (mm).>**
 2. Nominal Hood Width: **<Insert inches (mm).>**
 3. Canopy Height: **<Insert inches (mm).>**
 4. Exhaust Airflow: **<Insert cfm (L/s).>**
 5. Exhaust-Air Pressure Loss: **<Insert inches wg (kPa).>**
 6. Makeup Air Airflow: **<Insert cfm (L/s).>**
 7. Makeup Air Pressure Loss: **<Insert inches wg (kPa).>**

2.5 WET-CHEMICAL FIRE-SUPPRESSION SYSTEM

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. [Ansul Incorporated; a Tyco International Ltd. Company.](#)
 2. [Badger Fire Protection.](#)
 3. [Kidde Fire Systems.](#)
 4. [Pyro Chem.](#)
 5. **<Insert manufacturer's name.>**
 6. or approved equal.
- B. Description: Engineered distribution piping designed for automatic detection and release or manual release of fire-suppression agent by hood operator. Fire-suppression system shall be listed and labeled for complying with NFPA 17A, "Wet Chemical Extinguishing Systems," by a qualified testing agency acceptable to authorities having jurisdiction.
1. Steel Pipe, **NPS 2 (DN 50)** and Smaller: ASTM A 53/A 53M, Type S, Grade A, Schedule 40, plain ends.
 2. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300.
 3. Piping, fusible links and release mechanism, tank containing the suppression agent, and controls shall be factory installed. Controls shall be in stainless-steel control cabinet mounted on **[hood]** **[or]** **[wall]**. Furnish manual pull station for wall mounting. Exposed piping shall be covered with chrome-plated aluminum tubing. Exposed fittings shall be chrome plated.
 4. Liquid Extinguishing Agent: Noncorrosive, low-pH liquid.
 5. Furnish electric-operated gas shutoff valve; refer to **[Section 231123 "Facility Natural-Gas Piping.]"** **[Section 231126 "Facility Liquefied-Petroleum Gas Piping.]"**

6. Furnish electric-operated gas shutoff valve with clearly marked open and closed indicator for field installation.
7. Fire-suppression system controls shall be integrated with controls for fans, lights, and fuel supply and located in a single cabinet for each group of hoods immediately adjacent.
8. Wiring shall have color-coded, numbered terminal blocks and grounding bar. Spare terminals for fire alarm, optional wiring to start fan with fire alarm, red pilot light to indicate fan operation, and control switches shall all be factory wired in control cabinet with relays or starters. Include spare terminals for fire alarm, and wiring to start fan with fire alarm.

2.6 KITCHEN HOOD EXHAUST DUCTWORK

- A. Fabricate in accordance with SMACNA Low Pressure Duct Construction Standards, High Pressure Duct Construction Standards, and NFPA 96. Reference Section 233113 "Metal Ducts" for metal duct requirements.
- B. Construct of 0.055-inch-thick carbon steel or 0.044-inch-thick stainless steel (minimum), using continuous externally welded joints.
- C. Grease Duct Supports: Duct bracing and supports shall be of noncombustible material securely attached to the structure and designed to carry gravity and lateral loads within the stress limitations of governing codes. Bolts, screws, rivets and other mechanical fasteners shall not penetrate duct walls. Provide duct clean-out openings as required by NFPA 96.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before equipment installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Complete field assembly of hoods where required.
 1. Make closed butt and contact joints that do not require filler.
 2. Grind field welds on stainless-steel equipment smooth, and polish to match adjacent finish. Comply with welding requirements in Part 2 "General Hood Fabrication Requirements" Article.

- B. Install hoods and associated services with clearances and access for maintaining, cleaning, and servicing hoods, filters/baffles, grease extractor, and fire-suppression systems according to manufacturer's written instructions and requirements of authorities having jurisdiction.
- C. Make cutouts in hoods where required to run service lines and to make final connections, and seal openings according to UL 1978.
- D. Securely anchor and attach items and accessories to walls, floors, or bases with stainless-steel fasteners, unless otherwise indicated.
- E. Install hoods to operate free from vibration.
- F. Install seismic restraints according to SMACNA's "Kitchen Ventilation Systems & Food Service Equipment Guidelines," Appendix A, "Seismic Restraint Details."
- G. Install trim strips and similar items requiring fasteners in a bed of sealant. Fasten with stainless-steel fasteners at **48 inches** (1200 mm) o.c. maximum.
- H. Install sealant in joints between equipment and abutting surfaces with continuous joint backing, unless otherwise indicated. Provide airtight, watertight, vermin-proof, sanitary joints.
- I. Install lamps, with maximum recommended wattage, in equipment with integral lighting.
- J. Set initial temperatures, and calibrate sensors.
- K. Set field-adjustable switches.

3.3 CONNECTIONS

- A. Install piping with clearance to allow service and maintenance.
- B. Install reduced-pressure backflow preventer on washer-water supply. Backflow preventer is specified in Section 221119 "Domestic Water Piping Specialties."
- C. Install washer-water drain piping full size of hood connection to an adjacent floor drain or floor sink.
- D. Makeup Water Connection: Comply with applicable requirements in Section 221119 "Domestic Water Piping Specialties" for valves and accessories on piping connections to water-cooled units.
- E. Connect ducts according to requirements in Section 233300 "Air Duct Accessories." Install flexible connectors on makeup air supply duct. Weld exhaust-duct connections with continuous liquidtight joint.
- F. Install fire-suppression piping for remote-mounted suppression systems according to NFPA 17A, "Wet Chemical Extinguishing Systems."

3.4 PROTECTING

- A. Provide final protection and maintain conditions, in a manner acceptable to manufacturer and Installer that ensure equipment is without damage or deterioration at the time of Substantial Completion.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections and prepare test reports.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Tests and Inspections:
 - 1. Test each equipment item for proper operation. Repair or replace equipment that is defective, including units that operate below required capacity or that operate with excessive noise or vibration.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 3. Test water, drain, gas, and liquid-carrying components for leaks. Repair or replace leaking components.
 - 4. Perform hood performance tests required by authorities having jurisdiction.
 - 5. Perform fire-suppression system performance tests required by authorities having jurisdiction.
- E. Prepare test and inspection reports.

3.6 COMMISSIONING

- A. Startup Services: Engage factory-authorized service representatives to assist Contractor and perform startup services and to demonstrate and train Owner's maintenance personnel as specified below.
 - 1. Coordinate equipment startup with service-utility testing, balancing, and adjustments.
 - 2. Remove protective coverings and clean and sanitize equipment, both inside and out, and relamp equipment with integral lighting. Where applicable, comply with manufacturer's written cleaning instructions.
 - 3. Test each equipment item for proper operation. Repair or replace equipment that is defective in operation, including units that operate below required capacity or

- that operate with excessive noise or vibration.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 5. Test motors and rotating equipment for proper rotation and lubricate moving parts according to manufacturer's written instructions.
 6. Test liquid-carrying components for leaks. Repair or replace leaking components.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain commercial kitchen hoods. Review data in the operation and maintenance manuals. Refer to Section 017900 "Demonstration and Training."
 1. Schedule demonstration with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 233813

SECTION 234100 - PARTICULATE AIR FILTRATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Metal panel filters.
 - 2. Flat panel filters.
 - 3. Pleated panel filters.
 - 4. Ring panel filters.
 - 5. Nonsupported bag filters.
 - 6. Supported bag filters.
 - 7. Rigid cell box filters.
 - 8. V-bank cell filters.
 - 9. Self-supported pocket filters.
 - 10. Automatic roll filters.
 - 11. Bulk media.
 - 12. Front- and rear-access filter frames.
 - 13. Side-service housings.
 - 14. Filter gages.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

2. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
 3. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Shop Drawings: For air filters. Include plans, elevations, sections, details, and attachments to other work.
1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
 2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
 3. Wiring Diagrams: For power, signal, and control wiring.
- 1.4 CLOSEOUT SUBMITTALS
- A. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.
 - B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- 1.5 MAINTENANCE MATERIAL SUBMITTALS
- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Provide **[one (1)] <Insert number>** complete set(s) of filters for each filter bank. If system includes prefilters, provide only prefilters.
 2. Provide **[one (1)] <Insert number>** container(s) of red oil for inclined manometer filter gage.
- 1.6 QUALITY ASSURANCE
- A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air filters and are based on the specific system indicated. Refer to Division 1.
 - B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - C. ASHRAE Compliance:

1. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality"; Section 5 - "Systems and Equipment"; and Section 7 - "Construction and Startup."
2. Comply with ASHRAE 52.1 for arrestance and ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.

D. Comply with NFPA 90A and NFPA 90B.

1.7 PERFORMANCE TOLERANCES

- A. Conform to ARI 850 Section 7.4.
- B. Dust Spot Efficiency: Plus or minus [5] <Insert number> percent.

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 METAL PANEL FILTERS

- A. Description: Factory-fabricated, self-supported, cleanable, all-metal, impingement-type, panel-type, permanent air filters with holding frames.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Filtration Group.
 - e. Flanders-Precisionaire.
 - f. Koch Filter Corporation.
 - g. Purafil, Inc.
 - h. Research Products Corp.
 - i. <Insert manufacturer's name>.
 - j. or approved equal.

- B. Media: **[Four]** **[Six]** alternate layers of **[galvanized-steel]** **[aluminum]** **[stainless-steel]** flat and herringbone-crimp screen.
1. Nonoiled for grease removal application.
 2. Adhesive coating.
 - a. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Filter-Media Frame: **[Galvanized steel]** **[Hot-dip galvanized steel]** **[Aluminum]** **[Stainless steel]**, hinged, and with pull and retaining handles fastened to the media.
1. Drain holes.
- D. Capacities and Characteristics:
1. Face Area: **<Insert sq. in. (sq. mm)>**.
 2. Face Dimensions: **<Insert inches (mm)>**.
 3. Thickness or Depth: **<Insert inches (mm)>**.
 4. Surface Area: **<Insert sq. ft. (sq. m)>**.
 5. Holding Frame Size: **<Insert inches (mm)>**.
 6. Number of Filters: **<Insert number>**.
 7. System Airflow: **<Insert cfm (L/s)>**.
 8. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.
 9. Efficiency: 90 percent on particles 20 micrometers and larger at **500 fpm (2.5 m/s)**.
 10. Arrestance: **<Insert percentage>**.
 11. Initial Resistance: **<Insert inches wg (Pa)>**.
 12. Recommended Final Resistance: **<Insert inches wg (Pa)>**.

2.2 FLAT PANEL FILTERS

- A. Description: Factory-fabricated, self-supported, flat, nonpleated, panel-type, disposable air filters with holding frames.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.

- h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. Tri-Dim Filter Corporation.
 - m. <Insert manufacturer's name>.
 - n. or approved equal.
 - B. Filter Unit Class: UL 900, [Class 1] [Class 2].
 - C. Media: [Interlaced glass or synthetic fibers] [Cotton and synthetic fibers] coated with nonflammable adhesive.
 - 1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
 - 3. Media shall be coated with an antimicrobial agent.
 - 4. Metal Retainer: Upstream side and downstream side.
 - D. Filter-Media Frame: [Cardboard with perforated metal retainer] [Galvanized steel with metal grid on outlet side and steel rod grid on inlet side, hinged, with pull and retaining handles] sealed or bonded to the media.
 - E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
 - F. Capacities and Characteristics:
 - 1. Face Area: <Insert sq. in. (sq. mm)>.
 - 2. Face Dimensions: <Insert inches (mm)>.
 - 3. Depth: <Insert inches (mm)>.
 - 4. System Airflow: <Insert cfm (L/s)>.
 - 5. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
 - 6. Arrestance: [85] <Insert number> percent when tested according to ASHRAE 52.1.
 - 7. MERV Rating: [6] [13] <Insert number> when tested according to ASHRAE 52.2.
- ### 2.3 PLEATED PANEL FILTERS
- A. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters with holding frames.
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. Tri-Dim Filter Corporation.
 - m. **<Insert manufacturer's name>**.
 - n. or approved equal.
- B. Filter Unit Class: UL 900, **[Class 1]** **[Class 2]**.
- C. Media: **[Interlaced glass or synthetic fibers]** **[Cotton and synthetic fibers]** coated with nonflammable adhesive.
1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
 3. Media shall be coated with an antimicrobial agent.
 4. Separators shall be bonded to the media to maintain pleat configuration.
 5. Welded wire grid shall be on downstream side to maintain pleat.
 6. Media shall be bonded to frame to prevent air bypass.
 7. Support members on upstream and downstream sides to maintain pleat spacing.
- D. Filter-Media Frame: **[Cardboard frame with perforated metal retainer]** **[Galvanized steel]** **[Aluminized steel]** **[with metal grid on outlet side and steel rod grid on inlet side, hinged, with pull and retaining handles]** sealed or bonded to the media.
- E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
- F. Capacities and Characteristics:
1. Face Area: **<Insert sq. in. (sq. mm)>**.
 2. Face Dimensions: **<Insert inches (mm)>**.
 3. Thickness or Depth: **[1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)]**.
 4. Surface Area: **<Insert sq. ft. (sq. m)>**.
 5. Holding Frame Size: **<Insert inches (mm)>**.
 6. Number of Filters: **<Insert number>**.
 7. System Airflow: **<Insert cfm (L/s)>**.
 8. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.

9. Efficiency: 90 percent on particles 20 micrometers and larger at 500 fpm (2.5 m/s).
10. Arrestance: [85] <Insert number> percent when tested according to ASHRAE 52.1.
11. Initial Resistance: [0.25-inch wg (62 Pa)] [0.35-inch wg (87.2 Pa)] [0.45-inch wg (112 Pa)] [0.60-inch wg (150 Pa)] <Insert value> at [350 fpm (1.8 m/s)] [500 fpm (2.5 m/s)].
12. Recommended Final Resistance: <Insert inches wg (Pa)>.
13. MERV Rating: [7] [11] [13] [14] <Insert number> when tested according to ASHRAE 52.2.

2.4 RING PANEL FILTERS

- A. Description: Internally supported, flat panel filters for installation in a filter track.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
- B. Filter Unit Class: UL 900, [Class 1] [Class 2].
- C. Media: [Two] [Three] [Four]-ply polyester with sealed edges.
1. Panel Construction: [Single] [with one edge unsealed for support removal] [Linked].
 2. Media shall be coated with an antimicrobial agent.
- D. Internal Support: 9-gage steel wire frame.
- E. Capacities and Characteristics:
1. Face Dimensions: <Insert inches (mm)>.
 2. Thickness or Depth: [1-1/2 inches (38 mm)] [1-3/4 inches (44 mm)] [2 inches (50 mm)] <Insert value>.
 3. Surface Area: <Insert sq. ft. (sq. m)>.
 4. Holding Frame Size: <Insert inches (mm)>.

5. Number of Filters: **<Insert number>**.
6. System Airflow: **<Insert cfm (L/s)>**.
7. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.
8. Efficiency: 90 percent on particles 20 micrometers and larger at **500 fpm (2.5 m/s)**.
9. Arrestance: **[85] <Insert number>** percent when tested according to ASHRAE 52.1.
10. Initial Resistance: **<Insert inches wg (Pa)>**.
11. Recommended Final Resistance: **<Insert inches wg (Pa)>**.

2.5 NONSUPPORTED BAG FILTERS

- A. Description: Factory-fabricated, dry, extended-surface, nonsupported filters with header frames.
1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Flanders-Precisionaire.
 - e. Koch Filter Corporation.
 - f. Purafil, Inc.
 - g. Research Products Corp.
 - h. Tri-Dim Filter Corporation.
 - i. **<Insert manufacturer's name>**.
 - j. or approved equal.
- B. Filter Unit Class: UL 900, **[Class 1] [Class 2]**.
- C. Media: **[Glass-fiber] [Synthetic]** material constructed so individual pockets are maintained in tapered form under rated-airflow conditions by flexible internal supports.
1. Media shall be coated with an antimicrobial agent.
- D. Filter-Media Frame: **[Galvanized steel] [Hard polyurethane foam]**.
- E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
- F. Capacities and Characteristics:
1. Face Area: **<Insert sq. in. (sq. mm)>**.
 2. Face Dimensions: **<Insert inches (mm)>**.
 3. Thickness or Depth: **<Insert inches (mm)>**.
 4. Surface Area: **<Insert sq. ft. (sq. m)>**.
 5. Holding Frame Size: **<Insert inches (mm)>**.
 6. Number of Filters: **<Insert number>**.

7. System Airflow: <Insert cfm (L/s)>.
8. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
9. Efficiency: 90 percent on particles 20 micrometers and larger at 500 fpm (2.5 m/s).
10. Arrestance: [55] [65] [85] [95] <Insert number> percent when tested according to ASHRAE 52.1.
11. Initial Resistance: <Insert inches wg (Pa)>.
12. Recommended Final Resistance: <Insert inches wg (Pa)>.
13. MERV Rating: [8] [10] [12] [15] <Insert number> when tested according to ASHRAE 52.2.

2.6 SUPPORTED BAG FILTERS

- A. Description: Factory-fabricated, dry, extended-surface, self-supported filters with holding frames in steel, basket-type retainers.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
- B. Filter Unit Class: UL 900, [Class 1] [Class 2].
- C. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
 1. Media shall be coated with an antimicrobial agent.
- D. Filter-Media Frame: [Galvanized steel] [Hard polyurethane foam].
- E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
- F. Capacities and Characteristics:
 1. Face Area: <Insert sq. in. (sq. mm)>.
 2. Face Dimensions: <Insert inches (mm)>.

3. Thickness or Depth: <Insert inches (mm)>.
4. Surface Area: <Insert sq. ft. (sq. m)>.
5. System Airflow: <Insert cfm (L/s)>.
6. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
7. Arrestance: [85] <Insert number> percent when tested according to ASHRAE 52.1.
8. Initial Resistance: <Insert inches wg (Pa)>.
9. Recommended Final Resistance: <Insert inches wg (Pa)>.
10. MERV Rating: [6] [8] [13] <Insert number> when tested according to ASHRAE 52.2.

2.7 RIGID CELL BOX FILTERS

- A. Description: Factory-fabricated, [**adhesive-coated**,]disposable, packaged air filters with media perpendicular to airflow, and with holding frames.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. Tri-Dim Filter Corporation.
 - m. <Insert manufacturer's name>.
 - n. or approved equal.
- B. Filter Unit Class: UL 900, [**Class 1**] [**Class 2**].
- C. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
 3. Media shall be coated with an antimicrobial agent.
- D. Filter-Media Frames: [**Galvanized steel**] [**Hard polyurethane foam**].

- E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
- F. Capacities and Characteristics:
 - 1. Face Area: <Insert sq. in. (sq. mm)>.
 - 2. Face Dimensions: <Insert inches (mm)>.
 - 3. Thickness or Depth: <Insert inches (mm)>.
 - 4. Surface Area: <Insert sq. ft. (sq. m)>.
 - 5. System Airflow: <Insert cfm (L/s)>.
 - 6. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
 - 7. Arrestance: [85] <Insert number> percent when tested according to ASHRAE 52.1.
 - 8. Initial Resistance: <Insert inches wg (Pa)>.
 - 9. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - 10. MERV Rating: [6] [8] [13] <Insert number> when tested according to ASHRAE 52.2.

2.8 V-BANK CELL FILTERS

- A. Description: Factory-fabricated, [**adhesive-coated**,]disposable, packaged air filters with media angled to airflow, and with holding frames.
 - 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. Tri-Dim Filter Corporation.
 - m. <Insert manufacturer's name>.
 - n. or approved equal.
- B. Filter Unit Class: UL 900, [**Class 1**] [**Class 2**].
- C. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
 - 1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
 3. Media shall be coated with an antimicrobial agent.
- D. Filter-Media Frames: **[Galvanized steel] [Hard polyurethane foam]**.
- E. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
- F. Capacities and Characteristics:
1. Face Area: **<Insert sq. in. (sq. mm)>**.
 2. Face Dimensions: **<Insert inches (mm)>**.
 3. Thickness or Depth: **<Insert inches (mm)>**.
 4. Surface Area: **<Insert sq. ft. (sq. m)>**.
 5. System Airflow: **<Insert cfm (L/s)>**.
 6. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.
 7. Arrestance: **[85] <Insert number>** percent when tested according to ASHRAE 52.1.
 8. Initial Resistance: **<Insert inches wg (Pa)>**.
 9. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
 10. MERV Rating: **[6] [8] [13] <Insert number>** when tested according to ASHRAE 52.2.

2.9 SELF-SUPPORTED POCKET FILTERS

- A. Description: Factory-fabricated, panel-type, disposable air filters with contoured media for extended surface.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Columbus Industries, Inc.
 - d. Filtration Group.
 - e. Flanders-Precisionaire.
 - f. Koch Filter Corporation.
 - g. **<Insert manufacturer's name>**.
 - h. or approved equal.
- B. Filter Unit Class: UL 900, **[Class 1] [Class 2]**.
- C. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
1. Media shall be coated with an antimicrobial agent.

- D. Configuration: [**Single-pocket cube**] [**Multipocket**].
- E. Filter-Media Frame: [**Galvanized steel**] [**Hard polyurethane foam**].
- F. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.
- G. Capacities and Characteristics:
 - 1. Face Dimensions: <Insert inches (mm)>.
 - 2. Thickness or Depth: <Insert inches (mm)>.
 - 3. Surface Area: <Insert sq. ft. (sq. m)>.
 - 4. System Airflow: <Insert cfm (L/s)>.
 - 5. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
 - 6. Arrestance: [**85**] <Insert number> percent when tested according to ASHRAE 52.1.
 - 7. Initial Resistance: <Insert inches wg (Pa)>.
 - 8. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - 9. MERV Rating: [**6**] [**8**] [**13**] <Insert number> when tested according to ASHRAE 52.2.

2.10 AUTOMATIC ROLL FILTERS

- A. Description: Factory-fabricated, automatic, motor-driven, roll-type filters with holding casing.
 - 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders-Precisionaire.
 - i. Koch Filter Corporation.
 - j. Purafil, Inc.
 - k. Research Products Corp.
 - l. <Insert manufacturer's name>.
 - m. or approved equal.
- B. Arrangement: [**Horizontal**] [**Vertical**].
- C. Filter Unit Class: UL 900, [**Class 1**] [**Class 2**].
- D. Media: Compressed and rolled, fibrous-glass material; viscous coated.
 - 1. Media shall be coated with an antimicrobial agent.

- E. Holding Frame: Galvanized steel with enclosed, clean media roll arranged to allow upstream replacement of filter media.
1. Auxiliary Frame: Locate on downstream side of unit with **[downstream]** **[side]** access.
 2. Final Filter: Extended-surface, **[retained]** **[nonsupported]** media.
- F. Control and Drive: Electric, gear-reducer, motor-driven, feed-control mechanism equipped with manual media advance and runout switches for stopping media movement of filter bank and operating remote warning signal lights.
1. Manual Control: Manual switch to advance media, and wired to override automatic controls.
 2. Automatic Control: Prewired control package to advance media **[when filter resistance exceeds preselected high limit]** **[after preselected operating time]**.
- G. Capacities and Characteristics:
1. Face Area: **<Insert sq. in. (sq. mm)>**.
 2. Face Dimensions: **<Insert inches (mm)>**.
 3. Thickness or Depth: **<Insert inches (mm)>**.
 4. Surface Area: **<Insert sq. ft. (sq. m)>**.
 5. System Airflow: **<Insert cfm (L/s)>**.
 6. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.
 7. Arrestance: **[85]** **<Insert number>** percent when tested according to ASHRAE 52.1.
 8. Initial Resistance: **<Insert inches wg (Pa)>**.
 9. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
 10. MERV Rating: **[6]** **[8]** **[13]** **<Insert number>** when tested according to ASHRAE 52.2.
 11. Electrical Characteristics:
 - a. Volts: **<Insert value>**.
 - b. Phase: **[Single]** **[Three]**.
 - c. Hertz: 60.

2.11 BULK MEDIA

- A. Description: Air-filter media, factory custom cut or rolled.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Division.

- f. D-Mark.
- g. Filtration Group.
- h. Flanders-Precisionaire.
- i. Koch Filter Corporation.
- j. Purafil, Inc.
- k. Research Products Corp.
- l. **<Insert manufacturer's name>**.
- m. or approved equal.

B. Filter Unit Class: UL 900, **[Class 1]** **[Class 2]**.

C. Media: **[Spun glass]** **[Synthetic]** **[Polyester]**, **[in a roll]** **[cut into pads]**.

1. Pad Dimensions: **<Insert inches (mm)>** by **<Insert inches (mm)>**.

D. Capacities and Characteristics:

1. Thickness or Depth: **<Insert inches (mm)>**.
2. System Airflow: **<Insert cfm (L/s)>**.
3. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.
4. Arrestance: **[85]** **<Insert number>** percent when tested according to ASHRAE 52.1.
5. Initial Resistance: **<Insert inches wg (Pa)>**.
6. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
7. MERV Rating: **[6]** **[8]** **[13]** **<Insert number>** when tested according to ASHRAE 52.2.

2.12 FRONT- AND REAR-ACCESS FILTER FRAMES

A. Framing System: **[Galvanized-steel]** **[Aluminum]** framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

- a. AAF International.
- b. Airguard.
- c. Camfil Farr.
- d. Columbus Industries, Inc.
- e. CRS Industries, Inc.; CosaTron Division.
- f. D-Mark.
- g. Filtration Group.
- h. Flanders-Precisionaire.
- i. Koch Filter Corporation.
- j. Purafil, Inc.
- k. Research Products Corp.
- l. **<Insert manufacturer's name>**.

m. or approved equal.

- B. Prefilters: Incorporate a separate track[**with spring clips**], removable from front[**or back**].
- C. Sealing: Factory-installed, positive-sealing device for each row of filters, to ensure seal between gasketed filter elements and to prevent bypass of unfiltered air.

2.13 SIDE-SERVICE HOUSINGS

A. Description: Factory-assembled, side-service housings, constructed of [**galvanized steel**] [**aluminum**] with flanges to connect to duct or casing system.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. AAF International.
- b. Airguard.
- c. Camfil Farr.
- d. Columbus Industries, Inc.
- e. CRS Industries, Inc.; CosaTron Division.
- f. D-Mark.
- g. Filtration Group.
- h. Flanders-Precisionaire.
- i. Koch Filter Corporation.
- j. Purafil, Inc.
- k. Research Products Corp.
- l. **<Insert manufacturer's name>**.
- m. or approved equal.

- B. Prefilters: Integral tracks to accommodate **2-inch-** (50-mm-) deep, disposable [**or washable**] filters.
- C. Access Doors: [**Hinged, with continuous**] [**Continuous**] gaskets on perimeter and positive-locking devices, and arranged so filter cartridges can be loaded from either access door.
- D. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames and to prevent bypass of unfiltered air.

2.14 FILTER GAGES

A. Diaphragm-type gage with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. Airguard.

- b. Dwyer Instruments, Inc.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
2. Diameter: [4-1/2 inches (115 mm)] [2 inches (50 mm)].
 3. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
 4. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1.0-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).
 5. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).
 6. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).
 7. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).
- B. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale and logarithmic-curve tube gage with integral leveling gage, graduated to read from 0- to 3.0-inch wg (0 to 750 Pa), and accurate within 3 percent of the full scale range.
- C. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install air cleaning devices in accordance with manufacturer's instructions.
- B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
- C. Install filters in position to prevent passage of unfiltered air with felt, rubber, or neoprene gaskets.
- D. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
- E. Install filter gage for each filter bank.
- F. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
- G. Provide filter gages on filter banks, installed with separate static pressure tips upstream and downstream of filters.
- H. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.

- I. Coordinate filter installations with duct and air-handling-unit installations.

3.2 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 1. Operate automatic roll filters to demonstrate compliance with requirements.
 2. Test for leakage of unfiltered air while system is operating.
- D. Air filter will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

3.3 CLEANING

- A. After completing system installation and testing, adjusting, and balancing of air-handling and air-distribution systems, clean filter housings and install new filter media.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 234100

SECTION 234133 - HIGH-EFFICIENCY PARTICULATE FILTRATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. HEPA rigid-cell box filters.
 - 2. HEPA V-bank cell filters.
 - 3. HEPA filter diffusers.
 - 4. HEPA filter fan modules.
 - 5. ULPA filters.
 - 6. 95 percent DOP filters.
 - 7. Front- and rear-access filter frames.
 - 8. Side-service housings.
 - 9. Filter gages.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For air filters. Include plans, elevations, sections, details, and attachments to other work.

1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
3. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Provide **[one (1)] <Insert number>** complete set(s) of filters for each filter bank. If system includes prefilters, provide only prefilters.
 2. Provide **[one (1)] <Insert number>** container(s) of red oil for inclined manometer filter gage.

1.7 QUALITY ASSURANCE

- A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air filters and are based on the specific system indicated. Refer to Division 1.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended use.
- C. ASHRAE Compliance:
 1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Comply with IEST-RP-CC001.3.
- E. Comply with UL 586.
- F. Comply with IEST-RP-CC007.1.

- G. Comply with NFPA 90A and NFPA 90B.

1.8 PERFORMANCE TOLERANCES

- A. Conform to ARI 850 Section 7.4.
- B. Dust Spot Efficiency: Plus or minus [5] <Insert number> percent.

1.9 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 HEPA RIGID-CELL BOX FILTERS

- A. Description: Factory-fabricated, disposable, packaged air filters with media perpendicular to airflow and with holding frames.
 - 1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. AAF International.
 - b. Camfil Farr Co.
 - c. Flanders-Precisionaire.
 - d. <Insert manufacturer's name>.
 - e. or approved equal.
- B. Filter Unit Class: UL 900, [Class 1] [Class 2].
- C. Media: Fibrous material, constructed so individual pleats are maintained under rated-airflow conditions.
 - 1. Internal Separators: [None] [Aluminum in media folds].
 - 2. Gasket Material: [None] [Neoprene] [Blue gel].
 - 3. Gasket Location: [None] [Upstream] [and] [Downstream].
 - 4. Faceguard Material: [Aluminum] [Stainless steel].
 - 5. Faceguard Location: [None] [Upstream] [and] [Downstream].

D. Filter-Media Frames:

1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Materials: [**Stainless steel**] [**Fire-retardant plywood**] [**Fabricated aluminum**] [**Fire-retardant particleboard**] [**Galvanized sheet**] [**Non-fire-retardant particleboard**].
3. Style: [**Box**] [**Double-turned flange**] [**Deep channel**] [**Double-turned flange, one side**].

E. Mounting Frames: Welded galvanized steel with gaskets and fasteners; suitable for bolting together into built-up filter banks.

2.2 HEPA V-BANK CELL FILTERS

A. Description: Factory-fabricated, disposable, packaged air filters with media at an angle to airflow and with holding frames.

1. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - a. AAF International.
 - b. Camfil Farr Co.
 - c. Flanders-Precisionaire.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.

B. Filter Unit Class: UL 900, [**Class 1**] [**Class 2**].

C. Media: Fibrous material, constructed so individual pleats are maintained under rated-airflow conditions.

1. Internal Separators: [**None**] [**Aluminum in media folds**].
2. Gasket Material: [**None**] [**Neoprene**] [**Blue gel**].
3. Gasket Location: [**None**] [**Upstream**] [**and**] [**Downstream**].
4. Faceguard Material: [**Aluminum**] [**Stainless steel**].
5. Faceguard Location: [**None**] [**Upstream**] [**and**] [**Downstream**].

D. Filter-Media Frames:

1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Materials: [**Stainless steel**] [**Fire-retardant plywood**] [**Fabricated aluminum**] [**Fire-retardant particleboard**] [**Galvanized sheet**] [**Non-fire-retardant particleboard**].
3. Style: [**Box**] [**Double-turned flange**] [**Deep channel**] [**Double-turned flange, one side**].

E. Mounting Frames: Welded galvanized steel with gaskets and fasteners; suitable for bolting together into built-up filter banks.

2.3 HEPA FILTER DIFFUSERS

- A. Description: Factory-fabricated, individually ducted, HEPA filter-holding ceiling modules.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Camfil Farr Co.
 - c. Flanders-Precisionaire.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
- B. Media: Fibrous glass, constructed of continuous sheets with closely spaced pleats with glass filament separators.
1. Media to Module Side Bond: Urethane sealant.
 2. Media to Frame Side Bond: **[Polyurethane foam] [Silicone] [Neoprene adhesive] [Fiberglass-mat packing] [Thermosetting sealant] [Knife edge in fluid-filled channel]**.
 3. Application: **[Class 100] [Class 10] [Class 1] <Insert class>** clean room.
- C. Casing:
1. Configuration: **[Ducted inlet] [Plenum inlet] [Plenum inlet with prefilter]**.
 2. Module Material: Extruded aluminum, 16 gage with mill finish.
 3. Suspension: Ceiling grid.
- D. Accessories:
1. Diffusion damper.
 2. Diffusion-damper adjustment port.
 3. Filter test port.

2.4 HEPA FILTER FAN MODULES

- A. Description: Factory-fabricated, HEPA filter ceiling module with fan.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
- B. Casing:
1. Configuration: **[Ducted inlet] [Plenum inlet] [Plenum inlet with prefilter]**.
 2. Module Material: Extruded aluminum, 16 gage with mill finish.

3. Suspension: [**Ceiling grid**] [**Independent**].
- C. Media: Fibrous glass, constructed of continuous sheets with closely spaced pleats with [**aluminum separators**] [**vinyl-coated aluminum separators**] [**separators of ribbons of filter media**].
 1. Frame Material: [**3/4-inch- (19-mm-) thick, fire-retardant plywood**] [**3/4-inch- (19-mm-) thick, fire-retardant particleboard**] [**3/4-inch- (19-mm-) thick plywood**] [**3/4-inch- (19-mm-) thick particleboard**] [**Galvanized steel**] [**Aluminized steel**] [**Cadmium-plated steel**] [**Stainless steel**] [**Aluminum**].
 2. Media to Frame Side Bond: [**Polyurethane foam**] [**Silicone**] [**Neoprene adhesive**] [**Fiberglass-mat packing**] [**Thermosetting sealant**] [**Knife edge in fluid-filled channel**].
 3. Face Gasket: [**Neoprene expanded rubber**] [**Ceramic fiber**] [**Silicone**].
 4. Faceguard: [**Plastic**] [**Stainless steel**].
- D. Accessories: Filter test port.
- E. Control: Variable speed.
- F. Motor:
 1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Type: [**Permanent-split capacitor with SCR for speed adjustment**] [**Electronically commutated motor**].
 3. Fan-Motor Assembly Isolation: Rubber isolators.
 4. Enclosure: [**Open dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 5. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 6. Motor Bearings: <Insert special requirements>.
 7. Unusual Service Conditions:
 - a. Ambient Temperature: <Insert deg F (deg C)>.
 - b. Altitude: <Insert feet (m)> above sea level.
 - c. High humidity.
 - d. <Insert conditions>.
 8. Efficiency: Premium efficient.
 9. NEMA Design: <Insert designation>.
 10. Service Factor: <Insert value>.
 11. Motor Speed: [**Single speed**] [**Multispeed**].
 - a. Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.
 12. Electrical Characteristics:

- a. Horsepower: <Insert value>.
- b. Volts: [120] [208] [230] [460] <Insert value> V.
- c. Phase: [Single] [Poly].
- d. Hz: 60.
- e. Full-Load Amperes: <Insert value>.
- f. Minimum Circuit Ampacity: <Insert value>.
- g. Maximum Overcurrent Protection: <Insert amperage>.

2.5 ULPA FILTERS

A. Description: Factory-fabricated, ULPA filters with holding casing.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. AAF International.
- b. Airguard.
- c. Camfil Farr Co.
- d. Flanders-Precisionaire.
- e. <Insert manufacturer's name>.
- f. or approved equal.

B. Media: Fibrous glass, constructed of continuous sheets with closely spaced pleats with [aluminum separators] [vinyl-coated aluminum separators] [separators of ribbons of filter media].

C. Frame Material: [3/4-inch- (19-mm-) thick, fire-retardant plywood] [3/4-inch- (19-mm-) thick, fire-retardant particleboard] [3/4-inch- (19-mm-) thick plywood] [3/4-inch- (19-mm-) thick particleboard] [Galvanized steel] [Aluminized steel] [Cadmium-plated steel] [Stainless steel] [Aluminum].

D. Media to Frame Side Bond: [Polyurethane foam] [Silicone] [Neoprene adhesive] [Fiberglass-mat packing] [Thermosetting sealant] [Knife-edge in fluid-filled channel].

E. Face Gasket: [Neoprene expanded rubber] [Ceramic fiber] [Silicone].

F. Mounting Frames: Construct downstream corners of holding device with cushion pads to protect media. Provide bolted filter-sealing mechanism to mount and continuously seal each individual filter.

2.6 95 PERCENT DOP FILTERS

A. Description: Factory-fabricated, 95 percent DOP filters with holding casing.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. AAF International.

- b. Airguard.
 - c. Camfil Farr Co.
 - d. Flanders-Precisionaire.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
- B. Media: Fibrous glass, constructed of continuous sheets with closely spaced pleats with **[aluminum separators] [vinyl-coated aluminum separators] [separators of ribbons of filter media]**.
- C. Frame Material: **[3/4-inch- (19-mm-) thick, fire-retardant plywood] [3/4-inch- (19-mm-) thick, fire-retardant particleboard] [3/4-inch- (19-mm-) thick plywood] [3/4-inch- (19-mm-) thick particleboard] [Galvanized steel] [Aluminized steel] [Cadmium-plated steel] [Stainless steel] [Aluminum]**.
- D. Frame Style: **[Box single header] [Double header] [Double turned flange] [3/4-inch- (19-mm-) deep channel]**.
- E. Media to Frame Side Bond: **[Polyurethane foam] [Silicone] [Neoprene adhesive] [Fiberglass-mat packing] [Thermosetting sealant] [Knife edge in fluid-filled channel]**.
- F. Face Guard Material: **[Galvanized] [Aluminum]** mesh.
- G. Face Guard Location: **[Upstream] [and] [Downstream]**.
- H. Gasket Material: **[Neoprene expanded rubber] [Ceramic fiber] [Silicone]**.
- I. Gasket Location: **[Upstream] [and] [Downstream]**.
- J. Mounting Frames: Construct downstream corners of holding device with cushion pads to protect media. Provide bolted filter-sealing mechanism to mount and continuously seal each individual filter.

2.7 FRONT- AND REAR-ACCESS FILTER FRAMES

- A. Framing System: Aluminum framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr Co.
 - d. Flanders-Precisionaire.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.

- B. Prefilters: Incorporate a separate track, removable from front or back.
- C. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.
- D. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.8 SIDE-SERVICE HOUSINGS

- A. Description: Factory-assembled, side-service housings, constructed of **0.064-inch- (1.6-mm-)** thick, **[galvanized steel] [stainless steel] [double-wall casing with 1-inch (25-mm) insulation]** to hold filters. Side servicing is through gasketed access doors on one side, and housings are capable of connection to other housings. Equip housings with metal slide channel tracks with clamping mechanisms to hold filters, and the following:
 - 1. Pressure tap and fitting.
 - 2. DOP/freon test ports.
 - 3. Decontamination ports.
 - 4. Isolation dampers.
 - 5. Lifting lugs.
 - 6. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr Co.
 - d. Flanders-Precisionaire.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
- B. Prefilters: Integral tracks to accommodate **2-, 4-, and 6-inch-** (50-, 100-, and 150-mm-thick,) disposable filters.
- C. Access Doors: Continuous gaskets on perimeter and positive-locking **[swivel] devices. [Provide ribbed bagging rim behind access door and PVC bags for bag-in, bag-out arrangement.]** Arrange so filter cartridges can be loaded from an access door for each tier and section of the following:
 - 1. Combination prefilter and HEPA filter.
 - 2. Prefilter.
 - 3. HEPA filter.
 - 4. Upstream and downstream test section.
- D. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.
- E. Accessories:

1. Filter change-out trays.
2. Document-storage pocket.
3. Filter removal rod.

F. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.9 FILTER GAGES

A. Diaphragm type with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

- a. Airguard.
- b. Dwyer Instruments, Inc.
- c. **<Insert manufacturer's name>**.
- d. or approved equal.

2. Diameter: [4-1/2 inches (115 mm)] [2 inches (50 mm)].

3. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).

4. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1.0-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).

5. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).

6. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).

7. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).

B. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale, logarithmic-curve tube gage with integral leveling gage; graduated to read from 0- to 3.0-inch wg (0 to 750 Pa) and accurate within 3 percent of full-scale range.

C. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

2.10 CAPACITIES AND CHARACTERISTICS

A. Face Area: **<Insert sq. ft. (sq. m)>**.

B. Depth: **<Insert inches (mm)>**.

C. Surface Area: **<Insert sq. ft. (sq. m)>**.

D. Module Size: **<Insert size>**.

E. Number of Filters/Modules: **<Insert number>**.

- F. Frame Access Location: <Insert location>.
- G. System Airflow: <Insert cfm (L/s)>.
- H. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
- I. Initial Resistance: <Insert inches wg (Pa)>.
- J. Recommended Final Resistance: <Insert inches wg (Pa)>.
- K. Performance Level: [HEPA] [ULPA] [95 percent as tested according to MIL-STD 282] <Insert value>.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install air cleaning devices in accordance with manufacturer's instructions.
- B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
- C. Install filters in position to prevent passage of unfiltered air with felt, rubber, or neoprene gaskets.
- D. Install filter gage for each filter bank.
- E. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters that were used during construction and testing with new, clean filters.
- F. Provide filter gages on filter banks, installed with separate static pressure tips upstream and downstream of filters.
- G. Install filter-gage static-pressure tips upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.
- H. Coordinate filter installations with duct and air-handling unit installations.

3.2 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installation, including connections.
- B. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Tests and Inspections:

1. Operate automatic roll filters to demonstrate compliance with requirements.
2. Test for leakage of unfiltered air while system is operating.
3. HEPA Filters: Pressurize housing to a minimum of 3.0-inch wg (750 Pa) or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
4. HEPA Filters: Pressurize housing to a minimum of 3.0-inch wg (750 Pa) or to designed operating pressure, whichever is higher; and test housing joints, door seals, and sealing edges of filter for air leaks according to pressure-decay method in ASME N510.

D. Air filter will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.3 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new filter media.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 234133

SECTION 234200 - GAS-PHASE AIR FILTRATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Activated-carbon panel filters.
2. Activated-carbon, deep-V filters.
3. Activated carbon, V-cell filters.
4. Cylindrical-canister filters.
5. Permanganate filters.
6. Supported adsorber bag filters.
7. Front-access filter housings.
8. Side-service housings.
9. Filter gages.

- B. Related Sections:

1. Section 233119 "HVAC Casings" for customized housings used for gas-phase filters.
2. Section 233416 "Centrifugal HVAC Fans" for customized fan and filter units.
3. Section 234133 "High-Efficiency Particulate Filtration" for HEPA filters used in combination with gas-phase filters.
4. Section 234300 "Electronic Air Cleaners" for electronic units combined with gas-phase filters as part of a system.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.

1. Include data substantiating that materials comply with requirements.

B. LEED Submittal:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with applicable requirements in ASHRAE 62.1-2004, Section 5, "Systems and Equipment."

C. Shop Drawings: For air filters. Include plans, elevations, sections, details, and attachments to other work.

1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Provide **[one (1)] <Insert number>** complete set(s) of filters for each filter or filter bank.
 2. Provide **[one (1)] <Insert number>** complete 100 percent refill supply for each filter requiring loose-fill media.
 3. Provide **[one (1)] <Insert number>** container(s) of red oil for inclined manometer filter gage.

1.7 QUALITY ASSURANCE

- A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air filters and are based on the specific system indicated. Refer to Division 1.
- B. ASHRAE Compliance:

1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
- C. Comply with NFPA 90A and NFPA 90B.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 ACTIVATED-CARBON PANEL FILTERS

- A. Description: Factory-fabricated unit with activated-carbon media.
- B. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. AAF International.
 2. Airguard.
 3. Camfil Farr Co.
 4. Filtration Group.
 5. Flanders/CSC Corp.; a wholly owned subsidiary of Flanders Corporation.
 6. Flanders-Precisionaire.
 7. International Air Filtration Corporation.
 8. Koch Filter Corporation.
 9. Purafil, Inc.
 10. Research Products Corp.; Aprilaire Division.
 11. Tri-Dim Filter Corporation.
 12. **<Insert manufacturer's name>**.
 13. or approved equal.
- C. Media: Flat-panel, disposable multilayer filter with an inlet layer of polyester fibers, a layer of activated-carbon granules bonded to fibers, and a layer of polyurethane foam; housed in a cardboard frame.
- D. Media: Flat-panel, disposable honeycombed cellulose with cells filled with activated-carbon granules and a perforated mesh grid; housed in a cardboard frame.
- E. Media: Pleated, multilayer filter with an inlet layer of cotton and synthetic fibers and a layer of activated-carbon granules bonded to synthetic fibers; media formed into deep-V-shaped pleats, held by self-wire grid, and housed in a cardboard frame.
- F. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with [**polyurethane**]gaskets; capable of bolting together into built-up filter banks.

G. Capacities and Characteristics:

1. Face Size: [24 by 24 inches (600 by 600 mm)] [20 by 24 inches (500 by 600 mm)] [24 by 12 inches (600 by 300 mm)] <Insert dimensions> nominal.
2. Depth: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)] <Insert dimension> nominal.
3. System Airflow: <Insert cfm (L/s)>.
4. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
5. Initial Resistance: [0.50-inch wg (125 Pa)] <Insert value>.

2.2 ACTIVATED-CARBON, DEEP-V FILTERS

A. Description: Factory-fabricated unit with activated-carbon trays in deep-V arrangement with disposable [panel prefilter] [and] [final filter].

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. AAF International.
- b. Airguard.
- c. Camfil Farr Co.
- d. Filtration Group.
- e. Flanders/CSC Corp.; a wholly owned subsidiary of Flanders Corporation.
- f. Flanders-Precisionaire.
- g. International Air Filtration Corporation.
- h. Koch Filter Corporation.
- i. Purafil, Inc.
- j. Research Products Corp.; Aprilaire Division.
- k. <Insert manufacturer's name>.
- l. or approved equal.

B. Module Housing: 0.064-inch- (1.6-mm-) thick, [galvanized steel] [stainless steel] [double-wall casing with 1-inch- (25-mm-) thick insulation] to hold media-filled panels; with side servicing through gasketed access doors on both sides and able to connect to other housings. Equip housings with metal slide channel tracks to hold activated-carbon trays [and particulate prefilter] [and final filter].

1. Finish: Factory [primed] [primed and painted], [outside] [inside and outside] [inside].
2. Pressure tap and fitting.

C. Media-Holding Panels: 1-inch- (25-mm-) thick, perforated polystyrene to allow airflow through contained loose-fill media; with removable service cap for recharging.

D. Media-Holding Panels: [1 inch (25 mm)] [2 inches (50 mm)] [3 inches (75 mm)] deep and containing granular carbon bonded into a briquette form with a [galvanized] [stainless]-steel frame.

- E. Media: [45 lb (20.3 kg)] <Insert value> per 1000 cfm (470 L/s) of [loose-fill] [loose-fill or bonded-briquette] [bonded-briquette] coconut-shell activated carbon.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- F. Media: <Insert lb (kg)> per 1000 cfm (470 L/s) of [loose-fill] [loose-fill or bonded-briquette] [bonded-briquette] activated alumina impregnated with potassium permanganate.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- G. Media: <Insert lb (kg)> per 1000 cfm (470 L/s) of [loose-fill] [loose-fill or bonded-briquette] [bonded-briquette] impregnated carbon.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- H. Media: <Insert lb (kg)> per 1000 cfm (470 L/s) of [loose-fill] [loose-fill or bonded-briquette] [bonded-briquette] blended carbon and alumina impregnated with potassium permanganate.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- I. Capacities and Characteristics:
1. Face Size: [24 by 24 inches (600 by 600 mm)] [20 by 24 inches (500 by 600 mm)] [24 by 12 inches (600 by 300 mm)] <Insert dimensions> nominal.
 2. Depth: [12 inches (300 mm)] <Insert dimension> nominal.
 3. System Airflow: <Insert cfm (L/s)>.
 4. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
 5. Initial Resistance: [0.50-inch wg (125 Pa)] <Insert value>.

6. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
7. Prefilter: Comply with requirements in Section 234100 "Particulate Air Filtration" for **[flat] [pleated] [ring]** panel. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: **[1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)] <Insert dimension>**.
 - b. Maximum or Rated Face Velocity: **[500 fpm (2.5 m/s)] <Insert value>**.
 - c. Initial Resistance: **[0.25-inch wg (62.3 Pa)] [0.35-inch wg (87.2 Pa)] [0.45-inch wg (112.1 Pa)] [0.60-inch wg (150 Pa)] <Insert value>** at **[350 fpm (1.8 m/s)] [500 fpm (2.5 m/s)] <Insert value>**.
 - d. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
 - e. Filter Unit Class: UL 900, **[Class 1] [Class 2]**.
 - f. Arrestance: **[85] <Insert number>** percent when tested according to ASHRAE 52.1.
 - g. MERV: **[8] <Insert value>** when tested according to ASHRAE 52.2.
8. Final Filter: Comply with requirements in Section 234100 "Particulate Air Filtration" for **[supported bag] [unsupported bag] [rigid-cell box] [V-bank cell] [self-supported pocket]**. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: **[12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension>**.
 - b. Maximum or Rated Face Velocity: **[500 fpm (2.5 m/s)] <Insert value>**.
 - c. Initial Resistance: **[1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value>** at **500 fpm (2.5 m/s)**.
 - d. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
 - e. Arrestance: **[85] <Insert number>** percent when tested according to ASHRAE 52.1.

2.3 ACTIVATED-CARBON, V-CELL FILTERS

- A. Description: Factory-fabricated, dry, V-shaped cartridges containing loose-fill media with holding frames.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Camfil Farr Co.
 - b. Flanders/CSC Corp.; a wholly owned subsidiary of Flanders Corporation.
 - c. Flanders-Precisionaire.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
- B. Cartridges: V-cell configuration, plastic enclosure caps, galvanized-steel frame with vertical galvanized-steel channel supports. Integral, **1-inch- (25-mm-)** deep panels constructed of honeycombed paper and nylon mesh.

- C. Fill Media: Coconut-shell activated carbon; [45 lb (20.3 kg)] <Insert value> of activated carbon per 1000 cfm (470 L/s) of airflow.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- D. Fill Media: Activated alumina impregnated with potassium permanganate; [10.5 lb (4.8 kg)] <Insert value> of adsorbent per 500 cfm (236 L/s) of airflow.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- E. Fill Media: Impregnated carbon; [8.0 lb (3.6 kg)] <Insert value> of adsorbent per 500 cfm (236 L/s) of airflow.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- F. Fill Media: Blended carbon and alumina impregnated with potassium permanganate; [7.0 lb (3.1 kg)] <Insert value> of adsorbent per 500 cfm (236 L/s) of airflow.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- G. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with gaskets; capable of bolting together into built-up filter banks.
- H. Capacities and Characteristics:
1. Face Size: [24 by 24 inches (600 by 600 mm)] [20 by 24 inches (500 by 600 mm)] [24 by 12 inches (600 by 300 mm)] <Insert dimensions> nominal.
 2. Depth: [12 inches (300 mm)] <Insert dimension> nominal.
 3. System Airflow: <Insert cfm (L/s)>.
 4. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.

5. Initial Resistance: [0.50-inch wg (125 Pa)] <Insert value>.
6. Recommended Final Resistance: <Insert inches wg (Pa)>.
7. Prefilter: Comply with requirements in Section 234100 "Particulate Air Filtration" for [flat] [pleated] [ring] panel. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)] <Insert dimension>.
 - b. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
 - c. Initial Resistance: [0.25-inch wg (62.3 Pa)] [0.35-inch wg (87.2 Pa)] [0.45-inch wg (112.1 Pa)] [0.60-inch wg (150 Pa)] <Insert value> at [350 fpm (1.8 m/s)] [500 fpm (2.5 m/s)] <Insert value>.
 - d. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - e. Filter Unit Class: UL 900, [Class 1] [Class 2].
 - f. Arrestance: [85] <Insert value> percent when tested according to ASHRAE 52.1.
 - g. MERV: [8] <Insert value> when tested according to ASHRAE 52.2.
8. Final Filter: Comply with requirements in Section 234100 "Particulate Air Filtration" for [supported bag] [unsupported bag] [rigid-cell box] [V-bank cell] [self-supported pocket]. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: [12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension>.
 - b. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
 - c. Initial Resistance: [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value> at 500 fpm (2.5 m/s).
 - d. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - e. Filter Unit Class: UL 900, [Class 1] [Class 2].
 - f. Arrestance: [85] <Insert value> percent when tested according to ASHRAE 52.1.
 - g. MERV: [13] <Insert value> when tested according to ASHRAE 52.2.

2.4 CYLINDRICAL-CANISTER FILTERS

- A. Description: Factory-fabricated, dry, cylindrical canisters containing loose-fill adsorbent with holding frames.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Camfil Farr Co.
 - b. <Insert manufacturer's name>.
 - c. or approved equal.
- B. Cylinders: 0.0455-inch- (1.2-mm-) thick, perforated, [electroplated] [stainless] steel, with end plate.

- C. Fill Media: [5.0 lb (2.3 kg)] [6.7 lb (3.0 kg)] <Insert value> of [coconut-shell activated carbon] [activated alumina impregnated with potassium permanganate] [impregnated carbon] [blended carbon and alumina impregnated with potassium permanganate] per canister.
1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)] <Insert value>, 90 percent minimum.
 5. Hardness Factor: [95] <Insert value> when tested according to ASTM D 3802.
- D. Mounting Frames: Welded [galvanized, sheet steel with galvanized-steel fasteners] [stainless steel with stainless-steel fasteners] with gaskets; designed for bolting together into built-up filter banks.
- E. Capacities and Characteristics:
1. Face Size: [24 by 24 inches (600 by 600 mm)] [24 by 12 inches (600 by 300 mm)] <Insert dimensions>nominal.
 2. Cylinder Length: [18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension> nominal.
 3. Housing Depth: [34 inches (860 mm)] <Insert dimension> nominal.
 4. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
 5. Initial Resistance: [0.50-inch wg (125 Pa)] <Insert value>.
 6. Recommended Final Resistance: <Insert inches wg (Pa)>.
 7. Prefilter: Comply with requirements in Section 234100 "Particulate Air Filtration" for [flat] [pleated] [ring] panel. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)] <Insert dimension>.
 - b. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
 - c. Initial Resistance: [0.25-inch wg (62.3 Pa)] [0.35-inch wg (87.2 Pa)] [0.45-inch wg (112.1 Pa)] [0.60-inch wg (150 Pa)] <Insert value> at [350 fpm (1.8 m/s)] [500 fpm (2.5 m/s)] <Insert value>.
 - d. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - e. Filter Unit Class: UL 900, [Class 1] [Class 2].
 - f. Arrestance: [85] <Insert value> percent when tested according to ASHRAE 52.1.
 - g. MERV: [8] <Insert value> when tested according to ASHRAE 52.2.
 8. Final Filter: Comply with requirements in Section 234100 "Particulate Air Filtration" for [supported bag] [unsupported bag] [rigid-cell box] [V-bank cell] [self-supported pocket]. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: [12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension>.
 - b. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.

- c. Initial Resistance: [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value> at 500 fpm (2.5 m/s).
- d. Recommended Final Resistance: <Insert inches wg (Pa)>.
- e. Filter Unit Class: UL 900, [Class 1] [Class 2].
- f. Arrestance: [85] <Insert value> percent when tested according to ASHRAE 52.1.
- g. MERV: [13] <Insert value> when tested according to ASHRAE 52.2.

2.5 PERMANGANATE FILTERS

- A. Description: Factory-fabricated modules containing loose-fill adsorbent with holding frames.
 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Air Quality Engineering, Inc.
 - b. Air Technology Solutions, Inc.
 - c. BPA Air Quality Solutions, LLC.
 - d. Flanders-Precisionaire.
 - e. <Insert manufacturer's name>.
 - f. or approved equal.
- B. Modules: Permanent type, 24 inches wide by 24 inches high by 24 inches deep (600 mm wide by 600 mm high by 600 mm deep); shall hold both potassium permanganate and activated carbon. Manufactured in two pieces, each 12 inches (300 mm) wide for ease of installation.
- C. Media: Porous spherical pellets formed from a combination of powdered, activated carbon and other binders, impregnated with potassium permanganate.
 1. Leach Test: [180] <Insert number> minutes.
 2. Potassium Permanganate Content: [4] <Insert number> percent minimum.
 3. Moisture Content: [20] <Insert number> percent maximum.
 4. Bulk Density: [34 lb/cu. ft. (0.54 g/mL)] [50 lb/cu. ft. (0.8 g/mL)] <Insert value>.
 5. Crush Strength: [40] [50] [60] percent maximum.
 6. Abrasion: [4] <Insert number> percent maximum.
 7. Nominal Pellet Diameter: [0.125 inch (3.175 mm)] <Insert dimension>.
 8. Percent of Pellet Sizes: [80 to 85] <Insert number range> percent after screening.
- D. Media: High-grade carbon, manufactured from coconut shells, bituminous coal, or a combination of both.
 1. Ash Content: [2 to 3] <Insert number range> percent.
 2. Percent Carbon Tetrachloride Activity: [35 to 70] <Insert number range> percent when tested according to ASTM D 3467.
 3. Bulk Density: [32 lb/cu. ft. (510 kg/cu. m)] <Insert value>.
 4. Mesh Size: [4 by 6 inches (100 by 150 mm)], 90 percent minimum.

5. Hardness Factor: **[95]** <Insert value> when tested according to ASTM D 3802.
- E. Frame: **[Galvanized steel]** **[Hot-dip galvanized steel]** **[Aluminum]** **[Stainless steel]**, hinged, and with pull and retaining handles fastened to the media.
- F. Capacities and Characteristics:
 1. Face Size: <Insert inches (mm)>.
 2. Thickness or Depth: <Insert inches (mm)>.
 3. Surface Area: <Insert sq. ft. (sq. m)>.
 4. Holding Frame Size: <Insert inches (mm)>.
 5. Number of Filters: <Insert number>.
 6. System Airflow: <Insert cfm (L/s)>.
 7. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
 8. Efficiency: 90 percent on particles 20 micrometers and larger at **500 fpm (2.5 m/s)**.
 9. Initial Resistance: <Insert inches wg (Pa)>.
 10. Prefilter: Comply with requirements in Section 234100 "Particulate Air Filtration" for **[flat]** **[pleated]** **[ring]** panel. Size and airflow capacity shall match those of gas-phase filters.
 - a. Depth: **[1 inch (25 mm)]** **[2 inches (50 mm)]** **[4 inches (100 mm)]** <Insert dimension>.
 - b. Maximum or Rated Face Velocity: **[500 fpm (2.5 m/s)]** <Insert value>.
 - c. Initial Resistance: **[0.25-inch wg (62.3 Pa)]** **[0.35-inch (87.2 Pa)]** **[0.45-inch wg (112.1 Pa)]** **[0.60-inch wg (150 Pa)]** <Insert value> at **[350 fpm (1.8 m/s)]** **[500 fpm (2.5 m/s)]** <Insert value>.
 - d. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - e. Filter Unit Class: UL 900, **[Class 1]** **[Class 2]**.
 - f. Arrestance: **[85]** <Insert number> percent when tested according to ASHRAE 52.1.
 - g. MERV: **[8]** <Insert value> when tested according to ASHRAE 52.2.
 11. Final Filter: Comply with requirements in Section 234100 "Particulate Air Filtration" for **[supported bag]** **[unsupported bag]** **[rigid-cell box]** **[V-bank cell]** **[self-supported pocket]**. Size and airflow capacity shall match those of the gas-phase filters.
 - a. Depth: **[12 inches (300 mm)]** **[18 inches (450 mm)]** **[24 inches (600 mm)]** <Insert dimension>.
 - b. Maximum or Rated Face Velocity: **[500 fpm (2.5 m/s)]** <Insert value>.
 - c. Initial Resistance: **[1-inch wg (250 Pa)]** **[2-inch wg (500 Pa)]** <Insert value> at **500 fpm (2.5 m/s)**.
 - d. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - e. Filter Unit Class: UL 900, **[Class 1]** **[Class 2]**.
 - f. Arrestance: **[85]** <Insert number> percent when tested according to ASHRAE 52.1.
 - g. MERV: **[13]** <Insert value> when tested according to ASHRAE 52.2.

2.6 SUPPORTED ADSORBER BAG FILTERS

- A. Description: Factory-fabricated, dry, extended-surface, self-supporting filters with holding frames.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Camfil Farr Co.
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
- B. Media: Carbon-filled fibrous material constructed so individual pleats are maintained under rated-airflow conditions in tapered form by flexible internal supports.
- C. Filter-Media Frame: Galvanized steel.
- D. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with gaskets; capable of bolting together into built-up filter banks.
- E. Capacities and Characteristics:
1. Face Size: [24 by 24 inches (600 by 600 mm)] [24 by 12 inches (600 by 300 mm)] **<Insert dimensions>**nominal.
 2. Depth: [21 inches (530 mm)] **<Insert dimension>** nominal.
 3. System Airflow: **<Insert cfm (L/s)>**.
 4. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] **<Insert value>**.
 5. Initial Resistance: [0.56-inch wg (140 Pa)] **<Insert value>**.
 6. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
 7. Minimum Toluene Removal Efficiency: 90 percent.
 8. Filter Unit Class: UL 900, [Class 1] [Class 2].
 9. Arrestance: [85] **<Insert number>** percent when tested according to ASHRAE 52.1.
 10. MERV: [13] **<Insert value>** when tested according to ASHRAE 52.2.

2.7 FRONT-ACCESS FILTER FRAMES

- A. Framing System: [Galvanized-steel] [Aluminum] framing members with access for upstream (front) filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr Co.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Div.

- f. D-Mark.
 - g. Filtration Group.
 - h. Flanders/CSC Corp.; a wholly owned subsidiary of Flanders Corporation.
 - i. Flanders-Precisionaire.
 - j. International Air Filtration Corporation.
 - k. Koch Filter Corporation.
 - l. Purafil, Inc.
 - m. Research Products Corp.; Aprilaire Division.
 - n. **<Insert manufacturer's name.>**.
 - o. or approved equal.
- B. Prefilters: Incorporate a separate track[**with spring clips**], removable from front[**or back**].
- C. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.

2.8 SIDE-SERVICE HOUSINGS

- A. Description: Factory-assembled, side-service housings constructed of [**galvanized steel**] [**aluminum**] with flanges to connect to duct or casing system.
- 1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. AAF International.
 - b. Airguard.
 - c. Camfil Farr Co.
 - d. Columbus Industries, Inc.
 - e. CRS Industries, Inc.; CosaTron Div.
 - f. D-Mark.
 - g. Filtration Group.
 - h. Flanders/CSC Corp.; a wholly owned subsidiary of Flanders Corporation.
 - i. Flanders-Precisionaire.
 - j. International Air Filtration Corporation.
 - k. Koch Filter Corporation.
 - l. Purafil, Inc.
 - m. Research Products Corp.; Aprilaire Division.
 - n. **<Insert manufacturer's name.>**.
 - o. or approved equal.
- B. Prefilters: Integral tracks to accommodate **2-inch-** (50-mm-) thick, disposable[**or washable**] filters.
- C. Access Doors: [**Hinged with continuous**] [**Continuous**] gaskets on perimeter and with positive-locking devices. Arrange so filter cartridges can be loaded from either access door.

- D. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

2.9 FILTER GAGES

- A. Diaphragm type, with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Airguard.
 - b. Dwyer Instruments, Inc.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Diameter: [4-1/2 inches (115 mm)] [2 inches (50 mm)].
 3. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
 4. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1.0-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa.)
 5. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa.)
 6. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa.)
 7. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa.)
- B. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale, logarithmic-curve tube gage with integral leveling gage; graduated to read from 0- to 3.0-inch wg (0 to 750 Pa) and accurate within 3 percent of full-scale range.
- C. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install air cleaning devices in accordance with manufacturer's instructions.
- B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
- C. Install filters in position to prevent passage of unfiltered air with felt, rubber, or neoprene gaskets.
- D. Install filter gage for each filter bank.

- E. Do not operate fan system until particulate filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
- F. Do not install gas-phase filters until fan system is clean and there is no risk of construction debris loading the filter.
- G. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.
- H. Coordinate filter installations with duct and air-handling unit installations.

3.2 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installation, including connections.
- B. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations including connections, and to assist in testing.
- C. Tests and Inspections:
 - 1. Test for leakage of unfiltered air while system is operating.
- D. Air filter will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

3.3 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new particulate filter media.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 234200

SECTION 234300 - ELECTRONIC AIR CLEANERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Electronic air cleaners.
 - 2. Side-service housings.
 - 3. Front- and rear-access filter frames.
 - 4. Filter gages.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For each electronic air cleaner. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Show filter assembly, dimensions, materials, and methods of assembly of components.
 - 2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
 - 3. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of filter and housing to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Provide **[one (1)] <Insert number>** complete set(s) of prefilters for each filter bank.
 2. Provide detergent for **[one (1)] [two (2)] <Insert number>** refill(s).
 3. Provide **[one (1)] <Insert number>** container(s) of red oil for inclined manometer filter gage.

1.7 QUALITY ASSURANCE

- A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air filters and are based on the specific system indicated. Refer to Division 1.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. ASHRAE Compliance:
1. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality"; Section 5 - "Systems and Equipment"; and Section 7 - "Construction and Startup."
 2. Comply with ASHRAE 52.1 for arrestance and with ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.
- D. Comply with NFPA 90A and NFPA 90B.
- E. Comply with ARI 850.
- F. Comply with UL 867.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 ELECTRONIC AIR CLEANERS

- A. Description: Factory-fabricated electronic air cleaner operating by electrostatic precipitation principles.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Air Quality Engineering, Inc.
 - b. CRS Industries, Inc.; CosaTron Div.
 - c. Flanders-Precisionaire.
 - d. Trion, Inc.
 - e. **<Insert manufacturer's name>**.
 - f. or approved equal.
- B. Prefilter Media: **[Four] [Six]** alternate layers of **[galvanized-steel] [aluminum] [stainless-steel]**, flat and herringbone-crimp screen.
- C. Prefilter: Comply with requirements in Section 234100 "Particulate Air Filtration" for **[flat] [pleated] [ring]** panel. Size and airflow capacity shall match those of electronic air cleaners.
1. Depth: **[1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)] <Insert dimension>**.
 2. Filter Unit Class: UL 900, **[Class 1] [Class 2]**.
 3. Arrestance: **[85] <Insert number>** percent when tested according to ASHRAE 52.1.
 4. MERV: **[8] <Insert value>** when tested according to ASHRAE 52.2.
- D. Final Filter: Comply with requirements in Section 234100 "Particulate Air Filtration" for **[supported bag] [unsupported bag] [rigid-cell box] [V-bank cell] [self-supported pocket]**. Size and airflow capacity shall match those of gas-phase filters.
1. Depth: **[12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension>**.
 2. Filter Unit Class: UL 900, **[Class 1] [Class 2]**.
 3. Arrestance: **[85] <Insert number>** percent when tested according to ASHRAE 52.1.
 4. MERV: **[13] <Insert value>** when tested according to ASHRAE 52.2.
- E. Collection Cells: Aluminum, independently supported and nested.

1. Ionizing Section: Alternately spaced grounded struts and charged ionizing wires.
 2. Collecting Section: Alternately grounded and charged plates, with insulators located out of airstream.
- F. Power Pack: Self-contained, prewired rectifying unit to convert **[120] [208/240] [480]**-V ac, single-phase, 60-Hz power to approximately 12,000-V dc for ionizer and 6000-V dc for collector; include overload protection, on-off switch, pilot light showing operating status, and access door interlock.
- G. Safety Accessories: Manual-reset safety switches and warning lights for filter plenum access doors, signal lights and safety switching upstream and downstream from unit within duct, and enameled high-voltage warning signs.
- H. Collection Section Cleaning System:
1. Detergent Reservoir Tank: **[30 gal. (110 L)] [55 gal. (200 L)]** with pump, motor, solenoid valve, level sensor, backflow preventer, wye-strainer, and ball valve.
 2. Detergent.
 3. Dispensing System: Motor-driven oscillating copper manifolds with brass spray nozzles on each side of the collector.
- I. Mist Eliminators: **[Upstream][and downstream] [Downstream]**.
- J. Controls: Programmable logic controller in remotely mounted NEMA 250, Type 12 enclosure; with integral time clock and manual override.
1. Contacts for enable-disable control by building automation system.
- K. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- 2.2 FAN SECTION
- A. Fan: Forward curved, belt driven.
- B. Motor:
1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Type: **[Permanent-split capacitor with SCR for speed adjustment] [Electronically commutated motor]**.
 3. Fan-Motor Assembly Isolation: Rubber isolators.
 4. Enclosure: Totally enclosed, fan cooled, and **[explosion proof] [dust-ignition proof]**.
 5. Enclosure Materials: **[Cast iron] [Cast aluminum] [Rolled steel]**.
 6. Motor Bearings: Sealed ball, **<Insert special requirements>**.
 7. Unusual Service Conditions:
 - a. Ambient Temperature: **<Insert deg F (deg C)>**.

- b. Altitude: <Insert feet (m)> above sea level.
 - c. High humidity.
 - d. <Insert conditions>.
8. Efficiency: Premium efficient.
9. NEMA Design: <Insert designation>.
10. Service Factor: <Insert value>.
11. Motor Speed: [**Single speed**] [**Multispeed**].
- a. Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.

2.3 CABINET

- A. Description: 16-gage galvanized steel with epoxy powder finish for suspended, wall, frame, or duct mounting.

2.4 SIDE-SERVICE HOUSINGS

- A. Description: Factory-assembled, side-service housings, [**with bottom drain**,]constructed of [**galvanized steel**] [**aluminum**] and configured for stacking, with flanges to connect to duct or casing system.
- B. Access Doors: [**Hinged with continuous**] [**Continuous**] gaskets on perimeter and positive-locking devices.
- C. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.
- D. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.5 FRONT- AND REAR-ACCESS FILTER FRAMES

- A. Framing System: [**Galvanized-steel**] [**Aluminum**] framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and prepunched for assembly into modules[**with bottom drain**], and configured for stacking. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.
- B. Prefilters: Incorporate a separate track[**with spring clips**], removable from front[**or back**].
- C. Final Filters: Integral tracks to accommodate [**particulate**] [**gas-phase**] disposable filters.
- D. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.

- E. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.6 FILTER GAGES

- A. Diaphragm type, with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.
1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. Airguard.
 - b. Dwyer Instruments, Inc.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
 2. Diameter: [4-1/2 inches (115 mm)] [2 inches (50 mm)].
 3. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
 4. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).
 5. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).
 6. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).
 7. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).
- B. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale, logarithmic-curve tube gage, with integral leveling indicator, graduated to read from 0- to 3.0-inch wg (0 to 750 Pa), and accurate within 3 percent of full-scale range.
- C. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

2.7 CAPACITIES AND CHARACTERISTICS

- A. Unit Face Dimensions: [72 by 72 inches (1828 by 1828 mm)] **<Insert dimensions>** nominal.
- B. Number of Cleaner Units: **<Insert number>**.
- C. Unit Depth: [33 inches (825 mm)] [45 inches (1125 mm)] **<Insert dimension>** nominal.
- D. Holding Frame Size: **<Insert inches (mm)>**.
- E. Frame Access Location: [**Front**] [**back**] [**or**] [**side**].
- F. System Airflow: **<Insert cfm (L/s)>**.

- G. Maximum or Rated Face Velocity: [500 fpm (2.5 m/s)] <Insert value>.
- H. Power Pack:
1. Volts: [120] [208] [230] [460] <Insert value> V.
 2. Phase: [Single] [Three].
 3. Hertz: 60.
 4. Full-Load Amperes: <Insert value>.
 5. Minimum Circuit Ampacity: <Insert value>.
 6. Maximum Overcurrent Protection Device: <Insert amperage>.
- I. Efficiency: 90 percent on particles 20 micrometers and larger at 500 fpm (2.5 m/s).
- J. Efficiency: [85] [90] [95] percent as tested according to ASHRAE 52.1.
- K. Initial Resistance: [0.25-inch wg (63 Pa)] <Insert value>.
- L. Prefilter Type: Integral tracks to accommodate 2-inch- (50-mm-) thick disposable[or washable] filters.
- M. Final Filter Type: Integral tracks to accommodate [particulate] [gas-phase] disposable filters.
- N. Fan Motor Electrical Characteristics:
1. Horsepower: <Insert value>.
 2. Volts: [120] [208] [230] [460] <Insert value> V.
 3. Phase: [Single] [3].
 4. Hertz: 60.
 5. Full-Load Amperes: <Insert value>.
 6. Minimum Circuit Ampacity: <Insert value>.
 7. Maximum Overcurrent Protection Device: <Insert amperage>.
- O. Cleaning System: [Manual] [or] [automatic].
- P. Reservoir Tank: [30 gal. (114 L)] [50 gal. (190 L)].
- Q. Connections:
1. Water Supply: <Insert NPS (DN)>.
 2. Drain: <Insert NPS (DN)>.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install air cleaning devices in accordance with manufacturer's instructions.

- B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
- C. Install filters in position to prevent passage of unfiltered air with felt, rubber, or neoprene gaskets.
- D. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
- E. Operate electronic air cleaners for 24 hours as part of startup before filters are put into operation.
- F. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.
- G. Install and connect water-supply and drainage piping.
- H. Coordinate filter installations with duct and air-handling-unit installations.

3.2 FIELD QUALITY CONTROL

- A. **Manufacturer's Field Service:** Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installation, including connections.
- B. Perform tests and inspections.
 - 1. **Manufacturer's Field Service:** Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. **Tests and Inspections:** Test for leakage of unfiltered air while system is operating.
- D. Air filter will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

3.3 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new prefilter and final-filter media.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 234300

SECTION 235113.11 - DRAFT CONTROL FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Draft inducer fans.
2. Venturi-draft inducer fans.
3. Mechanical-draft vent fans.
4. Vent exhaust fans.
5. Combustion-air fans.

- B. Related Requirements:

1. Section 235113.16 "Vent Dampers" for barometric dampers and vent dampers.
2. Section 235116 "Fabricated Breechings and Accessories" for listed, refractory-lined metal breechings and field-fabricated metal breechings.
3. Section 235123 "Gas Vents" for Type B and BW vents, Type L vents, and listed special gas vents.
4. Section 235133 "Insulated Sectional Chimneys" for listed chimney liners; listed building-heating-appliance chimneys; listed, refractory-lined metal chimneys; and field-fabricated chimneys.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Breeching: Vent Connector.
- B. Chimney: Primarily vertical shaft enclosing at least one vent for conducting flue gases outdoors.
- C. Smoke Pipe: Round, single wall vent connector.
- D. Vent: That portion of a venting system designed to convey flue gases directly outdoors from a vent connector or from an appliance when a vent connector is not used.

- E. Vent Connector: That part of a venting system that conducts the flue gases from the flue collar of an appliance to a chimney or vent, and may include a draft control device.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each type of product.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Detail fabrication and assembly of hangers and seismic restraints.
 - 4. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For draft control fans to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this Section with minimum of three (3) years experience.
- B. Conform to **[applicable code] [NFPA 54 (ANSI Z223.1)]** code for installation of **[natural gas] [propane]** burning equipment.
- C. Conform to **[applicable code] [NFPA 31 (ANSI Z95.1)]** for installation of oil burning equipment.
- D. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. **[or other testing agency acceptable to the authority having jurisdiction]** as suitable for the purpose specified and indicated.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of **[draft inducer fans] [venturi-draft inducer fans] [mechanical-draft vent fans] [vent exhaust fans] [combustion-air fans]** that fail in materials or workmanship within specified warranty period.
1. Failure includes failure of the fan due to corrosion.
 2. Warranty Period: Minimum **[Two (2)] [Ten (10)] <Insert number>** years from date of Substantial Completion.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 DRAFT INDUCER FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Effikal International Inc.](#)
 2. [ENERVEX Inc.](#)
 3. [Field Controls L.L.C.](#)
 4. [Quickdraft.](#)
 5. [Tec-Air Inc.](#)
 6. [Tjernlund Products, Inc.](#)
 7. [Wing Draft Inducers.](#)
 8. **<Insert manufacturer's name>**.
 9. or approved equal.
- B. Fan Construction: **[Galvanized] [Aluminized]**-steel housing and radial-blade centrifugal fan.
1. Fan Motor: Permanent-split-capacitor type.
- C. Controls:
1. Draft-proving switch.
 2. Control kit to cycle fan with gas flow to a single burner.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 VENTURI-DRAFT INDUCER FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Quickdraft](#).
 2. **<Insert manufacturer's name>**.
 3. or approved equal.
- B. Fan Construction: Enameled-steel venturi tube for vents **20 inches** (508 mm) in diameter and smaller and ASTM A 666, Type 304, stainless-steel venturi tube for vents **22 to 48 inches** (559 to 1219 mm) in diameter. [**Galvanized**] [**Enameled**]-steel fan housing with radial-blade centrifugal wheel.
1. Fan Motor: Permanent-split-capacitor type.
- C. Controls:
1. Draft-proving switch.
 2. Control kit to cycle fan with gas flow to a single burner.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 MECHANICAL-DRAFT VENT FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Bradford White Corporation](#).
 2. [Effikal International Inc.](#)
 3. [ENERVEX Inc.](#)
 4. [Field Controls L.L.C.](#)
 5. [Quickdraft](#).
 6. [Tec-Air Inc.](#)
 7. [Tjernlund Products, Inc.](#)
 8. [Wing Draft Inducers](#).
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Fan Construction: Forward-curved centrifugal fan and scroll fabricated of [**aluminized**] [**galvanized**] steel; direct-drive, ball-bearing motor lubricated with synthetic oil; internal cooling fan; stainless-steel shaft; and integral pressure-sensing switch.
1. Fan Motor: Permanent-split-capacitor type.
- C. Controls:
1. Draft-proving switch.

2. Control kit to cycle fan with gas flow to **[single]** **[multiple]** burner(s).

D. Accessories:

1. **[Aluminized]** **[Stainless]**-steel, wall-vent hood.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.4 VENT EXHAUST FANS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [ENERVEX Inc.](#)
2. [Field Controls L.L.C.](#)
3. [Tjernlund Products, Inc.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

B. General: Centrifugal fan with **[variable]** **[constant]**-speed control mounted at end of **[sidewall]** **[vertical]** vent.

C. Test Standard: UL 378.

D. Fan Construction:

1. **[Cast-aluminum]** **[Galvanized-steel]** **[Stainless-steel]** housing **[painted manufacturer's standard color of baked enamel]**.
2. **[Galvanized]** **[Stainless]**-steel vent.
3. **[Cast-aluminum]** **[Stainless-steel]** wheel.
4. Backward-inclined centrifugal or axial fan wheel statically and dynamically balanced.
5. Access panel at the discharge area.
6. Concentric makeup air-inlet duct surrounding the vent to allow zero clearance to combustibles.

E. Motor: Fully enclosed, **[variable-speed duty,]** permanent-split capacitor, out of the airstream, with prelubricated and sealed ball bearings.

F. Constant-Speed Controls: Boiler interlock relay starts fan when burner control cycles on. Pressure switch permits burner operation via interlock with boiler. Fan-proving switch is adjustable between **minus 0.07- and minus 0.15-inch wg** (minus 17 and minus 37 Pa).

G. Variable-Speed Controls: Boiler interlock relay starts fan when burner control cycles on. Pressure controller, control transformer, and miscellaneous controls for automatic modulation of fan speed to maintain preset negative pressure between **zero- and minus 1.0-inch wg** (zero and minus 249 Pa). Include controller with indicator lights,

pressure-differential transmitter, chimney pressure-sensor probe, and fan-proving switch adjustable between **minus 0.07- and minus 0.15-inch wg** (minus 17 and minus 37 Pa). Include tubing.

- H. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.5 COMBUSTION-AIR FANS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [ENERVEX Inc.](#)
2. [Field Controls L.L.C.](#)
3. [Tjernlund Products, Inc.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

- B. Fan Construction: **[Galvanized]** **[Aluminized]**-steel housing; steel forward-curved fan and scroll; direct-drive, totally enclosed, fan-cooled motor with ball bearings; stainless-steel shaft; and integral pressure-sensing switch.

1. Internal bypass to temper supply-air temperature to room.

- C. Controls:

1. Fan-proving switch to permit burner operation when combustion-air fan is operating.
2. Multiple-appliance control starts fan with operation of any one of **[three]** **[four]** appliances.
3. Modulating combustion-air fan speed to control pressure differential in room with respect to outdoors.
4. Manual-reset, high-limit switch stops operation with **160 deg F** (71 deg C) room temperature.
5. Optional Controls:
 - a. Alarm circuit.
 - b. Excessive negative pressure limit.
 - c. Interface relay for vent exhaust fan, draft inducer fan, or mechanical-draft vent fan.
 - d. **[Galvanized-steel]** **[Aluminum]** intake hood.

- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.6 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.7 CAPACITIES AND CHARACTERISTICS

- A. Fan:
 - 1. Manufacturer: **<Insert manufacturer>**.
 - 2. Model No.: **<Insert number>**.
 - 3. Rated Appliance Input: **<Insert Btu/h (kW)>**.
 - 4. Airflow: **<Insert cfm (L/s)>**.
 - 5. Speed: **<Insert value>** rpm.
 - 6. Static Pressure: **<Insert inches wg (Pa)>**.
 - 7. Electrical Characteristics:
 - a. Motor Horsepower: **<Insert value>**.
 - b. Volts: **[115] [208] [230] [460] <Insert value>**.
 - c. Phase: **[Single] [Three]**.
 - d. Hertz: 60.
 - e. Full-Load Amperes: **<Insert value>**.
 - f. Minimum Circuit Ampacity: **<Insert value>**.
 - g. Maximum Overcurrent Protection: **<Insert amperage>**.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install listed components in a manner complying with the listing.
- C. Install draft inducer fans in single-wall vent section that is designed to couple with other vent materials.
- D. Secure draft inducer fans to appliances, breechings, or stacks with hardware compatible with connected materials.
- E. Install draft inducer fans with clearances for service and maintenance.
- F. Install **[PVC]** intake duct that is sized according to manufacturer's written instructions.

3.2 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235113.11

SECTION 235113.16 - VENT DAMPERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Barometric dampers.
- 2. Vent dampers.

- B. Related Requirements:

- 1. Section 235113.11 "Draft Control Fans" for draft inducer fans, venturi-draft inducer fans, mechanical-draft vent fans, vent exhaust fans, and combustion-air fans.
- 2. Section 235116 "Fabricated Breechings and Accessories" for listed, refractory-lined metal breechings and field-fabricated metal breechings.
- 3. Section 235123 "Gas Vents" for Type B and BW vents, Type L vents, and listed special gas vents.
- 4. Section 235133 "Insulated Sectional Chimneys" for listed chimney liners; listed building-heating-appliance chimneys; listed, refractory-lined metal chimneys; and field-fabricated chimneys.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Breeching: Vent Connector.
- B. Chimney: Primarily vertical shaft enclosing at least one vent for conducting flue gases outdoors.
- C. Smoke Pipe: Round, single wall vent connector.
- D. Vent: That portion of a venting system designed to convey flue gases directly outdoors from a vent connector or from an appliance when a vent connector is not used.
- E. Vent Connector: That part of a venting system that conducts the flue gases from the

flue collar of an appliance to a chimney or vent, and may include a draft control device.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each type of product.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Detail fabrication and assembly of hangers and seismic restraints.
 - 4. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For draft control devices to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this Section with minimum of three (3) years experience.
- B. Conform to **[applicable code] [NFPA 54 (ANSI Z223.1)]** code for installation of **[natural gas] [propane]** burning equipment.
- C. Conform to **[applicable code] [NFPA 31 (ANSI Z95.1)]** for installation of oil burning equipment.
- D. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. **[or other testing agency acceptable to the authority having jurisdiction]** as suitable for the purpose specified and indicated.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of **[barometric dampers] [vent dampers]** that fail in materials or workmanship within specified warranty period.
1. Failure includes failure due to corrosion.
 2. Warranty Period: Minimum **[Two (2)] [Ten (10)] <Insert number>** years from date of Substantial Completion.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 BAROMETRIC DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Effikal International Inc.](#)
 2. [ENERVEX Inc.](#)
 3. [FAMCO.](#)
 4. [Field Controls L.L.C.](#)
 5. [Quickdraft.](#)
 6. [Snappy Air Distribution Products.](#)
 7. [Tec-Air Inc.](#)
 8. [Tjernlund Products, Inc.](#)
 9. **<Insert manufacturer's name>.**
 10. or approved equal.
- B. Damper Construction: High-temperature-enamel-painted steel damper and housing with galvanized-steel breeching connection. Adjustable counterweight with lock. Include knife-edge bearings that do not require lubrication.

2.2 VENT DAMPERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Effikal International Inc.](#)
 2. [Field Controls L.L.C.](#)
 3. [Johnson Controls, Inc.](#)
 4. **<Insert manufacturer's name>.**

5. or approved equal.

B. Damper Construction: Stainless-steel damper blade, shaft, and vent pipe with metal, prelubricated bearings.

1. Electric motor sized to power damper open and closed in approximately 15 seconds in each direction. Power is off when damper is at rest.
2. Comply with ANSI Z21.66.

C. Controls:

1. Control transformer.
2. Keyed wiring harness.
3. Damper end switch to prove damper is open.
4. Interlock with boiler to permit burner operation when damper is open.
5. Hold-open switch for troubleshooting boiler controls.

2.3 MOTORS

A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.4 CAPACITIES AND CHARACTERISTICS

A. Damper:

1. Manufacturer: **<Insert manufacturer>**.
2. Model No.: **<Insert number>**.
3. Rated Appliance Input: **<Insert Btu/h (kW)>**.
4. Vent Size: **<Insert inches (mm)>**.
5. Electrical Characteristics:
 - a. Motor Horsepower: **<Insert value>**.
 - b. Volts: **[115] <Insert value>**.
 - c. Phase: Single.
 - d. Hertz: 60.
 - e. Full-Load Amperes: **<Insert value>**.
 - f. Minimum Circuit Ampacity: **<Insert value>**.
 - g. Maximum Overcurrent Protection: **<Insert amperage>**.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install in accordance with manufacturer's instructions.

- B. Install listed components in a manner complying with the listing.
- C. Secure barometric dampers to breechings with hardware compatible with connected materials.
- D. Locate barometric and motorized vent dampers as close to draft hood collar as possible.
- E. Secure barometric and motorized vent dampers to appliances, breechings, or chimneys with hardware compatible with connected materials.

3.2 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235113.16

SECTION 235116 - FABRICATED BREECHINGS AND ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Listed, refractory-lined breechings.
- 2. Field-fabricated metal breechings.
- 3. Guying and bracing materials.

- B. Related Requirements:

- 1. Section 235113.11 "Draft Control Fans" for draft inducer fans, venturi-draft inducer fans, mechanical-draft vent fans, vent exhaust fans, and combustion-air fans.
- 2. Section 235113.16 "Vent Dampers" for motorized and barometric dampers.
- 3. Section 235123 "Gas Vents" for Type B and BW vents, Type L vents, and listed special gas vents.
- 4. Section 235133 "Insulated Sectional Chimneys" for listed chimney liners; listed building-heating-appliance chimneys; listed, refractory-lined metal chimneys; and field-fabricated chimneys.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Breeching: Vent Connector.
- B. Chimney: Primarily vertical shaft enclosing at least one vent for conducting flue gases outdoors.
- C. Smoke Pipe: Round, single wall vent connector.
- D. Vent: That portion of a venting system designed to convey flue gases directly outdoors from a vent connector or from an appliance when a vent connector is not used.
- E. Vent Connector: That part of a venting system that conducts the flue gases from the

flue collar of an appliance to a chimney or vent, and may include a draft control device.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for product.
2. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For breechings.

1. Include plans, elevations, sections, and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Detail fabrication and assembly of hangers and seismic restraints.
4. Submit calculations, which verify the adequacy of the proposed breeching and stack system to handle the connected flue gas load.

1.5 INFORMATIONAL SUBMITTALS

A. Welding certificates.

B. Seismic Qualification Certificates: For factory-fabricated breeching, accessories, and components from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity, and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

C. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.

2. AWS D9.1/D9.1M, "Sheet Metal Welding Code," for shop and field welding of joints and seams in breechings.
- B. Certified Sizing Calculations: Manufacturer shall certify venting system sizing calculations.
- C. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this Section with minimum of three (3) years experience.
- D. Conform to [applicable code] [NFPA 54 (ANSI Z223.1)] code for installation of [natural gas] [propane] burning equipment.
- E. Conform to [applicable code] [NFPA 31 (ANSI Z95.1)] for installation of oil burning equipment.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. [or other testing agency acceptable to the authority having jurisdiction] as suitable for the purpose specified and indicated.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of venting system that fail in materials or workmanship within specified warranty period.
 1. Failures include, but are not limited to, structural failures caused by expansion and contraction.
 2. Warranty Period: Minimum [ten (10)] [fifteen (15)] [twenty-five (25)] <Insert number> years from date of Substantial Completion.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 BREECHINGS - GENERAL

- A. Provide adjustable self-actuating barometric draft dampers, where indicated, full size of breeching.
- B. Weld longitudinal seams. Fabricate joints by welding, lapping, and bolting, or with companion flanges. For breechings less than 24 inches diameter provide groove seam (pipe lock or flat lock) with end joints beaded and crimped.
- C. Reinforce rectangular breeching with angle frames and round breeching with flanged

girth joints or angle frames. Refer to SMACNA HVAC Duct Construction Standards - Metal and Flexible:

1. Sizes up to 30 inches: No reinforcing required.
2. Sizes 31 to 36 inches: 1-1/2 x 1-1/2 x 3/16 inches, at 60 inch centers.
3. Sizes 37 to 60 inches: 2 x 2 x 1/4 inch, at 60 inch centers.
4. Sizes over 60 inches: 3 x 3 x 1/2 inch, at 60 inch centers.

- D. Fabricate breeching fittings to match adjoining breechings. Fabricate elbows with centerline radius equal to breeching [**width.**] [**diameter.**] Limit angular tapers to 20 degrees maximum.

2.2 LISTED, REFRACTORY-LINED METAL BREECHINGS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Van-Packer Company, Inc.](#)
2. [Warren Environment, Inc.](#)
3. **<Insert manufacturer's name>.**
4. or approved equal.

- B. Comply with ASME STS-1.

- C. Design Wind Loads: [150 mph (241 km/h)] **<Insert wind speed>.**

- D. Design for seismic conditions at Project site.

- E. Refractory Lining: Tested according to UL 959 for temperature and acid resistance and bearing the testing laboratory label.

1. Temperature Rating: 1800 deg F (982 deg C) continuously and 2000 deg F (1093 deg C) intermittently.
2. Acid Extraction: Maximum of 0.2 percent.
3. Cold Crushing Strength: Minimum of 3200 psig (22 MPa).
4. Thickness: Minimum of 2 inches (50 mm).

- F. Finish: Factory-applied, high-heat-resistant paint; color as selected by DEN Project Manager.

2.3 FIELD-FABRICATED METAL BREECHINGS

- A. Fabricate breechings from ASTM A 1011/A 1011M hot-rolled steel with continuously welded joints, complying with NFPA 211 for minimum metal thickness.

1. Equal to or Less Than 1.069 Sq. Ft. (0.099 Sq. m.) or 14 Inches (356 mm) in Diameter: 0.053 inch (1.35 mm).
2. Up to 1.396 Sq. Ft. (0.129 Sq. m) or 16 Inches (406 mm) in Diameter: 0.067 inch (1.7 mm).

3. Up to 1.764 Sq. Ft. (0.164 Sq. m.) or 18 Inches (457 mm) in Diameter: 0.093 inch (2.36 mm).
4. Larger Than 1.764 Sq. Ft. (0.164 Sq. m.) or 18 Inches (457 mm) in Diameter: 0.123 inch (3.12 mm).

B. Fabricate cleanout doors from compatible material, same thickness as breeching, bolted and gasketed.

C. Fabricate engine exhaust from ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106/A 106M, Type S, Grade B, **[Schedule 40]** **[Schedule 80]** pipe; with welded joints and carbon-steel fittings and flanges.

1. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
2. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150, including bolts, nuts, and gaskets.

2.4 GUYING AND BRACING MATERIALS

A. Cable: **[Three]** **[Four]** <Insert number> galvanized, stranded wires of the following thickness:

1. Minimum Size: 1/4 inch (6 mm) in diameter.
2. For ID Sizes 4 to 15 Inches (100 to 381 mm): 5/16 inch (8 mm).
3. For ID Sizes 18 to 24 Inches (457 to 610 mm): 3/8 inch (9.5 mm).
4. For ID Sizes 27 to 30 Inches (685 to 762 mm): 7/16 inch (11 mm).
5. For ID Sizes 33 to 36 Inches (838 to 915 mm): 1/2 inch (13 mm).
6. For ID Sizes 39 to 48 Inches (990 to 1220 mm): 9/16 inch (14.3 mm).
7. For ID Sizes 51 to 60 Inches (1295 to 1524 mm): 5/8 inch (16 mm).

B. Pipe: **[Two]** **[Three]** <Insert number> galvanized steel, NPS 1-1/4 (DN 32).

C. Angle Iron: **[Two]** **[Three]** <Insert number> galvanized steel, 2 by 2 by 0.25 inch (50 by 50 by 6 mm).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of Work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATION

- A. Listed, Refractory-Lined Metal Breechings: Freestanding dual-fuel boiler vents, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.
- B. Field-Fabricated Metal Breechings: Dual-fuel boilers, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.

3.3 INSTALLATION OF UNLISTED, FIELD-FABRICATED BREECHINGS

- A. Suspend breechings independent of their appliance connections.
- B. Install seismic restrains according to manufacturer's written instructions. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC."
- C. Align breechings at connections, with smooth internal surface and a maximum 1/8-inch (3-mm) misalignment tolerance.
- D. Install breechings with minimum of joints. Align accurately at connections, with internal surfaces smooth.
- E. Slope breechings down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain.
- F. Lap joints in direction of flow.
- G. Support breechings from building structure with bolts, concrete inserts, steel expansion anchors, welded studs, C clamps, or beam clamps according to manufacturer's written instructions.
- H. Insulate breechings in accordance with Section 230716 "HVAC Equipment Insulation".
- I. At appliances, provide slip joints permitting removal of appliances without removal or dismantling of breechings, breeching insulation, chimneys, or stacks.
- J. Provide [minimum length] [maximum 2 feet] of breeching to connect appliance to chimney. **[Provide Type B chimney continuously from appliances.]**

3.4 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.
- B. Clean breechings internally, during and after installation, to remove dust and debris. Clean external surfaces to remove welding slag and mill film. Grind welds smooth and apply touchup finish to match factory or shop finish.

- C. Provide temporary closures at ends of breechings that are not completed or connected to equipment.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235116

SECTION 235123 - GAS VENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Listed double-wall vents.

- B. Related Requirements:

- 1. Section 235113.11 "Draft Control Fans" for draft inducer fans, venturi-draft inducer fans, mechanical-draft vent fans, vent exhaust fans, and combustion-air fans.
- 2. Section 235113.16 "Vent Dampers" for motorized and barometric dampers.
- 3. Section 235116 "Fabricated Breechings and Accessories" for listed, refractory-lined metal breechings and field-fabricated metal breechings.
- 4. Section 235133 "Insulated Sectional Chimneys" for listed chimney liners; listed building-heating-appliance chimneys; listed, refractory-lined metal chimneys; and field-fabricated chimneys.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Breeching: Vent Connector.
- B. Chimney: Primarily vertical shaft enclosing at least one vent for conducting flue gases outdoors.
- C. Smoke Pipe: Round, single wall vent connector.
- D. Vent: That portion of a venting system designed to convey flue gases directly outdoors from a vent connector or from an appliance when a vent connector is not used.
- E. Vent Connector: That part of a venting system that conducts the flue gases from the flue collar of an appliance to a chimney or vent, and may include a draft control device.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for product.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For vents.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Detail fabrication and assembly of hangers and seismic restraints.

1.5 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to the following:
 - 1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
 - 2. AWS D9.1/D9.1M, "Sheet Metal Welding Code," for shop and field welding of joints and seams in vents.
- B. Certified Sizing Calculations: Manufacturer shall certify venting system sizing calculations.
- C. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this Section with minimum of three (3) years experience.
- D. Conform to **[applicable code]** **[NFPA 54 (ANSI Z223.1)]** code for installation of **[natural gas]** **[propane]** burning equipment.
- E. Conform to **[applicable code]** **[NFPA 31 (ANSI Z95.1)]** for installation of oil burning equipment.

- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 LISTED TYPE B AND BW VENTS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [American Metal Products.](#)
 2. [Cleaver-Brooks.](#)
 3. [FAMCO.](#)
 4. [Hart & Cooley Inc.](#)
 5. [Heat-Fab, Inc.](#)
 6. [Industrial Chimney Company.](#)
 7. [LSP Products Group, Inc.](#)
 8. [M&G DuraVent, Inc.: a member of the M&G Group](#); Duravent GV Type B Gas Vent.
 9. [Metal-Fab, Inc.](#)
 10. [Schebler Co. \(The\).](#)
 11. [Security Chimneys International.](#)
 12. [Selkirk Corporation](#); Selkirk Metalbestos and Air Mate.
 13. [Tru-Flex Metal Hose Corp.](#)
 14. [Van-Packer Company, Inc.](#)
 15. **<Insert manufacturer's name>.**
 16. or approved equal.
- B. Description: Double-wall metal vents tested according to UL 441 and rated for **480 deg F** (248 deg C) continuously for Type B or **550 deg F** (288 deg C) continuously for Type BW; with neutral or negative flue pressure complying with NFPA 211.
- C. Construction: Inner shell and outer jacket separated by at least a **1/4-inch** (6-mm) airspace.
- D. Inner Shell: [**ASTM B 209** (ASTM B 209M), **Type 1100 aluminum**] [**ASTM B 209** (ASTM B 209M), **Type 3003 aluminum**] [**ASTM B 209** (ASTM B 209M), **Type 3105 aluminum**] [**ASTM A 666, Type 430 stainless steel**].
- E. Outer Jacket: [**Galvanized**] [**Aluminized**] steel.

- F. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
1. Termination: Stack cap designed to exclude minimum 90 percent of rainfall.
 2. Termination: Round chimney top designed to exclude minimum 98 percent of rainfall.
 3. Termination: Exit cone with drain section incorporated into riser.
 4. Termination: Antibackdraft.
 5. Termination: **<Insert termination>**.

2.2 LISTED TYPE L VENTS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [American Metal Products](#).
 2. [FAMCO](#).
 3. [Heat-Fab, Inc.](#)
 4. [Industrial Chimney Company](#).
 5. [LSP Products Group, Inc.](#)
 6. [M&G DuraVent, Inc.; a member of the M&G Group](#); Pellet Vent Pro.
 7. [Metal-Fab, Inc.](#)
 8. [Schebler Co. \(The\)](#).
 9. [Security Chimneys International](#).
 10. [Selkirk Corporation](#); Selkirk Metalbestos and Air Mate.
 11. [Simpson Dura-Vent Co., Inc.; Subsidiary of Simpson Manufacturing Co.](#)
 12. [Tru-Flex Metal Hose Corp.](#)
 13. [Van-Packer Company, Inc.](#)
 14. **<Insert manufacturer's name>**.
 15. or approved equal.
- B. Description: Double-wall metal vents tested according to UL 641 and rated for **570 deg F** (300 deg C) continuously or **1700 deg F** (926 deg C) for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
- C. Construction: Inner shell and outer jacket separated by at least a [**1/4-inch** (6-mm)] [**1-inch** (25-mm)] [**2-inch** (50-mm)] [**4-inch** (100-mm)] airspace filled with high-temperature, [**ceramic-fiber**] [**mineral-wool**] insulation.
- D. Inner Shell: ASTM A 666, [**Type 304**] [**Type 316**] stainless steel.
- E. Outer Jacket: [**Galvanized**] [**Aluminized**] [**Stainless**] steel.
- F. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.

1. Termination: Stack cap designed to exclude 90 percent of rainfall.
2. Termination: Round chimney top designed to exclude 98 percent of rainfall.
3. Termination: Exit cone with drain section incorporated into riser.
4. Termination: **<Insert termination>**.

2.3 LISTED SPECIAL GAS VENTS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Heat-Fab, Inc.](#)
 2. [Metal-Fab, Inc.](#)
 3. [Security Chimneys International.](#)
 4. [Selkirk Corporation](#); Selkirk Metalbestos and Air Mate.
 5. [Z-Flex; a division of the Novaflex Group; Flexmaster Canada Limited.](#)
 6. **<Insert manufacturer's name>**.
 7. or approved equal.
- B. Description: Double-wall metal vents tested according to UL 1738 and rated for **480 deg F** (248 deg C) continuously, with positive or negative flue pressure complying with NFPA 211.
- C. Construction: Inner shell and outer jacket separated by at least a **1/2-inch** (13-mm) airspace.
- D. Inner Shell: ASTM A 959, Type 29-4C stainless steel.
- E. Outer Jacket: **[Aluminized]** **[Stainless]** steel.
- F. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
1. Termination: Stack cap designed to exclude minimum 90 percent of rainfall.
 2. Termination: Round chimney top designed to exclude minimum 98 percent of rainfall.
 3. Termination: Exit cone with drain section incorporated into riser.
 4. Termination: **<Insert termination>**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATION

- A. Listed Type B and BW Vents: Vents for certified gas appliances.
- B. Listed Type L Vent: Vents for low-heat appliances.
- C. Listed Special Gas Vent: Condensing gas appliances.

3.3 INSTALLATION OF LISTED VENTS

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 077200 "Roof Accessories."
- C. Comply with minimum clearances from combustibles and minimum termination heights according to product listing or NFPA 211, whichever is most stringent.
- D. Seal between sections of positive-pressure vents according to manufacturer's written installation instructions, using sealants recommended by manufacturer.
- E. Support vents at intervals recommended by manufacturer to support weight of vents and all accessories, without exceeding appliance loading.
- F. Lap joints in direction of flow.
- G. For Type B double wall gas vents, maintain UL listed minimum clearances from combustibles. Assemble pipe and accessories as required for complete installation.
- H. Install vent dampers, locating close to draft hood collar, and secured to breeching.

3.4 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235123

SECTION 235133 - INSULATED SECTIONAL CHIMNEYS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Listed chimney liners.
2. Listed building-heating-appliance chimneys.
3. Listed, refractory-lined stacks.
4. Field-fabricated metal chimneys.
5. Guying and bracing materials.

- B. Related Requirements:

1. Section 235113.11 "Draft Control Fans" for draft inducer fans, venturi-draft inducer fans, mechanical-draft vent fans, vent exhaust fans, and combustion-air fans.
2. Section 235113.16 "Vent Dampers" for motorized and barometric dampers.
3. Section 235116 "Fabricated Breechings and Accessories" for listed, refractory-lined metal breechings and field-fabricated metal breechings.
4. Section 235123 "Gas Vents" for Type B and BW vents, Type L vents, and listed special gas vents.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Breeching: Vent Connector.
- B. Chimney: Primarily vertical shaft enclosing at least one vent for conducting flue gases outdoors.
- C. Smoke Pipe: Round, single wall vent connector.
- D. Vent: That portion of a venting system designed to convey flue gases directly outdoors from a vent connector or from an appliance when a vent connector is not used.

- E. Vent Connector: That part of a venting system that conducts the flue gases from the flue collar of an appliance to a chimney or vent, and may include a draft control device.
- F. Factory built vents and chimneys used for venting natural draft appliances shall comply with NFPA 211 and be UL listed and labeled.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, electrical characteristics and connection requirements, and finishes for product.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For chimneys and stacks.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Detail fabrication and assembly of hangers and seismic restraints.

1.5 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Seismic Qualification Certificates: For factory-fabricated chimneys and stacks, accessories, and components from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity, and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to the following:
 - 1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
 - 2. AWS D9.1/D9.1M, "Sheet Metal Welding Code," for shop and field welding of joints and seams in stacks.
- B. Certified Sizing Calculations: Manufacturer shall certify venting system sizing calculations.
- C. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this Section with minimum of three (3) years experience.
- D. Conform to [applicable code] [NFPA 54 (ANSI Z223.1)] code for installation of [natural gas] [propane] burning equipment.
- E. Conform to [applicable code] [NFPA 31 (ANSI Z95.1)] for installation of oil burning equipment.
- F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of venting system that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, structural failures caused by expansion and contraction.
 - 2. Warranty Period: Minimum [ten (10)] [fifteen (15)] [twenty-five (25)] <Insert number> years from date of Substantial Completion.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 LISTED CHIMNEY LINERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [American Metal Products.](#)
2. [Bernard Dalsin Manufacturing Company.](#)
3. [Deflect-O Corp.](#)
4. [Heat-Fab, Inc.](#)
5. [Industrial Chimney Company.](#)
6. [M&G DuraVent, Inc.; a member of the M&G Group.](#)
7. [Metal-Fab, Inc.](#)
8. [Selkirk Corporation.](#)
9. [Shook Manufactured Products, Inc.](#)
10. [Tru-Flex Metal Hose Corp.](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

- B. Description: [**Straight**] [**Corrugated**], single-wall chimney liner tested according to UL 1777 and rated for **1000 deg F** (538 deg C) continuously or **2100 deg F** (1150 deg C) for 10 minutes; with negative or positive flue pressure complying with NFPA 211.
- C. Straight Liner Materials: ASTM A 666, [**Type 304**] [**Type 316**] stainless steel.
- D. Corrugated Liner Materials: [**ASTM A 240/A 240M, Type 321**] [**ASTM A 240/A 240M, Type 430**] [**ASTM A 959, Type 29-4C**] stainless steel.
- E. Accessories:
1. Fittings: Tees, elbows, increasers, draft-hood connectors, metal caps with bird barriers, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar or compatible materials and designs.
 2. Sealant: Manufacturer's standard high-temperature sealant.
 3. Insulating Fill: Manufacturer's standard high-temperature insulation fill material in annular space surrounding chimney liner, including high-temperature, ceramic-fiber insulation required to seal chimney at top and bottom.

2.2 LISTED BUILDING-HEATING-APPLIANCE CHIMNEYS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [American Metal Products; MASCO Corporation.](#)
 2. [Cleaver-Brooks.](#)
 3. [FAMCO.](#)
 4. [Hart & Cooley Inc.](#)
 5. [Heat-Fab, Inc.](#)
 6. [Industrial Chimney Company.](#)
 7. [LSP Products Group, Inc.](#)
 8. [M&G DuraVent, Inc.; a member of the M&G Group;](#) Dura-Tech.
 9. [Metal-Fab, Inc.](#)
 10. [Schebler Co. \(The\).](#)
 11. [Security Chimneys International.](#)

12. [Selkirk Corporation](#); Selkirk Metalbestos and Air Mate.
 13. [Tru-Flex Metal Hose Corp.](#)
 14. <Insert manufacturer's name>.
 15. or approved equal.
- B. Description: Double-wall metal vents tested according to UL 103 and rated for **1000 deg F (538 deg C)** continuously or **1700 deg F (926 deg C)** for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
- C. Construction: Inner shell and outer jacket separated by at least a [**1/2-inch (25-mm)**] [**1-inch (50-mm)**] [**2-inch (50-mm)**] [**3-inch (75-mm)**] [**4-inch (100-mm)**] annular space[**filled with high-temperature, ceramic-fiber insulation**].
- D. Inner Shell: ASTM A 666, [**Type 304**] [**Type 316**] stainless steel.
- E. Description: Double-wall metal vents tested according to UL 103 and UL 959 and rated for **1400 deg F (760 deg C)** continuously or **1800 deg F (982 deg C)** for 10 minutes; with positive or negative flue pressure complying with NFPA 211.
- F. Construction: Inner shell and outer jacket separated by at least a [**1-inch (25-mm)**] [**2-inch (50-mm)**] [**3-inch (75-mm)**] [**4-inch (100-mm)**] annular space filled with high-temperature, ceramic-fiber insulation.
- G. Inner Shell: ASTM A 666, [**Type 304**] [**Type 316**] stainless steel.
- H. Description: Double-wall metal vents tested according to UL 103 and rated for **1000 deg F (538 deg C)** continuously or **2100 deg F (1150 deg C)** for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
- I. Construction: Inner shell and outer jacket separated by at least a [**1-inch (25-mm)**] [**1-1/2-inch (38-mm)**] [**2-inch (50-mm)**] [**4-inch (100-mm)**] annular space filled with high-temperature, ceramic-fiber insulation.
- J. Inner Shell: [**ASTM A 666, Type 304**] [**ASTM A 666, Type 316**] [**ASTM A 240/A 240M, Type 430**] stainless steel.
- K. Outer Jacket: [**Galvanized**] [**Aluminized**] [**Stainless**] steel.
- L. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
1. Termination: Stack cap designed to exclude minimum 90 percent of rainfall.
 2. Termination: Round chimney top designed to exclude minimum 98 percent of rainfall.
 3. Termination: Exit cone with drain section incorporated into riser.
 4. Termination: <Insert termination>.

2.3 LISTED, REFRACTORY-LINED METAL CHIMNEYS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Van-Packer Company, Inc.](#)
 2. [Warren Environment, Inc.](#)
 3. **<Insert manufacturer's name>**.
 4. or approved equal.
- B. Comply with ASME STS-1.
- C. Design Wind Loads: [150 mph (241 km/h)] **<Insert wind speed>**.
- D. Design for seismic conditions at Project site.
- E. Chimney Outer Jacket: [**Aluminized**] [**Galvanized**] steel with [**riveted**] [**welded**] seams.
- F. Refractory Lining: Tested according to UL 959 for temperature and acid resistance and bearing the testing laboratory label.
1. Temperature Rating: 1800 deg F (982 deg C) continuously and 2000 deg F (1093 deg C) intermittently.
 2. Acid Extraction: Maximum of 0.2 percent.
 3. Cold Crushing Strength: Minimum of 3200 psig (22 MPa).
 4. Thickness: Minimum of 2 inches (50 mm).
- G. Finish: Factory-applied, high-heat-resistant paint; color as selected by Architect.
- H. Base Section: Acid-resistant-coated, cast-iron anchor lugs for securing stack to foundation[**with anchorage designed by manufacturer**].
- I. Reinforced Cleanout Section: Smoke-tight connection, with gasketed and bolt-tightened inspection plate; neck shall be welded to stack section.
- J. T or Y Sections: Smoke-tight connection, with welded joints and refractory lining; finished with smooth transition and with no exposed metal on inside.
- K. Spark Screen: ASTM A 666, Type 316 stainless steel; 0.0625 inch (1.6 mm) thick; maximum 1/2-by-1/2-inch (13-by-13-mm) mesh; with ASTM A 666, Type 304 stainless-steel rolled angle and drawband.
- L. Guy Bands: 8-inch- (200-mm-) wide bands of same material as jacket, with bolted fasteners.
- M. Roof Penetration: Factory-fabricated thimbles, flashings, and counterflashings.
- N. Fabricate sections, fittings, and accessories as individual pieces or in combination lengths for field handling.

- O. Fabricate components with centrifugally cast refractory lining in lengths suitable for connection with drawbands.
- P. Bond refractory to steel jacket with calcium aluminate cement to prevent separation in finished product during shipping, handling, and installation.
- Q. Fabricate stacks with anchor lugs; cleanout; T sections; flashings and counterflashings; and provisions for support, expansion, and contraction.

2.4 FIELD-FABRICATED METAL CHIMNEYS

- A. Fabricate freestanding chimneys according to SMACNA's "Guide for Free Standing Steel Stack Construction." Design for minimum **<Insert feet (meters)>** high and **<Insert inches (mm)>** in diameter.
- B. Fabricate chimneys from ASTM A 1011/A 1011M hot-rolled steel with continuously welded joints, complying with NFPA 211 for minimum metal thickness.
 - 1. Equal to or Less Than **1.069 Sq. Ft.** (0.099 Sq. m.) or **14 Inches** (356 mm) in Diameter: **0.053 inch** (1.35 mm).
 - 2. Up to **1.396 Sq. Ft.** (0.129 Sq. m) or **16 Inches** (406 mm) in Diameter: **0.067 inch** (1.7 mm).
 - 3. Up to **1.764 Sq. Ft.** (0.164 Sq. m.) or **18 Inches** (457 mm) in Diameter: **0.093 inch** (2.36 mm).
 - 4. Larger Than: **0.123 inch** (3.12 mm).
- C. Fabricate chimneys and vent connectors from galvanized steel, complying with NFPA 211 for minimum metal thickness.
 - 1. Equal to or Less Than **6 Inches** (152 mm) in Diameter: **0.019 inch** (0.48 mm).
 - 2. Up to **10 Inches** (254 mm) in Diameter: **0.024 inch** (0.61 mm).
 - 3. Up to **16 Inches** (406 mm) in Diameter: **0.029 inch** (0.74 mm).
 - 4. Larger Than: **0.056 inch** (1.42 mm).
- D. Fabricate chimneys and vent connectors from ASTM B 209 (B 209M), Type 1100 or 3003, aluminum or stainless steel, complying with NFPA 211 for the following minimum metal thicknesses:
 - 1. Aluminum: **0.027 inch** (0.69 mm).
 - 2. Stainless Steel: **0.012 inch** (0.31 mm).
- E. Fabricate cleanout doors from compatible material, same thickness as breeching, bolted and gasketed.
- F. Fabricate engine exhaust from ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106/A 106M, Type S, Grade B, [**Schedule 40**] [**Schedule 80**] pipe; with welded joints and carbon-steel fittings and flanges.
 - 1. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.

2. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150, including bolts, nuts, and gaskets.

2.5 GUYING AND BRACING MATERIALS

- A. Cable: [Three] [Four] <Insert number> galvanized, stranded wires of the following thickness:
 1. Minimum Size: 1/4 inch (6 mm) in diameter.
 2. For ID Sizes 4 to 15 Inches (100 to 381 mm): 5/16 inch (8 mm).
 3. For ID Sizes 18 to 24 Inches (457 to 610 mm): 3/8 inch (9.5 mm).
 4. For ID Sizes 27 to 30 Inches (685 to 762 mm): 7/16 inch (11 mm).
 5. For ID Sizes 33 to 36 Inches (838 to 915 mm): 1/2 inch (13 mm).
 6. For ID Sizes 39 to 48 Inches (990 to 1220 mm): 9/16 inch (14.3 mm).
 7. For ID Sizes 51 to 60 Inches (1295 to 1524 mm): 5/8 inch (16 mm).
- B. Pipe: [Two] [Three] <Insert number> galvanized steel, NPS 1-1/4 (DN 32).
- C. Angle Iron: [Two] [Three] <Insert number> galvanized steel, 2 by 2 by 0.25 inch (50 by 50 by 6 mm).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of Work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATION

- A. Listed Chimney Liners: High-efficiency boiler or furnace vents in masonry chimney.
- B. Listed Building-Heating-Appliance Chimneys: Dual-fuel boilers, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.
- C. Listed, Refractory-Lined Metal Chimneys: Freestanding dual-fuel boiler vents, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.
- D. Field-Fabricated Metal Chimneys: Dual-fuel boilers, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.

3.3 INSTALLATION OF LISTED CHIMNEYS

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Comply with requirements in [**Section 033000 "Cast-in-Place Concrete"**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete"**] for concrete, reinforcement, and formwork.
- C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 077200 "Roof Accessories."
- D. Comply with minimum clearances from combustibles and minimum termination heights according to product listing or NFPA 211, whichever is most stringent.
- E. Support vertical chimneys and stacks at 12 foot spacing, to adjacent structural surfaces, or at floor penetrations. Refer to SMACNA HVAC Duct Construction Standards - Metal and Flexible for equivalent duct support configuration and size.
- F. Install concrete inserts for support of chimneys and stacks in coordination with formwork.
- G. Seal between sections of positive-pressure vents according to manufacturer's written installation instructions, using sealants recommended by manufacturer.
- H. Lap joints in direction of flow.
- I. Connect base section to foundation using anchor lugs of size and number recommended by manufacturer.
- J. Join sections with acid-resistant joint cement to provide continuous joint and smooth interior finish.
- K. Erect stacks plumb to finished tolerance of no more than **1 inch (25 mm)** out of plumb from top to bottom.

3.4 INSTALLATION OF UNLISTED, FIELD-FABRICATED CHIMNEYS

- A. Suspend chimneys independent of their appliance connections.
- B. Install seismic restrains according to manufacturer's written instructions. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC."
- C. Lap joints in direction of flow.
- D. Support chimneys from building structure with bolts, concrete inserts, steel expansion anchors, welded studs, C clamps, or beam clamps according to manufacturer's written instructions.

3.5 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.
- B. Provide temporary closures at ends of chimneys and stacks that are not completed or connected to equipment.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235133

SECTION 235213 - ELECTRIC BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes electric boilers, trim, and accessories for generating [**hot water**] [**and**] [**steam**].
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for boilers.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, wiring diagrams and connection requirements, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For boilers, boiler trim, and accessories.
 - 1. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
- C. Delegated-Design Submittal: For each boiler.
 - 1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.

- b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

1.4 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For boilers, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control reports.
- C. Field quality-control reports. Indicate conditions observed after start-up, including control settings.
- D. Sample Warranty: For special warranty.
- E. Other Informational Submittals:
 - 1. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.
 - 2. CSA B51 pressure vessel Canadian Registration Number (CRN).
 - 3. Startup service reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers, components, and accessories to include in emergency, operation, and maintenance manuals.
 - 1. Include manufacturer's descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.

- B. Protect units before, during, and after installation from damage to casing by leaving factory shipping packaging in place until immediately prior to final acceptance.

1.7 WARRANTY

- A. Manufacturer's Warranty: Manufacturer agrees to repair or replace boiler package and pressure vessels of boilers that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Minimum **[Five (5)]** <Insert number> years from date of Substantial Completion.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Acme Engineering Prod. Inc.](#)
2. [Argo Technology, Inc.](#)
3. [Benjamin Heating Products.](#)
4. [Bryan Boilers; Bryan Steam LLC.](#)
5. [Cleaver-Brooks.](#)
6. [Lion Boilers/Division of Concept Manufacturing, Inc.](#)
7. [Fulton Boiler Works, Inc.](#)
8. [Lattner Boiler Company.](#)
9. [Lochinvar, LLC.](#)
10. [Precision Boilers, LLC.](#)
11. [PVI Industries, LLC.](#)
12. [Reimers Electra Steam, Inc.](#)
13. [Sussman Electric Boilers.](#)
14. **<Insert manufacturer's name>.**
15. or approved equal.

2.2 MANUFACTURED UNITS

- A. Description: Factory-fabricated, -assembled, and -tested electric boilers with trim and controls necessary to generate **[hot water]** **[steam]**.

- B. Pressure Vessel: **[Carbon-steel]** **[Cast-iron]** pressure vessel mounted on structural-steel base.
 - C. Nozzles: Flanges for **[water inlet and]** **[steam]** outlet and heating element inserts; threaded connections for trim and controls.
 - D. Insulation: **[One layer]** **[Two layers]** of minimum **[1-inch- (25-mm-)]** **[2-inch- (50-mm-)]** **<Insert thickness>** thick, glass-fiber insulation.
 - E. Jacket: **[Galvanized]** sheet metal casing with **[baked-enamel]** **[powder-coated]** protective finish and removable panels with snap-in or interlocking closures for access to pressure vessel.
 - F. Lifting Lugs: Welded to pressure vessel, extending above jacket.
 - G. Heating Elements: **[Copper]** **[Incoloy]**-sheathed, replaceable electric-resistance element, rated 20-kW maximum, with maximum **[50 W/sq. in. (7.7 W/sq. cm)]** **[75 W/sq. in. (11.5 W/sq. cm)]** **<Insert value>** over heat-transfer length.
 - H. Mounting Base: For securing boiler to concrete base.
 - 1. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.
 - I. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - J. ASME Compliance: Fabricate and label boilers to comply with 2013 ASME Boiler and Pressure Vessel Code.
 - K. NFPA Compliance: Design and fabricate boilers to comply with NFPA 70, Article 424, Paragraphs G and H.
 - L. UL Compliance: Test boilers for compliance with UL 834. Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.
 - M. CSA Compliance: Test boilers for compliance with CSA B51.
- 2.3 TRIM FOR HOT-WATER BOILERS
- A. Include devices sized to comply with **[ASME B31.1]** **[ASME B31.9]** **[CSA B51]**.
 - B. Aquastat Controllers: Operating auto-reset high limit.
 - C. Safety Relief Valve: ASME rated.

- D. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges, so normal operating range is about 50 percent of full range.
- E. Boiler Air Vent: **[Automatic] [Manual]**.
- F. Dip-tube in water outlet.
- G. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end ball valve sized according to requirements of authorities having jurisdiction.
- H. Tankless Heater: Carbon-steel header with copper-tube heat exchanger mounted in an upper port of pressure vessel and sealed with fiber gasket.
 - 1. Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
 - 2. Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

2.4 TRIM FOR STEAM BOILERS

- A. Include devices sized to comply with **[ASME B31.1] [ASME B31.9] [CSA B51]**.
- B. Pressure Controllers: Operating auto-reset high limit.
- C. Safety Relief Valve:
 - 1. Size and Capacity: As required for equipment according to 2013 ASME Boiler and Pressure Vessel Code.
 - 2. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
 - a. Drip-Pan Elbow: Cast iron and having threaded inlet and outlet, with threads complying with ASME B1.20.1.
- D. Pressure Gage: Minimum 3-1/2-inch (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
- E. Water Column: Minimum 12-inch (300-mm) glass gage with shutoff cocks.
- F. Drain Valves: Minimum NPS 3/4 (DN 20) or nozzle size with hose-end connection.
- G. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle.**[Blowdown valves shall be combination of slow and quick acting, as required by ASME B31.1.]**
- H. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical

to boiler nozzle and same size or larger than nozzle. Valves larger than **NPS 2 (DN 50)** shall have rising stem.

- I. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet, with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.
- J. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in an upper port of pressure vessel and sealed with fiber gasket.
 - 1. Tappings **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
 - 2. Tappings **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

2.5 CONTROLS

- A. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Boiler operating controls shall include the following devices and features:
 - 1. Control transformer.
 - 2. Step controller.
 - 3. Recycling relay returns controller to off position after power failure.
 - 4. Multistage thermostat.
 - 5. Control-circuit switch.
 - 6. Visual indication for each step.
 - 7. Supply-voltage indicator.
 - 8. Set-Point Adjust: Set points shall be adjustable.
 - 9. Operating Level Control: Factory wired and mounted to cycle feedwater pump(s) for makeup water control.
 - 10. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control element sequence controller to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 - a. Include automatic, alternating-operation sequence for multiple boilers to provide equal runtime for boilers.
 - 11. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control element sequence controller to reset supply-water temperature inversely with outside-air temperature. At **[0 deg F (minus 17 deg C)] <Insert temperature>** outside-air temperature, set supply-water temperature at **[200 deg F (93 deg C)] <Insert temperature>**; at **[60 deg F (15 deg C)] <Insert temperature>** outside-air temperature, set supply-water temperature at **[140 deg F (60 deg C)] <Insert temperature>**.

- a. Include automatic, alternating-operation sequence for multiple boilers to provide equal runtime for boilers.
12. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control element sequence controller to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
- a. Include automatic, alternating-operation sequence for multiple boilers to provide equal runtime for boilers.
- C. Safety Controls: To maintain safe operating conditions, safety controls limit boiler operation.
1. High Cutoff: **[Manual] [Automatic]** reset stops boiler if operating conditions rise above set point or maximum boiler design **[temperature] [pressure]**.
 2. Low-Water Cutoff Switch: **[Electronic] [Float and electronic]** probe shall prevent boiler operation on low water. Cutoff switch shall be **[manual] [automatic]**-reset type.
 3. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
- D. Building Management System Interface: Factory install hardware and software to enable building management system to monitor, control, and display boiler status and alarms.
1. Hardwired Points:
 - a. Monitoring: On/off status, **[common trouble alarm] [low-water-level alarm] <Insert monitoring>**.
 - b. Control: On/off operation, **[hot water supply temperature set-point adjustment] [steam pressure adjustment] <Insert control>**.
 2. A communication interface with building management system shall enable building management system operator to remotely control and monitor the boiler from an operator workstation. Control features available and monitoring points displayed locally at boiler control panel shall be available through building management system.
- 2.6 ELECTRICAL POWER
- A. Single-Point Field Power Connection: Factory-installed and -wired switches, transformers, and electrical devices necessary shall provide a single-point field power connection to boiler.
1. Field power interface shall be to **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]**.
 2. Interlock with door to de-energize power with door open.
- B. Electrical Enclosures: NEMA 250, Type **[1] <Insert type>** enclosure with hinged door and key-locking handle.

- C. Install factory wiring outside of an enclosure in a **[metal]**raceway.
- D. Comply with NFPA 70.
 - 1. Electrical Circuits: 48 A, maximum.
- E. Connectors: Mechanical lugs bolted to copper bus bars or distribution blocks with pressure connectors.
- F. Fuses: NEMA FU 1, Class J or K5; 60 A, maximum.
- G. Contactors: Three-pole magnetic contactors, listed for 500,000 cycles at full load.
- H. Factory-wired internal control devices and heating elements.
 - 1. Wiring shall be numbered and color coded to match wiring diagram.

2.7 CAPACITIES AND CHARACTERISTICS

- A. Hot-Water Heating:
 - 1. Design Water-Pressure Rating: **[160 psig (1100 kPa)] <Insert pressure rating>**.
 - 2. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
 - 3. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - 4. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 - 5. Design Water Flow Rate: **<Insert gpm (L/s)>**.
 - 6. Design Pressure Drop: **<Insert psig (kPa)>**.
- B. Steam Heating:
 - 1. Design Steam-Pressure Rating: **[15 psig (104 kPa)] [60 psig (420 kPa)] [125 psig (860 kPa)] <Insert pressure rating>**.
 - 2. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
 - 3. Steam Operating Pressure: **<Insert psig (kPa)>**.
 - 4. Steam Flow Rate: **<Insert lb/h (kg/s)>**.
- C. Output Capacity: **<Insert MBh (kW)>**.
- D. Equivalent Direct Radiation: **<Insert EDR (W)>**.
- E. Tankless Water Heater:
 - 1. Design Water Flow: **<Insert gpm (L/s)>**.
 - 2. Design Pressure Drop: **<Insert psig (kPa)>**.
 - 3. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - 4. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
- F. Electrical Characteristics:
 - 1. Kilowatts: **<Insert number> kW**.

2. Volts: **[208] [480] <Insert number> V.**
3. Phase: Three.
4. Hertz: **[50] [60] <Insert number> Hz.**
5. Full-Load Amperes: **<Insert number> A.**
6. Minimum Circuit Ampacity: **<Insert number> A.**
7. Maximum Overcurrent Protection: **<Insert number> A.**

2.8 SOURCE QUALITY CONTROL

- A. Test and inspect factory-assembled boilers, before shipping, according to **[2013 ASME Boiler and Pressure Vessel Code] [CSA B51]**.
- B. Hydrostatic Test: Factory test assembled boiler, including hydrostatic test.
- C. Allow Owner access to source quality-control testing of boilers. Notify Architect 14 days in advance of testing.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance of the Work.
 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces, including required space for element removal, for suitable conditions where boilers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

- A. Equipment Mounting:
 1. Install boilers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete."]** **[Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
 2. Comply with requirements for vibration isolation and seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Install electrical devices furnished with boiler but not specified to be factory mounted.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in [**Section 232113 "Hydronic Piping"**] [**and**] [**Section 232213 "Steam and Condensate Heating Piping."**]. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to boiler to allow service and maintenance.
- C. Connect hot-water piping to supply- and return-boiler tappings, with shutoff valve and union or flange at each connection.
- D. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings, with shutoff valve and union or flange at each connection.
- E. Install piping from safety relief valves to nearest floor drain.
- F. Install piping from safety relief valves to drip-pan elbow and to nearest floor drain.
- G. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Perform installation and startup checks according to manufacturer's written instructions.
 - 2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
 - 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Check and adjust initial operating set points and high- and low-limit safety set points of water level and [**water temperature**] [**steam pressure**].
 - b. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Performance Tests:
 - 1. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.

2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
3. Perform field performance tests to determine the capacity of boilers.
4. Repeat tests until results comply with requirements indicated.
5. Provide analysis equipment required to determine performance.
6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are inadequate.
7. Notify Architect in advance of test dates.
8. Document test results in a report and submit to Architect.

F. Boiler will be considered defective if it does not pass tests and inspections.

G. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Occupancy Adjustments: When requested within [**twelve (12) months**] <Insert time period> of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain boilers. Refer to Section 017900 "Demonstration and Training."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235213

SECTION 235216 - CONDENSING BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes gas-fired, [**pulse-combustion**] [**fire-tube**] [**water-tube**] [**water-jacketed**] condensing boilers, trim, and accessories for generating [**hot water**] [**and**] [**steam**].
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Provide data indicating general assembly, components, controls, safety controls, and wiring diagrams with electrical characteristics and connection requirements, and service connections.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for boilers.
 - 2. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For boilers, boiler trim, and accessories.
 - 1. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
 - 4. Include diagrams for power, signal, and control wiring.

- C. Delegated-Design Submittal: For each boiler.
 - 1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
 - b. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

1.4 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For boiler, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control reports.
- C. Manufacturer's Certificate: Certify that units meet or exceed specified requirements.
- D. Field quality-control reports. Indicate condition of equipment after start-up including control settings and performance chart of control system.
- E. Test Reports: Indicate specified performance and efficiency is met or exceeded. Provide factory combustion test data for substantially identical unit that includes boiler firing rate, overfire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.
- F. Sample Warranty: For special warranty.
- G. Other Informational Submittals:
 - 1. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.
 - 2. CSA B51 pressure vessel Canadian Registration Number (CRN).

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers to include in emergency, operation, and maintenance manuals.
 - 1. Include manufacturer's descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- C. MAINTENANCE MATERIALS
- D. Provide wire brush and **[one-piece] [hinged]** handle for tube cleaning.

1.6 MAINTENANCE SERVICE

- A. Provide service and maintenance of boilers for **[one (1)] <Insert number>** year from Date of Substantial Completion.

1.7 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum of five (5) years documented experience.
- B. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store, protect and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Protect boilers from damage by leaving factory inspection openings and shipping packaging in place until final installation.

1.9 WARRANTY

- A. Manufacturer's Warranty: Manufacturer agrees to repair or replace components of boilers that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Pulse-Combustion Boilers:
 - a. Heat Exchanger Damaged by Thermal Shock: Minimum **[ten (10)] <Insert number>** years from date of Substantial Completion.

- b. Heat-Exchanger Corrosion: [**Prorated**] [**Nonprorated**] for [**five (5)**] <Insert number> years from date of Substantial Completion.
 2. Warranty Period for Fire-Tube Condensing Boilers:
 - a. Leakage and Materials: Minimum [**ten (10)**] <Insert number> years from date of Substantial Completion.
 - b. Heat Exchanger Damaged by Thermal Stress and Corrosion: [**Prorated**] [**Nonprorated**] for [**five (5)**] <Insert number> years from date of Substantial Completion.
 3. Warranty Period for Water-Tube Condensing Boilers: Minimum [**twenty (20)**] <Insert number> years from date of Substantial Completion.
 4. Warranty Period for Water-Jacketed Condensing Boilers:
 - a. Leakage and Materials: Minimum[**eight (8)**] <Insert number> years from date of Substantial Completion.
 - b. Heat Exchanger Damaged by Thermal Stress and Corrosion: [**Prorated**] [**Nonprorated**] for [**five (5)**] <Insert number> years from date of Substantial Completion.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label boilers to comply with 2010 ASME Boiler and Pressure Vessel Code.
- C. ASHRAE/IES 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
- D. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N.
- E. UL Compliance: Test boilers for compliance with UL 795. Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.
- F. CSA Compliance: Test boilers for compliance with CSA B51.

- G. Mounting Base: For securing boiler to concrete base.
1. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

2.2 PULSE-COMBUSTION, FIRE-TUBE CONDENSING BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Fulton Boiler Works, Inc.](#)
 2. [Gasmaster Industries Incorporated.](#)
 3. [Hydrotherm, Inc./Mestek, Inc.](#)
 4. **<Insert manufacturer's name>.**
 5. or approved equal.
- B. Description: Factory-fabricated, -assembled, and -tested, pulse-combustion condensing boiler with heat exchanger sealed pressure tight, built on a steel base, including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls.
- C. Heat Exchanger: **[Type 316L, stainless-steel]** **[Carbon-steel]** primary and secondary combustion chamber.
- D. Pressure Vessel: Carbon steel with welded heads and tube connections.
- E. Exhaust Decoupler: Fiberglass composite material in a corrosion-resistant steel box.
- F. Burner: **[Natural]** **[Propane]** gas, self-aspirating and self-venting after initial start.
- G. Blower: Centrifugal fan to operate only during start of each burner sequence.
1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- H. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
- I. Ignition: Spark ignition with 100 percent main-valve shutoff with electronic flame supervision.
- J. Casing:

1. Jacket: Sheet metal, with snap-in or interlocking closures.
 2. Control Compartment Enclosure: NEMA 250, Type 1A.
 3. Finish: **[Baked-enamel]** **[Powder-coated]** protective finish.
 4. Insulation: Minimum **2-inch-** (50-mm-) thick, mineral-fiber insulation surrounding heat exchanger.
 5. Draft Hood: **[Integral]** **[External]**.
 6. Combustion-Air Connection: Inlet duct collar and sheet metal closure over burner compartment.
- K. Mufflers: Carbon-steel intake muffler and stainless-steel exhaust.
- L. Condensate Trap: Cast-iron body with stainless-steel internal parts.
- M. Capacities and Characteristics:
- N. Hot-Water Heating:
1. Design Water-Pressure Rating: **[15 psig (104 kPa)] [150 psig (1035 kPa)] <Insert pressure rating>**.
 2. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
 3. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 4. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 5. Design Water Flow Rate: **<Insert gpm (L/s)>**.
 6. Design Pressure Drop: **<Insert psig (kPa)>**.
- O. Steam Heating:
1. Design Steam-Pressure Rating: **[Steam, 60 psig (415 kPa)] [100 psig (690 kPa)] [160 psig (1100 kPa)] <Insert pressure rating>**.
 2. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
 3. Steam Operating Pressure: **<Insert psig (kPa)>**.
 4. Steam Flow Rate: **<Insert lb/h (kg/s)>**.
 5. Minimum Efficiency AFUE: **<Insert number>** percent.
 6. Minimum Thermal Efficiency: **<Insert number>** percent.
 7. Minimum Combustion Efficiency: **<Insert number>** percent.
 8. AGA Input: **<Insert MBh (kW)>**.
 9. Gas Input: **<Insert cfh (mL/s)>**.
 10. AGA Output Capacity: **<Insert MBh (kW)>**.
 11. DOE Output Capacity: **<Insert MBh (kW)>**.
 12. Equivalent Direct Radiation: **<Insert EDR (W)>**.
 13. Blower:
 - a. Motor Horsepower: **<Insert number>** hp.
 - b. RPM: **<Insert number>**.
 14. Electrical Characteristics:
 - a. Volts: **[115] [208] [230] [460] <Insert number>** V.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: **[50] [60] <Insert number>** Hz.

- d. Full-Load Amperes: <Insert value> A.
- e. Minimum Circuit Ampacity: <Insert number> A.
- f. Maximum Overcurrent Protection: <Insert number> A.

2.3 FORCED-DRAFT, FIRE-TUBE CONDENSING BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [AERCO International, Inc.](#)
 2. [Bosch Thermotechnology Corp.](#)
 3. [Heat Transfer Products, Inc.](#)
 4. [Triangle Tube.](#)
 5. <Insert manufacturer's name>.
 6. or approved equal.
- B. Description: Factory-fabricated, -assembled, and -tested, fire-tube condensing boiler with heat exchanger sealed pressure tight, built on a steel base, including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls. Water-heating service only.
- C. Heat Exchanger: Nonferrous, corrosion-resistant combustion chamber.
- D. Pressure Vessel: Carbon steel with welded heads and tube connections.
- E. Burner: **[Natural]** **[Propane]** gas, forced draft.
- F. Blower: Centrifugal fan to operate during each burner firing sequence and to prepurge and postpurge the combustion chamber.
1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- G. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
- H. Ignition: Spark ignition with 100 percent main-valve shutoff with electronic flame supervision.
- I. Casing:
1. Jacket: **[Sheet metal]** **[Plastic]**, with snap-in or interlocking closures.
 2. Control Compartment Enclosures: NEMA 250, Type 1A.
 3. Finish: **[Baked-enamel]** **[Powder-coated]** protective finish.
 4. Insulation: Minimum **2-inch-** (50-mm-) thick, **[mineral-fiber]** **[polyurethane-foam]** insulation surrounding the heat exchanger.

5. Combustion-Air Connections: Inlet and vent duct collars.

J. Capacities and Characteristics:

1. Heating Medium: Hot water.
2. Design Water-Pressure Rating: [160 psig (1100 kPa)] <Insert value>.
3. Safety Relief Valve Setting: <Insert psig (kPa)>.
4. Entering-Water Temperature: <Insert deg F (deg C)>.
5. Leaving-Water Temperature: <Insert deg F (deg C)>.
6. Design Water Flow Rate: <Insert gpm (L/s)>.
7. Minimum Water Flow Rate: <Insert gpm (L/s)>.
8. Design Pressure Drop: <Insert psig (kPa)>.
9. Minimum Efficiency AFUE: <Insert number> percent.
10. Minimum Thermal Efficiency: <Insert number> percent.
11. Minimum Combustion Efficiency: <Insert number> percent.
12. AGA Input: <Insert MBh (kW)>.
13. Gas Input: <Insert cfh (mL/s)>.
14. AGA Output Capacity: <Insert MBh (kW)>.
15. DOE Output Capacity: <Insert MBh (kW)>.
16. Equivalent Direct Radiation: <Insert EDR (W)>.
17. Blower:

- a. Motor Horsepower: <Insert number> hp.
- b. RPM: <Insert number>.

18. Electrical Characteristics:

- a. Volts: [115] [208] [230] [460] <Insert number> V.
- b. Phase: [Single] [Three].
- c. Hertz: [50] [60] <Insert number> Hz.
- d. Full-Load Amperes: <Insert number> A.
- e. Minimum Circuit Ampacity: <Insert number> A.
- f. Maximum Overcurrent Protection: <Insert number> A.

2.4 WATER-TUBE CONDENSING BOILERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [LAARS Heating Systems Company](#).
2. [Lochinvar, LLC](#).
3. [Triangle Tube](#).
4. <Insert manufacturer's name>.
5. or approved equal.

B. Description: Factory-fabricated, -assembled, and -tested, copper-finned, water-tube condensing boiler with heat exchanger sealed pressure tight, built on a steel base, including insulated jacket; flue-gas vent; combustion-air intake connections; water

- supply, return, and condensate drain connections; and controls. Water-heating service only.
- C. Heat Exchanger: Finned-copper primary and stainless-steel secondary heat exchangers.
- D. Combustion Chamber: Stainless steel, sealed.
- E. Burner: **[Natural]** **[Propane]** gas, forced draft drawing from gas premixing valve.
- F. Blower: Centrifugal fan to operate during each burner firing sequence and to prepurge and postpurge the combustion chamber.
1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- G. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
- H. Ignition: Silicone carbide hot-surface ignition that includes flame safety supervision and 100 percent main-valve shutoff.
- I. Integral Circulator: Cast-iron body and stainless-steel impeller sized for minimum flow required in heat exchanger.
- J. Casing:
 1. Jacket: Sheet metal, with snap-in or interlocking closures.
 2. Control Compartment Enclosures: NEMA 250, Type 1A.
 3. Finish: Textured epoxy.
 4. Insulation: Minimum **[1-inch- (25-mm-)]** **[2-inch- (50-mm-)]** thick, mineral-fiber insulation surrounding the heat exchanger.
 5. Combustion-Air Connections: Inlet and vent duct collars.
- K. Capacities and Characteristics:
 1. Heating Medium: Hot water.
 2. Design Water-Pressure Rating: **[160 psig (1100 kPa)]** **<Insert value>**.
 3. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
 4. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 5. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 6. Design Water Flow Rate: **<Insert gpm (L/s)>**.
 7. Minimum Water Flow Rate: **<Insert gpm (L/s)>**.
 8. Design Pressure Drop: **<Insert psig (kPa)>**.
 9. Minimum Efficiency AFUE: **<Insert number>** percent.
 10. Minimum Thermal Efficiency: **<Insert number>** percent.

11. Minimum Combustion Efficiency: <Insert number> percent.
12. AGA Input: <Insert MBh (kW)>.
13. Gas Input: <Insert cfh (mL/s)>.
14. AGA Output Capacity: <Insert MBh (kW)>.
15. DOE Output Capacity: <Insert MBh (kW)>.
16. Blower:
 - a. Motor Horsepower: <Insert number> hp.
 - b. RPM: <Insert number>.
17. Electrical Characteristics:
 - a. Volts: [115] [208] [230] [460] <Insert number> V.
 - b. Phase: [Single] [Three].
 - c. Hertz: [50] [60] <Insert number> Hz.
 - d. Full-Load Amperes: <Insert number> A.
 - e. Minimum Circuit Ampacity: <Insert number> A.
 - f. Maximum Overcurrent Protection: <Insert number> A.

2.5 WATER-JACKETED CONDENSING BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Viessmann Manufacturing Co. \(US\) Inc.](#)
 2. <Insert manufacturer's name>.
 3. or approved equal.
- B. Description: Factory-fabricated, -assembled, and -tested, water-jacketed condensing boiler with heat exchanger sealed pressure tight, built on a steel base, including insulated jacket; flue-gas vent; water supply, return, and condensate drain connections; and controls. Water-heating service only.
- C. Heat Exchanger: Stainless-steel primary and secondary combustion chamber.
- D. Pressure Vessel: Carbon steel with welded heads and tube connections where not in contact with combustion or flue gases.
- E. Burner: [Natural] [Propane] gas, forced draft; swing-open front and burner observation port.
- F. Blower: Centrifugal fan, forced draft. Include prepurge and postpurge of the combustion chamber.
 1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- G. Gas Train: Combination gas valve with manual shutoff and pressure regulator. Include 100 percent safety shutoff with electronic flame supervision.
- H. Ignition: Electric-spark ignition with 100 percent main-valve shutoff with electronic flame supervision.
- I. Casing:
1. Jacket: Sheet metal, with snap-in or interlocking closures.
 2. Control Compartment Enclosures: NEMA 250, Type 1A.
 3. Finish: Powder-coated protective finish.
 4. Insulation: Minimum 4-inch- (100-mm-) thick, mineral-fiber insulation surrounding the heat exchanger.
 5. Combustion-Air Connections: Inlet and vent duct collars.
- J. Capacities and Characteristics:
1. Heating Medium: Hot water.
 2. Design Water-Pressure Rating: [30 psig (207 kPa)] **<Insert value>**.
 3. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
 4. Maximum Design Temperature: 210 deg F (99 deg C).
 5. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 6. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 7. Design Water Flow Rate: **<Insert gpm (L/s)>**.
 8. Design Pressure Drop: **<Insert psig (kPa)>**.
 9. Minimum Efficiency AFUE: **<Insert number>** percent.
 10. Minimum Thermal Efficiency: **<Insert number>** percent.
 11. Minimum Combustion Efficiency: **<Insert number>** percent.
 12. AGA Input: **<Insert MBh (kW)>**.
 13. Gas Input: **<Insert cfh (mL/s)>**.
 14. AGA Output Capacity: **<Insert MBh (kW)>**.
 15. DOE Output Capacity: **<Insert MBh (kW)>**.
 16. Equivalent Direct Radiation: **<Insert EDR (W)>**.
 17. Blower:
 - a. Motor Horsepower: **<Insert number>** hp.
 - b. RPM: **<Insert number>**.
 18. Electrical Characteristics:
 - a. Volts: [115] [208] [230] [460] **<Insert number>** V.
 - b. Phase: [Single] [Three].
 - c. Hertz: [50] [60] **<Insert number>** Hz.
 - d. Full-Load Amperes: **<Insert number>** A.
 - e. Minimum Circuit Ampacity: **<Insert number>** A.
 - f. Maximum Overcurrent Protection: **<Insert number>** A.

2.6 TRIM

- A. Include devices sized to comply with [ASME B31.1] [ASME B31.9].
- B. Aquastat Controllers: Operating[, **firing rate**,] and high limit.
- C. Safety Relief Valve: ASME rated.
- D. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges, so normal operating range is about 50 percent of full range.
- E. Boiler Air Vent: [Automatic] [Manual].
- F. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end gate valve.
- G. Circulation Pump: Nonoverloading, in-line pump with split-capacitor motor having thermal-overload protection and lubricated bearings; designed to operate at specified boiler pressures and temperatures.

2.7 TRIM

- A. Include devices sized to comply with [ASME B31.1] [ASME B31.9].
- B. Pressure Controllers: Operating[, **firing rate**,] and high limit.
- C. Safety Relief Valve:
 - 1. Size and Capacity: As required for equipment according to 2010 ASME Boiler and Pressure Vessel Code.
 - 2. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
 - a. Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
- D. Pressure Gage: Minimum 3-1/2-inch (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
- E. Water Column: Minimum 12-inch (300-mm) glass gage with shutoff cocks.
- F. Drain Valves: Minimum NPS 3/4 (DN 20) or nozzle size with hose-end connection.
- G. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle. [**Blowdown valves shall be combination of slow and quick acting as required by ASME B31.1.**]
- H. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical

to boiler nozzle and same size or larger than nozzle. Valves larger than **NPS 2 (DN 50)** shall have rising stem.

- I. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.

2.8 CONTROLS

- A. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

- B. Boiler operating controls shall include the following devices and features:

1. Control transformer.
2. Set-Point Adjust: Set points shall be adjustable.
3. Operating Pressure Control: Factory wired and mounted to cycle burner.
4. Low-Water Cutoff and Pump Control: Cycle feedwater pump(s) for makeup water control.
5. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 - a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
6. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At [0 deg F (minus 17 deg C)] **<Insert temperature>** outside-air temperature, set supply-water temperature at [200 deg F (93 deg C)] **<Insert temperature>**; at [60 deg F (15 deg C)] **<Insert temperature>** outside-air temperature, set supply-water temperature at [140 deg F (60 deg C)] **<Insert temperature>**.
 - a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
7. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
 - a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.

- C. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.

1. High Cutoff: **[Manual] [Automatic]** reset stops burner if operating conditions rise above maximum boiler design **[temperature] [pressure]**.
 2. Low-Water Cutoff Switch: **[Electronic] [Float and electronic]** probe shall prevent burner operation on low water. Cutoff switch shall be **[manual] [automatic]**-reset type.
 3. Blocked Inlet Safety Switch: Manual-reset pressure switch field mounted on boiler combustion-air inlet.
 4. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
- D. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
1. Hardwired Points:
 - a. Monitoring: On/off status, **[common trouble alarm] [low-water-level alarm] <Insert monitoring>**.
 - b. Control: On/off operation, **[hot-water-supply temperature set-point adjustment] [steam pressure adjustment] <Insert control>**.
 2. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

2.9 ELECTRICAL POWER

- A. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in electrical Sections.
- B. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
1. House in NEMA 250, Type **[1] <Insert type>** enclosure.
 2. Wiring shall be numbered and color coded to match wiring diagram.
 3. Install factory wiring outside of an enclosure in a **[metal]** raceway.
 4. Field power interface shall be to **[wire lugs] [fused disconnect switch] [nonfused disconnect switch] [circuit breaker]**.
 5. Provide branch power circuit to each motor and to controls **[with a disconnect switch or circuit breaker]**.
 6. Provide each motor with overcurrent protection.

2.10 VENTING KITS

- A. Kit: Complete system, ASTM A 959, Type 29-4C stainless steel, pipe, vent terminal, thimble, indoor plate, vent adapter, condensate trap and dilution tank, and sealant.

- B. Combustion-Air Intake: Complete system, stainless steel, pipe, vent terminal with screen, inlet air coupling, and sealant.

2.11 SOURCE QUALITY CONTROL

- A. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
- B. Test and inspect factory-assembled boilers, before shipping, according to 2010 ASME Boiler and Pressure Vessel Code.
- C. Allow Owner access to source quality-control testing of boilers. Notify DEN Project Manager 14 days in advance of testing.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance of the Work.
 - 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces for suitable conditions where boilers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

- A. Equipment Mounting:
 - 1. Install boilers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Install gas-fired boilers according to NFPA 54.
- C. Install in accordance with manufacturer's instructions.

- D. Assemble and install boiler trim.
- E. Install electrical devices furnished with boiler but not specified to be factory mounted.
- F. Install control wiring to field-mounted electrical devices.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to boiler to allow service and maintenance.
- C. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
- D. Connect piping to boilers, except safety relief valve connections, with flexible connectors of materials suitable for service. Flexible connectors and their installation are specified in Section 232116 "Hydronic Piping Specialties."
- E. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas-train connection. Provide a reducer if required.
- F. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
- G. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings with shutoff valve and union or flange at each connection.
- H. Install piping from safety relief valves to nearest floor drain.
- I. Install piping from safety valves to drip-pan elbow and to nearest floor drain.
- J. Boiler Venting:
 - 1. Install flue venting kit and combustion-air intake.
 - 2. Connect full size to boiler connections.[**Comply with requirements in Section 235123 "Gas Vents."**]
- K. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- L. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Perform installation and startup checks according to manufacturer's written instructions.
 2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
 3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and [**water temperature**] [**steam pressure**].
 - b. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Boiler will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.
- F. Occupancy Adjustments: When requested within [**12 months of date of Substantial Completion**] <Insert time period>, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.
- G. Performance Tests:
1. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
 2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment to comply.
 3. Perform field performance tests to determine capacity and efficiency of boilers.
 - a. Test for full capacity.
 - b. Test for boiler efficiency at [**low fire 20, 40, 60, 80, 100, 80, 60, 40, and 20**] <Insert range> percent of full capacity. Determine efficiency at each test point.
 4. Repeat tests until results comply with requirements indicated.
 5. Provide analysis equipment required to determine performance.
 6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are inadequate.
 7. Notify DEN Project Manager [**24**] <Insert number> hours minimum in advance of test dates.
 8. Document test results in a report and submit to DEN Project Manager.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain boilers. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235216

SECTION 235223 - CAST-IRON BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes cast-iron boilers, trim, and accessories for generating **[hot water]** **[and]** **[steam]**.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Provide data indicating general assembly, components, controls, safety controls, and wiring diagrams with electrical characteristics and connection requirements, and service connections.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for boilers.
 - 2. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For boilers, boiler trim, and accessories.
 - 1. Include plans, elevations, sections, and **[mounting]** **[attachment]** details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
 - 4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
- C. Delegated-Design Submittal: For each boiler.

1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
 - b. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

1.4 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For boiler, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control reports.
- C. Manufacturer's Certificate: Certify that units meet or exceed specified requirements.
- D. Field quality-control reports. Indicate condition of equipment after start-up including control settings and performance chart of control system.
- E. Test Reports: Indicate specified performance and efficiency is met or exceeded. Provide factory combustion test data for substantially identical unit that includes boiler firing rate, overfire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.
- F. Sample Warranty: For special warranty.
- G. Other Informational Submittals:
 1. CSA B51 pressure vessel Canadian Registration Number (CRN).
 2. Startup service reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers, components, and accessories to include in emergency, operation, and maintenance manuals.
 1. Include manufacturer's descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE SERVICE

- A. Provide service and maintenance of boilers for [**one (1)**] <Insert number> year from Date of Substantial Completion.

1.7 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum of five (5) years documented experience.
- B. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Protect units before, during, and after installation from damage to casing by leaving factory shipping packaging in place until immediately prior to final acceptance.

1.9 WARRANTY

- A. Manufacturer's Warranty: Manufacturer agrees to repair or replace controls and heat exchangers of boilers that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Controls: Minimum [**two (2)**] <Insert number> years from date of Substantial Completion.
 - 2. Warranty Period for Heat Exchangers: Minimum [**five (5)**] [**ten (10)**] [**twenty (20)**] <Insert number> years from date of Substantial Completion.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label boilers to comply with 2010 ASME Boiler and Pressure Vessel Code.
- C. ASHRAE/IES 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
- D. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N.
- E. I=B=R Compliance: Boilers shall be tested and rated according to AHRI's "Rating Procedure for Heating Boilers" and "Testing Standard for Commercial Boilers," with I=B=R emblem on a nameplate affixed to boiler.
- F. UL Compliance: Test boilers for compliance with [UL 726] [UL 726 and UL 795] [UL 795]. Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.
- G. CSA Compliance: Test boilers for compliance with CSA B51.
- H. Mounting Frame: Steel rails used to mount assembled boiler package on concrete base.
 - 1. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

2.2 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Burnham Hydronics.](#)
 - 2. [Crown Boiler Co.](#)
 - 3. [Hydrotherm, Inc./ Mestek Inc.](#)
 - 4. [Lennox Industries, Inc.; Lennox International.](#)
 - 5. [Peerless Boilers; PB Heat, LLC.](#)
 - 6. [Slant/Fin Corp.](#)
 - 7. [Smith Cast Iron Boilers: a Mestek company.](#)
 - 8. [Viessmann Manufacturing Co. \(US\) Inc.](#)
 - 9. [Weil-McLain.](#)

10. **<Insert manufacturer's name>**.
11. or approved equal.

2.3 MANUFACTURED UNITS

- A. Description: Factory fabricated and **[field]** assembled.
1. Cast-iron sections shall be sealed pressure tight and held together with tie rods **[set on an insulated steel base]**, including insulated jacket and flue-gas vent connection.
 2. Ship cast-iron sections disassembled with all materials and equipment, including seals, tie rods, and insulated jacket and flue-gas vent connection for field assembly.
- B. Cast-Iron Section Design:
1. Configuration: Wet **[base]** **[back]** **[leg]**.
 2. Number of Passes: **[Single]** **[Multiple]**.
 3. Sectional Joints: High-temperature sealant to seal flue-gas passages not in contact with heating medium, **[tapered cast-iron push nipples,]** **[O-ring gaskets,]** **[fiber roping,]** and held together with tie rods.
 4. Drain and blowdown tappings.
 5. Return injection tube to equalize water flow to all sections.
 6. Crown inspection tappings with brass plugs.
 7. Built-in air separator.
- C. Combustion Chamber: Equipped with **[ceramic-fiber target wall]** **[refractory]** **[insulation]** **[and]** flame observation ports, front and back.
- D. Casing:
1. Jacket: **[Galvanized sheet]** **[Sheet]** metal, with snap-in or interlocking closures and **[baked-enamel]** **[powder-coated]** protective finish.
 2. Insulation: Minimum **[1-inch- (25-mm-)]** **[2-inch- (50-mm-)]** thick, mineral-fiber insulation surrounding the heat exchanger.
 3. Combustion Chamber Access: Refractory lined, hinged, front.
 4. Access: For cleaning between cast-iron sections.
 5. Draft Hood: Flue canopy and **[top]** **[rear]** flue connection shall be constructed of **[aluminized]** **[stainless]** steel containing adjustable outlet damper assembly.
 6. Insulated base constructed of aluminized steel to permit boiler to be installed on combustible floor.
 7. Control Cabinet: Sheet metal casing shall cover all controls, gas train, and burner.
- E. Draft Diverter: **[Steel assembly integral with boiler casing]** **[Separate galvanized-steel assembly]**.

2.4 ATMOSPHERIC-GAS BURNER

- A. Burner Tubes and Orifices: **[Stainless steel]** **[Cast iron]**, for **[natural]** **[propane]** gas.
- B. Gas Train: Control devices and **[full-modulation]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FM Global]** **[IRI]** **[UL]**.
- C. Gas Train: Combination-gas valve with manual shutoff, pressure regulator, and pilot adjustment.
- D. Pilot: **[Standing]** **[Intermittent-electric-spark]** pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

2.5 SEALED-COMBUSTION BURNER

- A. Burner Tubes and Orifices: **[Stainless steel]** **[Cast iron]**, for **[natural]** **[propane]** gas.
- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor, with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
 - 1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- C. Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
- D. Pilot: **[Standing]** **[Intermittent-electric-spark]** pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

2.6 FORCED-DRAFT BURNER

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for **[natural]** **[propane]** gas.
- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor, with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
 - 1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

- C. Gas Train: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FM Global]** **[IRI]** **[UL]**.
- D. Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
- E. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
 - 1. Maximum Oxides of Nitrogen Emissions: **[20]** **[30]** **<Insert number>** ppm.

2.7 OIL BURNER

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil.
- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor, with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
 - 1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- C. Oil Supply: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FM Global]** **[IRI]** **[UL]**.
 - 1. Oil Pump: Two-stage, gear-type oil pump[**integral to and directly driven by blower**] shall be capable of producing **300-psig (2070-kPa)** discharge pressure and **15-inch Hg (50.7-kPa)** vacuum.
 - 2. Oil Piping Specialties:
 - a. Suction-line, manual gate valve.
 - b. Removable-mesh oil strainer.
 - c. **0- to 30-inch Hg (0- to 101.3-kPa)** vacuum; **0- to 30-psig (0- to 207-kPa)** vacuum-pressure gage.
 - d. **0- to 300-psig (0- to 2070-kPa)** oil-nozzle pressure gage.
 - e. Nozzle-line, solenoid-safety-shutoff oil valve.
- D. Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid using **[cadmium sulfide]** **[UV scanner]** flame-safety control.
- E. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
 - 1. Maximum Oxides of Nitrogen Emissions: **[20]** **[30]** **<Insert number>** ppm.

2.8 COMBINATION GAS AND OIL BURNER

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil and **[natural] [propane]** gas.
- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor, with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- a. Motor Sizes: Minimum size as indicated; if not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- C. Oil Supply: Control devices and **[modulating] [on-off] [low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1] [FM Global] [IRI] [UL]**.
1. Oil Pump: Two-stage, gear-type oil pump **[integral to and directly driven by blower]** shall be capable of producing **300-psig (2070-kPa)** discharge pressure and **15-inch Hg (50.7-kPa)** vacuum.
2. Oil Piping Specialties:
- a. Suction-line, manual, gate valve.
- b. Removable-mesh oil strainer.
- c. **0- to 30-inch Hg (0- to 101.3-kPa)** vacuum; **0- to 30-psig (0- to 207-kPa)** vacuum-pressure gage.
- d. **0- to 300-psig (0- to 2070-kPa)** oil-nozzle pressure gage.
- e. Nozzle-line, solenoid-safety-shutoff oil valve.
- D. Gas Train: Control devices and **[modulating] [on-off] [low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1] [FM Global] [IRI] [UL]**.
- E. Gas Pilot: **[Intermittent] [Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
- F. Oil Pilot: **[Intermittent] [Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with **[cadmium sulfide] [UV scanner]** flame-safety control.
- G. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
1. Maximum Oxides of Nitrogen Emissions: **[20] [30] <Insert number>** ppm.

2.9 TRIM FOR HOT-WATER BOILERS

- A. Include devices sized to comply with ASME B31.9.

- B. Aquastat Controllers: Operating[, **firing rate,**] and high limit.
- C. Safety Relief Valve: ASME rated.
- D. Pressure and Temperature Gage: Minimum **3-1/2-inch- (89-mm-)** diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges, so normal operating range is about 50 percent of full range.
- E. Boiler Air Vent: [**Automatic**] [**Manual**].
- F. Drain Valve: Minimum **NPS 3/4 (DN 20)** hose-end gate valve.
- G. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in an upper port of cast-iron sections and sealed with fiber gasket.
 - 1. Tappings **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
 - 2. Tappings **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

2.10 TRIM FOR STEAM BOILERS

- A. Include devices sized to comply with ASME B31.9.
- B. Pressure Controllers: Operating[, **firing rate,**] and high limit.
- C. Safety Relief Valve:
 - 1. Size and Capacity: As required for equipment according to 2010 ASME Boiler and Pressure Vessel Code.
 - 2. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
 - a. Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
- D. Pressure Gage: Minimum **3-1/2-inch (89-mm)** diameter. Gage shall have normal operating pressure about 50 percent of full range.
- E. Water Column: Minimum **12-inch (300-mm)** glass gage with shutoff cocks.
- F. Drain Valves: Minimum **NPS 3/4 (DN 20)** or nozzle size with hose-end connection.
- G. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle.
- H. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical

to boiler nozzle and same size as or larger than nozzle. Valves larger than NPS 2 (DN 50) shall have rising stem.

- I. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.
- J. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in an upper port of cast-iron sections and sealed with fiber gasket.
 - 1. Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
 - 2. Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

2.11 CONTROLS

- A. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Boiler operating controls shall include the following devices and features:
 - 1. Control transformer.
 - 2. Set-Point Adjust: Set points shall be adjustable.
 - 3. Operating Pressure Control: Factory wired and mounted to cycle burner.
 - 4. Low-Water Cutoff and Pump Control: Cycle feedwater pump(s) for makeup water control.
 - 5. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 - a. Include automatic, alternating-firing sequence for multiple boilers to provide equal runtime for boilers.
 - 6. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At [0 deg F (minus 17 deg C)] <Insert temperature> outside-air temperature, set supply-water temperature at [200 deg F (93 deg C)] <Insert temperature>; at [60 deg F (15 deg C)] <Insert temperature> outside-air temperature, set supply-water temperature at [140 deg F (60 deg C)] <Insert temperature>.
 - a. Include automatic, alternating-firing sequence for multiple boilers to provide equal runtime for boilers.
 - 7. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.

- a. Include automatic, alternating-firing sequence for multiple boilers to provide equal runtime for boilers.
- C. Safety Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
1. High Cutoff: **[Manual] [Automatic]** reset stops burner if operating conditions rise above maximum boiler design **[temperature] [pressure]**.
 2. Low-Water Cutoff Switch: **[Electronic] [Float and electronic]** probe shall prevent burner operation on low water. Cutoff switch shall be **[manual] [automatic]**-reset type.
 3. Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.
 4. Rollout Safety Switch: Factory mounted on boiler combustion chamber.
 5. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
- D. Building Management System Interface: Factory install hardware and software to enable building management system to monitor, control, and display boiler status and alarms.
1. Hardwired Points:
 - a. Monitoring: On/off status, **[common trouble alarm] [low-water-level alarm] <Insert monitoring>**.
 - b. Control: On/off operation, **[hot-water-supply temperature set-point adjustment] [steam pressure adjustment] <Insert control>**.
 2. A communication interface with building management system shall enable building management system operator to remotely control and monitor the boiler from an operator workstation. Control features available and monitoring points displayed, locally at boiler control panel shall be available through building management system.

2.12 ELECTRICAL POWER

- A. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in electrical Sections.
- B. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
1. House in NEMA 250, Type **[1] <Insert type>** enclosure.
 2. Wiring shall be numbered and color coded to match wiring diagram.
 3. Install factory wiring outside of an enclosure in a **[metal]** raceway.
 4. Field power interface shall be to **[wire lugs] [fused disconnect switch] [nonfused disconnect switch] [circuit breaker]**.

5. Provide branch power circuit to each motor and to controls[**with disconnect switch or circuit breaker**].
6. Provide each motor with overcurrent protection.

2.13 CAPACITIES AND CHARACTERISTICS

A. Hot-Water Heating:

1. Design Water-Pressure Rating: [30 psig (207 kPa)] [50 psig (345 kPa)] [80 psig (550 kPa)] **<Insert pressure rating>**.
2. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
3. Entering-Water Temperature: **<Insert deg F (deg C)>**.
4. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
5. Design Water Flow Rate: **<Insert gpm (L/s)>**.
6. Design Pressure Drop: **<Insert psig (kPa)>**.

B. Steam Heating:

1. Design Steam-Pressure Rating: [**Steam, 15 psig** (104 kPa)] **<Insert pressure rating>**.
2. Safety Relief Valve Setting: **<Insert psig (kPa)>**.
3. Steam Operating Pressure: **<Insert psig (kPa)>**.
4. Steam Flow Rate: **<Insert lb/h (kg/s)>**.

C. Minimum Efficiency AFUE: **<Insert number>** percent.

D. Minimum Thermal Efficiency: **<Insert number>** percent.

E. Minimum Combustion Efficiency: **<Insert number>** percent.

F. Number of Passes: [**One**] [**Two**] **<Insert number>**.

G. Input Rating Method:

1. AGA Input: **<Insert MBh (kW)>**.
2. I=B=R Input: **<Insert MBh (kW)>**.
3. Gas Input: **<Insert cfh (mL/s)>**.
4. Oil Input: **<Insert gph (mL/s)>**.

H. Output Capacity

1. AGA Output Capacity: **<Insert MBh (kW)>**.
2. DOE Output Capacity: **<Insert MBh (kW)>**.
3. Net I=B=R Output Capacity: **<Insert MBh (kW)>**.
4. Gross I=B=R Output Capacity: **<Insert MBh (kW)>**.
5. Equivalent Direct Radiation: **<Insert EDR (W)>**.

I. Tankless Water Heater:

1. Design Water Flow: **<Insert gpm (L/s)>**.

2. Design Pressure Drop: <Insert psig (kPa)>.
3. Entering-Water Temperature: <Insert deg F (deg C)>.
4. Leaving-Water Temperature: <Insert deg F (deg C)>.

J. Blower:

1. Motor Horsepower: <Insert number> hp.
2. RPM: <Insert number>.

K. Electrical Characteristics:

1. Volts: [115] [208] [230] [460] <Insert number> V.
2. Phase: [Single] [Three].
3. Hertz: [50] [60] <Insert number> Hz.
4. Full-Load Amperes: <Insert number> A.
5. Minimum Circuit Ampacity: <Insert number> A.
6. Maximum Overcurrent Protection: <Insert number> A.

2.14 SOURCE QUALITY CONTROL

- A. Test and inspect factory-assembled boilers, before shipping, according to [2010 ASME Boiler and Pressure Vessel Code] [CSA B51].
- B. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
- C. Allow Owner access to source quality-control testing of boilers. Notify DEN Projexct Manager 14 days in advance of testing.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance of the Work.
 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces for suitable conditions where boilers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

A. Equipment Mounting:

1. Install boilers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
2. Comply with requirements for vibration isolation and seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

B. Install gas-fired boilers according to NFPA 54.

C. Install oil-fired boilers according to NFPA 31.

D. Install in accordance with manufacturer's instructions.

E. Install circulator and diaphragm expansion tank on piping to the boiler.

F. Assemble boiler sections in sequence and seal between each section.

G. Assemble and install boiler trim.

H. Install electrical devices furnished with boiler but not specified to be factory mounted.

I. Install control wiring to field-mounted electrical devices.

3.3 CONNECTIONS

A. Piping installation requirements are specified in [**Section 232113 "Hydronic Piping"**] [**and**] [**Section 232213 "Steam and Condensate Heating Piping."**]. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to boiler to allow service and maintenance.

C. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas-train connection. Provide a reducer if required.

D. Connect oil piping full size to burner inlet with shutoff valve and union.

E. Connect hot-water piping to supply- and return-boiler tapplings with shutoff valve and union or flange at each connection.

F. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tapplings with shutoff valve and union or flange at each connection.

G. Install piping from safety relief valves to nearest floor drain.

- H. Install piping from safety valves to drip-pan elbow and to nearest floor drain.
- I. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
- J. Connect breeching full size to boiler outlet. Comply with requirements in Section 235116 "Fabricated Breechings and Accessories" for venting materials.
- K. Install flue-gas recirculation duct from vent to burner. Comply with requirements in Section 235123 "Gas Vents" for recirculation duct materials.

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections **[with the assistance of a factory-authorized service representative]**:
 - 1. Perform installation and startup checks according to manufacturer's written instructions.
 - 2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
 - b. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and **[water temperature] [steam pressure]**.
 - c. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Performance Tests:
 - 1. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
 - 2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment to comply.
 - 3. Perform field performance tests to determine capacity and efficiency of boilers.

- a. For dual-fuel boilers, perform tests for each fuel.
 - b. Test for full capacity.
 - c. Test for boiler efficiency at [**low fire 20, 40, 60, 80, 100, 80, 60, 40, and 20**] **<Insert range>** percent of full capacity. Determine efficiency at each test point.
4. Repeat tests until results comply with requirements indicated.
 5. Provide analysis equipment required to determine performance.
 6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are inadequate.
 7. Notify DEN Project Manager in advance of test dates.
 8. Document test results in a report and submit to DEN Project Manager.
- F. Boiler will be considered defective if it does not pass tests and inspections.
- G. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Occupancy Adjustments: When requested within [**12 months**] **<Insert time period>** of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain boilers. Refer to Section 017900 "Demonstration and Training."
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235223

SECTION 235233 - WATER-TUBE BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes packaged, factory-fabricated and -assembled, gas-fired, finned water-tube boilers, trim, and accessories for generating hot water.
- B. This Section includes packaged, water-tube boilers, trim, and accessories for generating **[hot water]** **[steam]** with the following configurations, burners, and outputs:
 - 1. **[Factory]** **[Field]** assembled.
 - 2. **[Atmospheric gas]** **[Forced-draft gas]** **[Oil]** **[Combination gas and oil]** burner.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: Provide data indicating general assembly, components, controls, safety controls, and wiring diagrams with electrical characteristics and connection requirements, and service connections.
 - 1. Include performance data, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
 - b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.

2. Wiring Diagrams: Power, signal, and control wiring.
3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.4 INFORMATIONAL SUBMITTALS

- A. Manufacturer Seismic Qualification Certification: Submit certification that boiler, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means, "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control test reports.
- C. Manufacturer's Certificate: Certify that units meet or exceed specified requirements.
- D. Field quality-control test reports. Indicate condition of equipment after start-up including control settings and performance chart of control system.
- E. Test Reports: Indicate specified performance and efficiency is met or exceeded. Provide factory combustion test data for substantially identical unit that includes boiler firing rate, overfire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.
- F. Warranty: Special warranty specified in this Section.
- G. Other Informational Submittals:

1. ASME "A" Stamp Certification and Report: Submit "A" stamp certificate of authorization as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.
2. Startup service reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers, components, and accessories to include in emergency, operation, and maintenance manuals.
 1. Include manufacturer's descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE SERVICE

- A. Provide service and maintenance of boilers for [**one (1)**] <Insert number> year from Date of Substantial Completion.

1.7 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum of five (5) years documented experience.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
- D. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
- E. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N, "Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers."
- F. I=B=R Compliance: Boilers shall be tested and rated according to HI's "Rating Procedure for Heating Boilers" and "Testing Standard for Commercial Boilers," with I=B=R emblem on a nameplate affixed to boiler.
- G. UL Compliance: Test boilers for compliance with [**UL 726, "Oil-Fired Boiler Assemblies."**] [**UL 726, "Oil-Fired Boiler Assemblies"** and **UL 795, "Commercial-Industrial Gas Heating Equipment."**] [**UL 795,**

"Commercial-Industrial Gas Heating Equipment."] Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

1.8 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.9 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Protect units before, during, and after installation from damage to casing by leaving factory shipping packaging in place until immediately prior to final acceptance.

1.10 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace heat exchangers damaged by thermal shock and vent dampers of boilers that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Heat Exchangers: Minimum [**twenty (20)**] <Insert number> years from date of Substantial Completion.
 - 2. Warranty Period for Vent Dampers: Minimum [**Five (5)**] <Insert number> years from date of Substantial Completion.
- B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace drums, tubes, headers, cabinets, atmospheric gas burners, and pressure vessels of boilers that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Drums, Tubes, Headers, Cabinets, and Atmospheric Gas Burner: Minimum [**five (5)**] <Insert number> years from date of Substantial Completion, pro rata.
 - 2. Warranty Period for Pressure Vessel: Minimum [**twenty (20)**] <Insert number> years from date of Substantial Completion, for thermal shock.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 FINNED WATER-TUBE BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [A. O. Smith Corporation.](#)
 2. [Ajax Boiler Inc.](#)
 3. [Allied Engineering Co.](#)
 4. [Laars Heating Systems Company.](#)
 5. [Lochinvar LLC.](#)
 6. [Patterson-Kelley.](#)
 7. [PRECISION Boilers, LLC.](#)
 8. [Raypak.](#)
 9. [RBI Water Heaters.](#)
 10. [RECO USA.](#)
 11. [Weben-Jarco, Inc.](#)
 12. **<Insert manufacturer's name.>**
 13. or approved equal.
- B. Description: Factory-fabricated, -assembled, and -tested boiler with tubes sealed into headers pressure tight, and set on a steel base; including insulated jacket, flue-gas vent, combustion-air intake connections, water supply and return connections, and controls.
- C. Heat Exchanger:
1. Finned **[copper]** **[steel]** **[copper-nickel]** tubing with stainless-steel baffles.
 2. **[Bronze]** **[Cast-iron]** **[Steel]** headers.
 3. **[Single]** **[Two]**-pass, **[horizontal]** **[vertical]** **[coil]** configuration.
 4. Tubes shall be sealed in header **[with silicone O-ring gaskets]** **[by welding]** **[by mechanically rolling tubes in header]**.
- D. Combustion Chamber Internal Insulation: Interlocking panels of refractory insulation, high-temperature cements, mineral fiber, and ceramic refractory tile for service temperatures to **2000 deg F (1100 deg C)**.
- E. Casing:
1. Jacket: **[Sheet metal]** **[Stainless steel]**, with snap-in or interlocking closures.
 2. Control Compartment Enclosure: NEMA 250, Type 1A.
 3. Finish: **[Baked enamel over primer]** **[Baked enamel over galvanizing]** **[Powder coated]**.
 4. Insulation: Minimum **[1-inch- (25-mm-)]** **[2-inch- (50-mm-)]** thick, mineral-fiber insulation surrounding the heat exchanger.
 5. Draft Hood: **[Integral]** **[External]**.
 6. Combustion-Air Connection: Inlet duct collar and sheet metal closure over burner compartment.

7. Mounting base to secure boiler[**with accessory for mounting on combustible surface**].
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

F. Burner:

1. Burner Tubes and Orifices: Stainless steel, for **[natural] [propane] gas.[Mount burner tubes in a slide-out burner drawer for ease of inspection.]**
 - a. Sealed Combustion: Factory-mounted centrifugal fan to draw outside air into boiler and discharge into burner compartment.
 - b. Direct Vent: Factory-mounted centrifugal fan to draw flue gas out of boiler and discharge into boiler vent.
2. Vertical Burner:
 - a. **[High-temperature stainless steel] [Ceramic]** to fire in a 360-degree pattern.
 - b. Burner shall have a viewing port for observation of burner operation and a factory-mounted centrifugal fan to supply **[room] [outside] air[through a replaceable 99 percent efficient (1-micrometer particles) filter]** to boiler burner.
 - c. Fan shall be controlled to prepurge and postpurge the combustion chamber before firing.
3. Gas Train: Control devices and **[full-modulation] [on-off] [low-high-low] [proportional]** control sequence shall comply with requirements in **[AGA] [ASME CSD-1] [FMG] [IRI] [UL]**. In addition to these requirements, include shutoff cock, pressure regulator, and control valve.
4. Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
5. Pilot: **[Standing] [Intermittent-electric-spark] [Hot-surface]** pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
6. Flue-Gas Recirculation Fans: Centrifugal fans on burner assembly to recirculate flue gas to decrease oxides of nitrogen emissions to less than **[30] <Insert value>** ppm.
 - a. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

G. Trim:

1. Aquastat Controllers: Operating[, **firing rate,**] and high limit.
2. Safety Relief Valve: ASME rated.

3. Pressure and Temperature Gage: Minimum **3-1/2-inch-** (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
4. Boiler Air Vent: **[Automatic] [Manual]**.
5. Drain Valve: Minimum **NPS 3/4 (DN 20)** hose-end gate valve.
6. Circulation Pump: Non-overloading, in-line pump with split-capacitor motor having thermal-overload protection and lubricated bearings; designed to operate at specified boiler pressures and temperatures.

H. Controls:

1. Refer to Section 230900 "Instrumentation and Control for HVAC."
2. Boiler operating controls shall include the following devices and features:
 - a. Control transformer.
 - b. Motorized Vent Damper: Interlocked with burner to open before burner starts. If damper fails to open, stop burner operation.
 - c. Set-Point Adjust: Set points shall be adjustable.
 - d. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 - e. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At **[0 deg F (minus 17 deg C)] <Insert temperature>** outside-air temperature, set supply-water temperature at **[200 deg F (93 deg C)] <Insert temperature>**; at **[60 deg F (15 deg C)] <Insert temperature>** outside-air temperature, set supply-water temperature at **[140 deg F (60 deg C)] <Insert temperature>**.
 - f. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
3. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
 - a. High Cutoff: **[Manual] [Automatic]** reset stops burner if operating conditions rise above maximum boiler design temperature.
 - b. Water Flow Switch: Automatic-reset paddle-switch shall prevent burner operation on low water flow.
 - c. Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.
 - d. Rollout Safety Switch: Factory mounted on boiler combustion chamber.
 - e. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
4. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.

- a. Monitoring: On/off status, [**common trouble alarm**] [**low water level alarm**] <Insert monitoring>.
- b. Control: On/off operation, [**hot water supply temperature set-point adjustment**] <Insert control>.
- c. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

2.2 [STEEL] [FLEXIBLE] WATER-TUBE BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [AESYS Technologies, LLC.](#)
 2. [Ajax Boiler Inc.](#)
 3. [Bryan Boilers: Bryan Steam LLC.](#)
 4. [Cleaver-Brooks.](#)
 5. [Parker Boiler Co.](#)
 6. [Rite Engineering & Mfg. Corp.](#)
 7. <Insert manufacturer's name.>
 8. or approved equal.
- B. Description: Factory-fabricated and [**field**]-assembled, water-tube boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, supply and return connections, and controls.
- C. Heat-Exchanger Design: Straight steel tubes rolled into steel headers.
1. Accessible head plates at both ends.
 2. Handholes[**or couplings**] in headers for water-side inspections.
 3. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
 4. Lifting lugs on top of boiler.
 5. Built-in air separator.
- D. Heat-Exchanger Design: Bent steel tubes [**swaged**] [**welded**] into steel headers[**with membrane waterwall design**].
1. Limit tube configurations to [**two**] [**four**] <Insert number>.
 2. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
 3. Accessible inspection ports in drum, mud legs, and tube manifolds.
 4. Lifting lugs on top of boiler.
 5. Built-in air separator.
- E. Combustion Chamber: Equipped with minimum [2-1/2-inch (64-mm)] [3-inch (75-mm)] [4-inch (100-mm)], 2700 deg F (1482 deg C) poured refractory on floor and minimum

[2-inch (50-mm)] [3-1/2-inch (89-mm)] lap-jointed cast refractory with fiber-blanket joint seals on side walls. Combustion chamber shall have flame observation ports in front [and] [or] back.

F. Casing:

1. Insulation: Minimum [2-inch (50-mm) **thick, lightweight refractory; 1-inch (25-mm) thick insulating board; galvanized-steel membrane, and**] 2-inch (50-mm) thick, mineral-fiber insulation surrounding the heat exchanger and combustion chamber.
2. Top Flue Connection: Constructed of [aluminized] [stainless] steel.
3. Jacket: Mirror-finish stainless steel, with screw-fastened closures.
4. Jacket: [Galvanized] sheet metal, with screw-fastened closures and [baked-enamel] [powder-coated] protective finish.
5. Mounting base to secure boiler to concrete base.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.
6. Control Compartment Enclosure: NEMA 250, Type 1A.

G. [Draft Diverter] [Barometric Damper]: Galvanized-steel assembly with flue-gas thermometer.

H. Burner:

1. Burner and Orifices: [Stainless steel] [Cast iron], for [natural] [propane] gas.
2. Gas Train: Control devices and [full-modulation] [on-off] [low-high-low] control sequence shall comply with requirements in [AGA] [ASME CSD-1] [FMG] [IRI] [UL].
3. Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
4. Pilot: [Standing] [Intermittent-electric-spark] pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

I. Burner:

1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for [natural] [propane] gas. [Mount burner on hinged access door to permit access to combustion chamber.]
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
 - a. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- 1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 3. Gas Train: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[AGA]** **[ASME CSD-1]** **[FMG]** **[IRI]** **[UL]**.
 4. Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
 5. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
 - a. Maximum Oxides of Nitrogen Emissions: **[20]** **[30]** **<Insert value>** ppm.
- J. Burner:
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil.**[Mount burner on hinged access door to permit access to combustion chamber.]**
 2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
 - a. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 3. Oil Supply: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FMG]** **[IRI]** **[UL]**.
 - a. Oil Pump: Two-stage, gear-type oil pump **[integral to and directly driven by blower]** shall be capable of producing **300-psig** (2070-kPa) discharge pressure and **15-inch Hg** (50.7-kPa) vacuum.
 - b. Oil Piping Specialties:
 - 1) Suction-line, manual, gate valve.
 - 2) Removable-mesh oil strainer.
 - 3) **0- to 30-inch Hg** (0- to 101.3-kPa) vacuum; **0- to 30-psig** (0- to 207-kPa) vacuum-pressure gage.
 - 4) **0- to 300-psig** (0- to 2070-kPa) oil-nozzle pressure gage.
 - 5) Nozzle-line, solenoid-safety-shutoff oil valve.
 4. Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid using **[cadmium sulfide]** **[UV scanner]** flame-safety control.
 5. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.

- a. Maximum Oxides of Nitrogen Emissions: **[30]** <Insert value> ppm.

K. Burner:

1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil and **[natural]** **[propane]** gas.**[Mount burner on hinged access door to permit access to combustion chamber.]**
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
 - a. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Oil Supply: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FMG]** **[IRI]**.
 - a. Oil Pump: Two-stage, gear-type oil pump **[integral to and directly driven by blower]** shall be capable of producing **300-psig** (2070-kPa) discharge pressure and **15-inch Hg** (50.7-kPa) vacuum.
 - b. Oil Piping Specialties:
 - 1) Suction-line, manual, gate valve.
 - 2) Removable-mesh oil strainer.
 - 3) **0- to 30-inch Hg** (0- to 101.3-kPa) vacuum; **0- to 30-psig** (0- to 207-kPa) vacuum-pressure gage.
 - 4) **0- to 300-psig** (0- to 2070-kPa) oil-nozzle pressure gage.
 - 5) Nozzle-line, solenoid-safety-shutoff oil valve.
4. Gas Train: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FMG]** **[IRI]** **[UL]**.
5. Gas Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
6. Oil Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with **[cadmium sulfide]** **[UV scanner]** flame-safety control.
7. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
 - a. Maximum Oxides of Nitrogen Emissions: **[20]** **[30]** <Insert value> ppm.

L. Trim:

1. Include devices sized to comply with **[ANSI B31.1, "Power Piping]** **[ANSI B31.9, "Building Services Piping]."**

2. Aquastat Controllers: Operating[, **firing rate**,] and high limit.
3. Safety Relief Valve: ASME rated.
4. Pressure and Temperature Gage: Minimum **3-1/2-inch-** (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
5. Boiler Air Vent: [**Automatic**] [**Manual**].
6. Drain Valve: Minimum **NPS 3/4** (DN 20) hose-end gate valve.
7. Tankless Heater: [**Carbon-steel**] [**Bronze**] header with copper-tube heat exchanger, mounted in a port of upper drum and sealed with fiber gasket.
 - a. Tappings **NPS 2** (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
 - b. Tappings **NPS 2-1/2** (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

M. Trim:

1. Include devices sized to comply with [**ANSI B31.1, "Power Piping**] [**ANSI B31.9, "Building Services Piping**]."
2. Pressure Controllers: Operating[, **firing rate**,] and high limit.
3. Safety Relief Valve:
 - a. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
 - b. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
 - 1) Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
4. Pressure Gage: Minimum **3-1/2-inch** (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
5. Water Column: Minimum **12-inch** (300-mm) glass gage with shutoff cocks.
6. Drain Valves: Minimum **NPS 3/4** (DN 20) or nozzle size with hose-end connection.
7. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle.**[Blowdown valves shall be combination of slow and quick acting as required by ANSI B31.1.]**
8. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size or larger than nozzle. Valves larger than **NPS 2** (DN 50) shall have rising stem.
9. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.
10. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in a port of upper manifold and sealed with fiber gasket.

- a. Tappings **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
- b. Tappings **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

N. Controls:

1. Refer to Section 230900 "Instrumentation and Control for HVAC."
2. Boiler operating controls shall include the following devices and features:
 - a. Control transformer.
 - b. Set-Point Adjust: Set points shall be adjustable.
 - c. Operating Pressure Control: Factory wired and mounted to cycle burner.
 - d. Low-Water Cutoff and Pump Control: Cycle feedwater pump(s) for makeup water control.
 - e. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 - f. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At **[0 deg F (minus 17 deg C)]** **<Insert temperature>** outside-air temperature, set supply-water temperature at **[200 deg F (93 deg C)]** **<Insert temperature>**; at **[60 deg F (15 deg C)]** **<Insert temperature>** outside-air temperature, set supply-water temperature at **[140 deg F (60 deg C)]** **<Insert temperature>**.
 - g. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
 - h. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
3. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
 - a. High Cutoff: **[Manual] [Automatic]** reset stops burner if operating conditions rise above maximum boiler design **[temperature] [pressure]**.
 - b. Low-Water Cutoff Switch: **[Electronic] [Float and electronic]** probe shall prevent burner operation on low water. Cutoff switch shall be **[manual] [automatic]**-reset type.
 - c. Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.
 - d. Rollout Safety Switch: Factory mounted on boiler combustion chamber.
 - e. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
4. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.

- a. Monitoring: On/off status, [**common trouble alarm**] [**low water level alarm**] <Insert monitoring>.
- b. Control: On/off operation, [**hot water supply temperature set-point adjustment**] [**steam pressure adjustment**] <Insert control>.
- c. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

2.3 ELECTRICAL POWER

- A. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in electrical Sections.
- B. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
 1. House in NEMA 250, Type [1] <Insert type> enclosure.
 2. Wiring shall be numbered and color-coded to match wiring diagram.
 3. Install factory wiring outside of an enclosure in a [**metal**] raceway.
 4. Field power interface shall be to [**wire lugs**] [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**].
 5. Provide branch power circuit to each motor and to controls[**with disconnect switch or circuit breaker**].
 6. Provide each motor with overcurrent protection.

2.4 VENTING KITS

- A. Vent Damper: Motorized, UL listed for use on atmospheric burner boiler equipped with draft hood; motor to open and close damper; stainless-steel vent coupling and damper blade; keyed wiring harness connector plug; and dual-position switches to permit burner operation.
- B. Kit: Complete system, [**ASTM A 959, Type 29-4C**] stainless steel, pipe, vent terminal, thimble, indoor plate, vent adapter, condensate trap, and sealant.
- C. Combustion-Air Intake: Stainless steel, pipe, vent terminal with screen, inlet air coupling, and sealant.

2.5 CAPACITIES AND CHARACTERISTICS

- A. Heating Medium: [**Hot water**] [**Steam**].
- B. Design Pressure and Temperature Rating: [**160 psig (1100 kPa), 250 deg F (120 deg C)**] <Insert values>.

- C. Design Pressure Rating: [60 psig (420 kPa)] [100 psig (690 kPa)] [140 psig (966 kPa)] [160 psig (1100 kPa)] <Insert value>.
- D. Design Pressure Rating: [15 psig (104 kPa)] [150 psig (1035 kPa)] [250 psig (1725 kPa)] <Insert value>.
- E. Safety Relief Valve Setting: <Insert psig (kPa).>
- F. Entering-Water Temperature: <Insert deg F (deg C).>
- G. Leaving-Water Temperature: <Insert deg F (deg C).>
- H. Design Water Flow Rate: <Insert gpm (L/s).>
- I. Design Pressure Drop: <Insert psig (kPa).>
- J. Steam Operating Pressure: <Insert psig (kPa).>
- K. Steam Flow Rate: <Insert lb/h (kg/s).>
- L. Minimum Efficiency AFUE: <Insert number> percent.
- M. Minimum Thermal Efficiency: <Insert number> percent.
- N. Minimum Combustion Efficiency: <Insert number> percent.
- O. Number of Passes: [One] [Two] <Insert number>.
- P. AGA Input: <Insert MBh (kW).>
- Q. I=B=R Input: <Insert MBh (kW).>
- R. Gas Input: <Insert cfh (mL/s).>
- S. Oil Input: <Insert gph (mL/s).>
- T. DOE Output Capacity: <Insert MBh (kW).>
- U. AGA Output Capacity: <Insert MBh (kW).>
- V. Net I=B=R Output Capacity: <Insert MBh (kW).>
- W. Gross I=B=R Output Capacity: <Insert MBh (kW).>
- X. Equivalent Direct Radiation: <Insert EDR (W).>
- Y. Tankless Water Heater:
 - 1. Design Water Flow: <Insert gpm (L/s).>
 - 2. Design Pressure Drop: <Insert psig (kPa).>
 - 3. Entering-Water Temperature: <Insert deg F (deg C).>

4. Leaving-Water Temperature: <Insert deg F (deg C).>

Z. Burner Blower:

1. Motor Horsepower: <Insert value.>
2. RPM: <Insert value.>

AA. Electrical Characteristics:

1. Volts: [115] [208] [230] [460] <Insert value> V.
2. Phase: [Single] [Three].
3. Hertz: [50] [60].
4. Full-Load Amperes: <Insert value.>
5. Minimum Circuit Ampacity: <Insert value.>
6. Maximum Overcurrent Protection: <Insert amperage.>

2.6 SOURCE QUALITY CONTROL

- A. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.
- B. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
- C. Allow Owner access to source quality-control testing of boilers. Notify DEN Project Manager 14 days in advance of testing.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before boiler installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting boiler performance, maintenance, and operations.
 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces for suitable conditions where boilers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

- A. Equipment Mounting:

1. Install boilers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Install gas-fired boilers according to NFPA 54.
- C. Install oil-fired boilers according to NFPA 31.
- D. Install in accordance with manufacturer's instructions.
- E. Assemble boiler tubes in sequence and seal each tube joint.
- F. Assemble and install boiler trim.
- G. Install electrical devices furnished with boiler but not specified to be factory mounted.
- H. Install control wiring to field-mounted electrical devices.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to boiler to allow service and maintenance.
- C. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
- D. Connect oil piping full size to burner inlet with shutoff valve and union.
- E. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
- F. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings with shutoff valve and union or flange at each connection.
- G. Install piping from safety relief valves to nearest floor drain.
- H. Install piping from safety valves to drip-pan elbow and to nearest floor drain.
- I. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
- J. Boiler Flue Venting:

1. Install venting kit and combustion-air intake.
 2. Connect full size to boiler connections. [**Comply with requirements in Section 235123 "Gas Vents."**]
- K. Connect breeching to full size of boiler outlet. Comply with requirements in Section 235116 "Fabricated Breechings and Accessories" for venting materials.
- L. Install flue-gas recirculation duct from vent to burner. Comply with requirements in Section 235123 "Gas Vents." for recirculation duct materials.
- M. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- N. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- 3.4 FIELD QUALITY CONTROL
- A. Perform tests and inspections and prepare test reports.
1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
1. Perform installation and startup checks according to manufacturer's written instructions.
 2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
 3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
 - b. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and [**water temperature**] [**steam pressure**].
 - c. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Remove and replace malfunctioning units and retest as specified above.
- D. Occupancy Adjustments: When requested within [**12 months of date of Substantial Completion**] <Insert time period>, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other than normal occupancy hours for this purpose.
- E. Performance Tests:

1. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
3. Perform field performance tests to determine the capacity and efficiency of the boilers.
 - a. For dual-fuel boilers, perform tests for each fuel.
 - b. Test for full capacity.
 - c. Test for boiler efficiency at [**low fire 20, 40, 60, 80, 100, 80, 60, 40 and 20**] **<Insert range>** percent of full capacity. Determine efficiency at each test point.
4. Repeat tests until results comply with requirements indicated.
5. Provide analysis equipment required to determine performance.
6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
7. Notify DEN Project Manager in advance of test dates.
8. Document test results in a report and submit to DEN Project Manager.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain boilers. [**Video training sessions.**] Refer to Section 017900 "Demonstration and Training."
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235233

SECTION 235239 - FIRE-TUBE BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes packaged, factory-fabricated and -assembled boilers, trim, and accessories for generating [**hot water**] [**steam**] with the following configurations and burners:
 - 1. [**Horizontal, fire-tube**] [**Vertical, fire-tube**] [**Fire-box**] boiler.
 - 2. [**Gas**] [**Oil**] [**Combination gas and oil**] burner.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: Provide data indicating general assembly, components, controls, safety controls, and wiring diagrams with electrical characteristics and connection requirements, and service connections.
 - 1. Include performance data, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.

Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

- 1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
 - b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.

2. Include diagrams for power, signal, and control wiring.
3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.4 INFORMATIONAL SUBMITTALS

- A. Manufacturer Seismic Qualification Certification: Submit certification that boiler, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control reports.
- C. Manufacturer's Certificate: Certify that units meet or exceed specified requirements.
- D. Field quality-control reports. Indicate condition of equipment after start-up including control settings and performance chart of control system.
- E. Test Reports: Indicate specified performance and efficiency is met or exceeded. Provide factory combustion test data for substantially identical unit that includes boiler firing rate, overfire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.
- F. Warranty: Special warranty specified in this Section.
- G. Other Informational Submittals:

1. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.
2. Startup service reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers, components, and accessories to include in emergency, operation, and maintenance manuals.
 1. Include manufacturer's descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIALS

- A. Provide wire brush and [**one piece**] [**hinged**] handle for tube cleaning.

1.7 MAINTENANCE SERVICE

- A. Provide service and maintenance of boilers for [**one (1)**] <Insert number> year from Date of Substantial Completion.

1.8 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum of five (5) years documented experience.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
- D. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
- E. UL Compliance: Test Boilers for compliance with [**UL 726, "Oil-Fired Boiler Assemblies."**] [**UL 726, "Oil-Fired Boiler Assemblies"** and **UL 795, "Commercial-Industrial Gas Heating Equipment."**] [**UL 795, "Commercial-Industrial Gas Heating Equipment."**] Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

1.9 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.10 DELIVERY, STORAGE AND PROTECTION

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Protect units before, during, and after installation from damage to casing by leaving factory shipping packaging in place until immediately prior to final acceptance.

1.11 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace front- and rear-door refractories and heat exchangers of boilers that fail in materials or workmanship within specified warranty period.
 - 1. Horizontal, Fire-Tube and Fire-Box Boilers: Refractory in front and rear doors, minimum **[ten (10)] <Insert number>** years from date of startup by factory-authorized personnel.
 - 2. Vertical, Fire-Tube Boilers and Heat Exchanger: Minimum**[five (5)] <Insert number>** years from date of Substantial Completion, if following water-treatment program recommended by manufacturer.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 HORIZONTAL, FIRE-TUBE BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [AESYS Technologies, LLC.](#)
 - 2. [Burnham Hydronics.](#)
 - 3. [Cleaver-Brooks.](#)
 - 4. [Hurst Boiler & Welding Company, Inc.](#)
 - 5. [Iron Fireman Combustion Products.](#)
 - 6. [Lattner Boiler Manufacturing.](#)
 - 7. [L.E.S., Inc.](#)

8. [Sellers Engineering Co.](#)
 9. [Superior Boiler Works, Inc.](#)
 10. <Insert manufacturer's name>.
 11. or approved equal.
- B. Description: Factory-fabricated, -assembled, and -tested, horizontal, fire-tube boilers with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, water supply and return connections, and controls.
- C. Pressure Vessel Design: Straight, steel tubes [**rolled**] [**welded**] into steel headers. [**Three**] [**Four**] passes with [**dry**] [**wet**]-back design. Minimum heat-exchanger surface of 5 sq. ft./bhp (2.1 sq. m/10 kW). Include the following accessories:
1. Handholes for water-side inspections.
 2. Lifting lugs on top of boiler.
 3. Minimum NPS 1 (DN 25) hose-end drain valves at shell low point.
 4. Tappings or flanges for supply- and return-water piping.
 5. Built-in air separator.
 6. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
 7. Tappings for steam supply, makeup, level controls, and chemical treatment.
- D. Front and Rear Doors:
1. [**Bolted**] [**Hinged**] [**Davited**], sealed with heat-resistant gaskets and fastened with lugs and cap screws.
 2. Designed so tube sheets and flues are fully accessible for inspection or cleaning when doors are open.
 3. Include observation ports in doors at both ends of boiler for inspection of flame conditions.
 4. Door [**refractory**] [**insulation**] shall be accessible for inspection and maintenance.
- E. Casing:
1. Insulation: Minimum 2-inch- (50-mm-) thick, mineral-fiber insulation surrounding the boiler shell.
 2. Flue Connection: Flange at top of boiler.
 3. Jacket: [**Galvanized sheet**] [**Sheet**] metal, with screw-fastened closures and [**baked-enamel**] [**powder-coated**] protective finish.
 4. Mounting base to secure boiler to concrete base.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.
 5. Control Compartment Enclosure: NEMA 250, Type [1] [4] [4X] [12] <Insert type>.

- F. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer having a minimum **3-1/2-inch-** (89-mm-) diameter dial.

2.2 VERTICAL, FIRE-TUBE BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Columbia Boiler Company.](#)
2. [Fulton Boiler Works, Inc.](#)
3. [Hurst Boiler & Welding Company, Inc.](#)
4. [L.E.S., Inc.](#)
5. [Lattner Boiler Manufacturing.](#)
6. [Lochinvar Corporation.](#)
7. [Patterson-Kelley.](#)
8. [PRECISION Boilers, LLC.](#)
9. [PVI Industries, LLC.](#)
10. **<Insert manufacturer's name>.**
11. or approved equal.

- B. Description: Factory-fabricated, -assembled, and -tested, vertical, fire-tube boilers with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, water supply and return connections, and controls.

- C. Pressure Vessel Design: Straight, steel pipe welded in a concentric pattern to separate flue-gas and heating media to form **[two]** **[four]** passes with welded fins to improve heat transfer in secondary flue-gas passages. Include the following accessories:

1. Handholes for water-side inspections.
2. Lifting lugs on top of boiler.
3. Minimum **NPS 1 (DN 25)** hose-end drain valves at water passage low point.
4. Tappings or flanges for supply- and return-water piping.
5. Built-in air separator.
6. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
7. Tappings for steam supply, makeup, level controls, and chemical treatment.

- D. Combustion Chamber: Equipped with flame retainer to lengthen flame-residence time.

- E. Casing:

1. Insulation: Minimum **4-inch-** (100-mm-) thick, mineral-fiber insulation surrounding the heat exchanger and combustion chamber.
2. Flue Connection: Top connection, constructed of **[aluminized]** **[stainless]** steel.
3. Jacket: Mirror-finish stainless steel with screw-fastened closures.
4. Jacket: **[Galvanized sheet]** **[Sheet]** metal, with screw-fastened closures and **[baked-enamel]** **[powder-coated]** protective finish.
5. Mounting base to secure boiler to concrete base.

- a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.
6. Control Compartment Enclosure: NEMA 250, Type [1] [4] [4X] [12] <Insert type>.
- F. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer having a minimum 3-1/2-inch- (89-mm-) diameter dial.

2.3 FIRE-BOX BOILERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Hurst Boiler & Welding Company, Inc.](#)
 2. [L.E.S., Inc.](#)
 3. <Insert manufacturer's name>.
 4. or approved equal.
- B. Description: Factory-fabricated, -assembled, and -tested, fire-box boilers with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, water supply and return connections, and controls.
- C. Pressure Vessel Design: Straight, steel tubes **[rolled]** **[welded]** into steel headers. Three passes with wet-back design. Minimum heat-exchanger surface of 5 sq. ft./bhp (2.1 sq. m/10 kW). Include the following features and accessories:
 1. Tube Size and Thickness: **[Minimum NPS 2 (DN 50), minimum 0.105 inch (2.667 mm) thick]** <Insert size and thickness>.
 2. Brass washout plugs.
 3. Steel turbulators.
 4. Lifting lugs on top of boiler.
 5. Minimum **NPS 1 (DN 25)** hose-end drain valves at shell low point.
 6. Tappings or flanges for supply- and return-water piping.
 7. Built-in air separator.
 8. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
 9. Tappings for steam supply, makeup, level controls, and chemical treatment.
- D. Combustion Chamber: Welded steel, **[waterwall and -floor design]** **[water-leg design with refractory insulation poured in the floor]**. Flame observation port.
- E. Casing:
 1. Insulation: Minimum **2-inch- (50-mm-)** thick, **[foil-backed,]** mineral-fiber insulation surrounding the boiler shell.

2. Insulated removable smoke boxes and reversing chamber cover.
3. Flue Connection: Steel **[top]** **[rear]**.
4. Jacket: Sheet metal, with screw-fastened closures and **[baked-enamel]** **[powder-coated]** protective finish.
5. Control Compartment Enclosure: NEMA 250, Type **[1]** **[1A]** **[4]** **[4X]** **[12]** **<Insert type>**.
6. Mounting base to secure boiler to concrete base.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

- F. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer having a minimum **3-1/2-inch-** (89-mm-) diameter dial.

2.4 FORCED-DRAFT GAS BURNERS

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for **[natural]** **[propane]** gas. **[Mount burner on hinged access door to permit access to combustion chamber.]**
- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
1. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- C. Gas Train: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FMG]** **[IRI]** **[UL]**.
- D. Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
- E. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
1. Maximum Oxides of Nitrogen Emissions: **[20]** **[30]** **<Insert value>** ppm.

2.5 OIL BURNERS

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil. **[Mount burner on hinged access door to permit access to combustion chamber.]**

- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
1. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- C. Oil Supply: Control devices and **[modulating]** **[on-off]** **[low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1]** **[FMG]** **[IRI]** **[UL]**.
1. Oil Pump: Two-stage, gear-type oil pump **[integral to and directly driven by blower]** shall be capable of producing **300-psig** (2070-kPa) discharge pressure and **15-inch Hg** (50.7-kPa) vacuum.
 2. Oil Piping Specialties:
 - a. Suction-line, manual, gate valve.
 - b. Removable-mesh oil strainer.
 - c. **0- to 30-inch Hg** (0- to 101.3-kPa) vacuum; **0- to 30-psig** (0- to 207-kPa) vacuum-pressure gage.
 - d. **0- to 300-psig** (0- to 2070-kPa) oil-nozzle pressure gage.
 - e. Nozzle-line, solenoid-safety-shutoff oil valve.
- D. Pilot: **[Intermittent]** **[Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with **[cadmium sulfide]** **[UV scanner]** flame-safety control.
- E. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
1. Maximum Oxides of Nitrogen Emissions: **[30]** **<Insert value>** ppm.

2.6 COMBINATION GAS AND OIL BURNERS

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil and **[natural]** **[propane]** gas. **[Mount burner on hinged access door to permit access to combustion chamber.]**
- B. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
1. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

- C. Oil Supply: Control devices and **[modulating] [on-off] [low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1] [FMG] [IRI] [UL]**.
1. Oil Pump: Two-stage, gear-type oil pump **[integral to and directly driven by blower]** shall be capable of producing **300-psig (2070-kPa)** discharge pressure and **15-inch Hg (50.7-kPa)** vacuum.
 2. Oil Piping Specialties:
 - a. Suction-line, manual, gate valve.
 - b. Removable-mesh oil strainer.
 - c. **0- to 30-inch Hg (0- to 101.3-kPa)** vacuum; **0- to 30-psig (0- to 207-kPa)** vacuum-pressure gage.
 - d. **0- to 300-psig (0- to 2070-kPa)** oil-nozzle pressure gage.
 - e. Nozzle-line, solenoid-safety-shutoff oil valve.
- D. Gas Train: Control devices and **[modulating] [on-off] [low-high-low]** control sequence shall comply with requirements in **[ASME CSD-1] [FMG] [IRI] [UL]**.
- E. Gas Pilot: **[Intermittent] [Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
- F. Oil Pilot: **[Intermittent] [Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with **[cadmium sulfide] [UV scanner]** flame-safety control.
- G. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
1. Maximum Oxides of Nitrogen Emissions: **[20] [30] <Insert value>** ppm.

2.7 TRIM

- A. Include devices sized to comply with **[ANSI B31.1, "Power Piping] [ANSI B31.9, "Building Services Piping]."**
- B. Aquastat Controllers: Operating[, **firing rate,**] and high limit.
- C. Safety Relief Valve: ASME rated.
- D. Pressure and Temperature Gage: Minimum **3-1/2-inch- (89-mm-)** diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
- E. Boiler Air Vent: **[Automatic] [Manual]**.
- F. Drain Valve: Minimum **NPS 3/4 (DN 20)** hose-end gate valve.
- G. Tankless Heater: **[Carbon-steel] [Bronze]** header with copper-tube heat exchanger, mounted in a port of upper drum and sealed with fiber gasket.

1. Tappings **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
2. Tappings **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

2.8 TRIM

- A. Include devices sized to comply with [**ANSI B31.1, "Power Piping]** [**ANSI B31.9, "Building Services Piping]."**
- B. Pressure Controllers: Operating[, **firing rate,**] and high limit.
- C. Safety Relief Valve:
 1. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
 2. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
 - a. Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
- D. Pressure Gage: Minimum **3-1/2-inch (89-mm)** diameter. Gage shall have normal operating pressure about 50 percent of full range.
- E. Water Column: Minimum **12-inch (300-mm)** glass gage with shutoff cocks.
- F. Drain Valves: Minimum **NPS 3/4 (DN 20)** or nozzle size with hose-end connection.
- G. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle. [**Blowdown valves shall be combination of slow and quick acting as required by ANSI B31.1.]**
- H. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size or larger than nozzle. Valves larger than **NPS 2 (DN 50)** shall have rising stem.
- I. Stop-Check Valves: Factory-installed, stop-check valve and stop valve for field installation at boiler outlet with free-blow drain valve for field installation between the two valves and visible when operating stop-check valve.
- J. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in a port of upper manifold and sealed with fiber gasket.
 1. Tappings **NPS 2 (DN 50)** and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.

2. Tappings **NPS 2-1/2 (DN 65)** and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

2.9 CONTROLS

- A. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC."
- B. Boiler operating controls shall include the following devices and features:
 1. Control transformer.
 2. Set-Point Adjust: Set points shall be adjustable.
 3. Operating Pressure Control: Factory wired and mounted to cycle burner.
 4. Low-Water Cutoff and Pump Control: [**Cycle feedwater pump(s)**] [**Operate feedwater pump(s) continuously and modulate valve**] for makeup water control.
 5. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 6. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At [0 deg F (minus 17 deg C)] **<Insert temperature>** outside-air temperature, set supply-water temperature at [200 deg F (93 deg C)] **<Insert temperature>**; at [60 deg F (15 deg C)] **<Insert temperature>** outside-air temperature, set supply-water temperature at [140 deg F (60 deg C)] **<Insert temperature>**.
 7. Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
 - a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
- C. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
 1. High Cutoff: [**Manual**] [**Automatic**] reset stops burner if operating conditions rise above maximum boiler design [**temperature**] [**pressure**].
 2. Low-Water Cutoff Switch: [**Electronic**] [**Float and electronic**] probe shall prevent burner operation on low water. Cutoff switch shall be [**manual**] [**automatic**]-reset type.
 3. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
- D. Building Automation System Interface: Factory-install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
 1. Hardwired Points:

- a. Monitoring: On/off status, [**common trouble alarm**] [**low water level alarm**] <Insert monitoring>.
 - b. Control: On/off operation, [**hot water supply temperature set-point adjustment**] [**steam pressure adjustment**] <Insert control>.
2. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

2.10 ELECTRICAL POWER

- A. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in electrical Sections.
- B. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
1. House in NEMA 250, Type [1] [4] [4X] [12] <Insert type> enclosure.
 2. Wiring shall be numbered and color-coded to match wiring diagram.
 3. Install wiring outside of an enclosure in a [**metal**] raceway.
 4. Field power interface shall be to [**wire lugs**] [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**].
 5. Provide branch power circuit to each motor and to controls[**with a disconnect switch or circuit breaker**].
 6. Provide each motor with overcurrent protection.

2.11 CAPACITIES AND CHARACTERISTICS

- A. Heating Medium: [**Hot water**] [**Steam**].
- B. Design Pressure Rating: [30 psig (207 kPa)] [60 psig (420 kPa)] [100 psig (690 kPa)] [125 psig (860 kPa)] [140 psig (966 kPa)] [160 psig (1100 kPa)] <Insert value>.
- C. Design Pressure Rating: [15 psig (104 kPa)] [150 psig (1035 kPa)] [200 psig (1380 kPa)] [250 psig (1725 kPa)] [300 psig (2070 kPa)] [350 psig (2415 kPa)] <Insert value>.
- D. Safety Relief Valve Setting: <Insert psig (kPa).>
- E. Entering-Water Temperature: <Insert deg F (deg C).>
- F. Leaving-Water Temperature: <Insert deg F (deg C).>
- G. Design Water Flow Rate: <Insert gpm (L/s).>
- H. Design Pressure Drop: <Insert psig (kPa).>

- I. Steam Operating Pressure: <Insert psig (kPa).>
- J. Steam Flow Rate: <Insert lb/h (kg/s).>
- K. Minimum Efficiency AFUE: <Insert number> percent.
- L. Minimum Thermal Efficiency: <Insert number> percent.
- M. Minimum Combustion Efficiency: <Insert number> percent.
- N. Number of Passes: [Two] [Four] <Insert number>.
- O. AGA Input: <Insert MBh (kW).>
- P. I=B=R Input: <Insert MBh (kW).>
- Q. Gas Input: <Insert cfh (mL/s).>
- R. Oil Input: <Insert gph (mL/s).>
- S. AGA Output Capacity: <Insert MBh (kW).>
- T. DOE Output Capacity: <Insert MBh (kW).>
- U. Equivalent Direct Radiation: <Insert EDR (W).>
- V. Tankless Water Heater:
 - 1. Design Water Flow: <Insert gpm (L/s).>
 - 2. Design Pressure Drop: <Insert psig (kPa).>
 - 3. Entering-Water Temperature: <Insert deg F (deg C).>
 - 4. Leaving-Water Temperature: <Insert deg F (deg C).>
- W. Burner Blower:
 - 1. Motor Horsepower: <Insert value.>
 - 2. RPM: <Insert value.>
- X. Electrical Characteristics:
 - 1. Volts: [115] [208] [230] [460] <Insert value> V.
 - 2. Phase: [Single] [Three].
 - 3. Hertz: [50] [60].
 - 4. Full-Load Amperes: <Insert value.>
 - 5. Minimum Circuit Ampacity: <Insert value.>
 - 6. Maximum Overcurrent Protection: <Insert amperage.>

2.12 SOURCE QUALITY CONTROL

- A. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.
- B. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
- C. Allow Owner access to source quality-control testing of boilers. Notify DEN Project Manager 14 days in advance of testing.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before boiler installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting boiler performance, maintenance, and operations.
 - 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces for suitable conditions where boilers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

- A. Equipment Mounting:
 - 1. Install boilers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Install gas-fired boilers according to NFPA 54.
- C. Install oil-fired boilers according to NFPA 31.
- D. Install in accordance with manufacturer's instructions.
- E. Assemble and install boiler trim.

- F. Install electrical devices furnished with boiler but not specified to be factory mounted.
- G. Install control wiring to field-mounted electrical devices.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to boiler to allow service and maintenance.
- C. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
- D. Connect oil piping full size to burner inlet with shutoff valve and union.
- E. Connect hot-water piping to supply- and return-boiler tapplings with shutoff valve and union or flange at each connection.
- F. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tapplings with shutoff valve and union or flange at each connection.
- G. Install piping from safety relief valves to nearest floor drain.
- H. Install piping from safety valves to drip-pan elbow and to nearest floor drain.
- I. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
- J. Connect breeching full size to boiler outlet. Comply with requirements in Section 235116 "Fabricated Breechings and Accessories" for venting materials.
- K. Install flue-gas recirculation duct from vent to burner. Comply with requirements in Section 235123 "Gas Vents" for recirculation duct materials.
- L. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- M. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

- A. Testing Agency: **[Owner will engage]** **[Engage]** a qualified testing agency to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Perform installation and startup checks according to manufacturer's written instructions.
 2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
 3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
 - b. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and [**water temperature**] [**steam pressure**].
 - c. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Prepare test and inspection reports.
- F. Occupancy Adjustments: When requested within [**12 months of date of Substantial Completion**] <Insert time period>, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <Insert number> visits to Project during other than normal occupancy hours for this purpose.
- G. Performance Tests:
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
 2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
 3. Perform field performance tests to determine the capacity and efficiency of boilers.
 - a. For dual-fuel boilers, perform tests for each fuel.
 - b. Test for full capacity.
 - c. Test for boiler efficiency at [**low fire, 20, 40, 60, 80, 100, 80, 60, 40 and 20**] <Insert range> percent of full capacity. Determine efficiency at each test point.
 4. Repeat tests until results comply with requirements indicated.
 5. Provide analysis equipment required to determine performance.

6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
7. Notify DEN Project Manager in advance of test dates.
8. Document test results in a report and submit to DEN Project Manager.

3.5 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train] Owner's maintenance personnel to adjust, operate, and maintain boilers.[Video training sessions.]** Refer to Section 017900 "Demonstration and Training."

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235239

SECTION 235313 - BOILER FEEDWATER PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes the following:
 - 1. Feedwater pumps and receivers.
 - 2. Vacuum-type feedwater pumps and receivers.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITION

- A. NPSH: Net-positive suction head.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacity, temperature and NPSH required, pump performance curves with selection points clearly indicated, and furnished specialties and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Include plans, elevations, sections, details, dimensions, weights, loadings, required clearances, method of field assembly, and attachments to other work.
 - 1. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
 - 2. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Manufacturer Seismic Qualification Certification: Submit certification that feedwater equipment, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
1. Basis of Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of internal and external parts during a seismic event."
 - b. The term "withstand" means, "The unit will remain in place without separation of internal and external parts during a seismic event and the unit will be fully operational after the event."
2. Dimensioned Outline Drawings of Equipment: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which certification is based and their installation requirements.
- B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For feedwater equipment to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Minimum one or 10% of quantity pumps delivered.

1.8 QUALITY ASSURANCE

- A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

- B. Regulatory Requirements: Fabricate and test unit according to ASME PTC 12.1, "Closed Feedwater Heaters."
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- D. ASME Compliance: **[ASME B31.1, "Power Piping," for systems more than 15 psig (104 kPa)] [ASME B31.9, "Building Services Piping," for systems equal to or less than 15 psig (104 kPa)]**. Safety valves and pressure vessels shall bear the appropriate ASME label.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Preparation for Shipping: Clean flanges and exposed-metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.
- B. Store units in dry location.
- C. Retain protective flange covers and machined-surface protective coatings during storage.
- D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.
- E. Comply with manufacturer's written rigging instructions.

1.10 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.11 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Mechanical Requirements".

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 FEEDWATER UNITS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [AESYS Technologies, LLC; Boiler Div.](#)
2. [Alyan Pump.](#)
3. [Aurora Pump; Pentair Pump Group.](#)
4. [BFS Industries, LLC.](#)
5. [Bryan Boilers; Bryan Steam, LLC.](#)
6. [Cleaver-Brooks; Div. of Aqua-Chem, Inc.](#)
7. [Deaerating Designs; a division of Precision Boilers, Inc.](#)
8. [Domestic Pump; a unit of ITT Fluid Technology.](#)
9. [Eastern Industrial Products, Inc.; Smith-Koch, Inc. Div.](#)
10. [Flotronics, Inc.](#)
11. [Gerow Equipment Co.; Pump & Hydraulic Division.](#)
12. [Hurst Boiler & Welding Company, Inc.](#)
13. [Industrial Steam.](#)
14. [Lattner Boiler Manufacturing.](#)
15. [Lockwood Products, Inc.; Sub. of John L. Underwood Co., Inc.](#)
16. [MEPCO \(Marshall Engineered Products Co.\).](#)
17. [Parker Boiler Co.](#)
18. [PVI Industries, LLC.](#)
19. [Roth Pump Company; a subsidiary of Roy E. Roth Co.](#)
20. [Sellers Engineering Co.](#)
21. [Shippensburg Pump Co., Inc.](#)
22. [Skidmore.](#)
23. [Stickle Steam Specialties Co., Inc.](#)
24. [Superior Boiler Works, Inc.](#)
25. [U.S. Deaerator Co.](#)
26. [US Filter.](#)
27. **<Insert manufacturer's name.>**
28. or approved equal.

B. Description: Factory-assembled and -tested unit consisting of a receiver, **[simplex]** **[duplex]** feedwater pumps, controls, and the following features and accessories:

1. **[Liquid-filled industrial][Bimetal dial-type]** thermometer graduated in **[Fahrenheit] [Celsius] [both Fahrenheit and Celsius]**.
2. Level gage glass[, **reflex flat type,**] with stops at top and bottom.
3. Lifting eyes.
4. Companion flanges.
5. Pump, suction and discharge isolation valve, inlet strainer, discharge check valve, and liquid-filled pressure gage.
6. Makeup Water Assembly: **[Float operated with integral valve] [Electric level controller and valve]**; with inlet strainer and three-valve bypass.
7. Feedwater Heater: Sparge tube, thermostat, and control valve.

8. Factory-Installed Pipe, **NPS 2-1/2 (DN 65)** and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule **[40] [80]**; with threaded joints and fittings.
 - a. Cast-Iron Threaded Fittings: ASME B16.4; Class **[125] [250]**.
 - b. Malleable-Iron Threaded Fittings: ASME B16.3, Class **[150] [300]**.
 - c. Forged-Steel Fittings: ASME B16.11, Class 3000.
 - d. Malleable-Iron Unions: ASME B16.39; Class **[150] [300]**.
 - e. Forged-Steel Unions: MSS SP-83, Class 3000.
 9. Factory-Installed Pipe, **NPS 3 (DN 80)** and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule **[40] [80]**; with welded joints and carbon-steel fittings and flanges.
 - a. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
 - b. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class **[150] [300]**, including bolts, nuts, and gaskets.
- C. Receiver:
1. Material: **[Close-grain cast iron] [Welded carbon steel] [Welded carbon steel galvanized after fabrication] [Stainless steel]**.
 2. Additional corrosion protection:
 - a. **[0.07-inch (1.8-mm)] [0.13-inch (3.3-mm)] [0.19-inch (4.8-mm)] <Insert thickness>** thickness allowance.
 - b. Electrolytic corrosion-inhibitor anode.
 3. Finish: **[Primer] [Primer under enamel topcoat] [Primer under epoxy topcoat]**.
 4. Factory-Applied Insulation and Jacket: Minimum thickness of **[2 inches (50 mm)] <Insert thickness>** for mineral-fiber pipe and tank insulation. Cover insulation with **[painted steel] [stucco-embossed aluminum] [stainless-steel]** jacket.
 5. Mounting Arrangement: **[Recessed below floor] [Floor mounted]**.
 6. Mounting Frame: Structural-steel stand to support receiver and pumps. **[Fabricate stand with bracing adequate for seismic forces according to authorities having jurisdiction and to allow anchoring mounting frame to floor.]**
- D. Vertical Feedwater Pump: Flange-mounted, close-coupled, **[single-stage,] [multistage,]** radially split-case-design centrifugal pump; rated for **[175-psig (1205-kPa)] <Insert pressure>** minimum working pressure and a continuous water temperature of at least **[225 deg F (107 deg C)] <Insert temperature>**; with the following features:
1. Impeller: **[Bronze] [Stainless steel]**.
 2. Seals: Mechanical.

3. Motor: **[Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled]** enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- E. Horizontal Feedwater Pump: Base-mounted, **[single-stage,] [multistage,]** radially split-case-design centrifugal pump; rated for **[175-psig (1205-kPa)] <Insert pressure>** minimum working pressure and a continuous water temperature of at least **[225 deg F (107 deg C)] <Insert temperature>**; with the following features:
1. Impeller: **[Bronze] [Stainless steel]**.
 2. Coupling: **[Close] [Flexible]**.
 3. Seals: Mechanical.
 4. Motor: **[Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled]** enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- F. Control panel shall be unit mounted and factory wired and include the following:
1. NEMA 250, Type **[1] [4] [4X] [12] <Insert type>** enclosure.
 2. Single-point field power interface to **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]**.
 - a. Branch power circuit to each motor and to controls **[with a disconnect switch or circuit breaker]**.
 3. NEMA-rated motor controller for each motor, and include a hand-off-auto switch and overcurrent protection.
 - a. Alternating controls for duplex units with intermittent operation as indicated by control sequence.
 4. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 5. Wiring outside of an enclosure in a **[metal]**raceway. Make connections to motor with liquidtight conduit.
 6. Removable control mounting plate.
 7. Visual indication of status and alarm **[with momentary test push button]**.
 8. Audible alarm and silence switch.
 9. Visual indication of elapsed run time, graduated in hours.
 10. Fused control-circuit transformer.
 11. Microprocessor-based controller.
- G. Feedwater Simplex-Pump Control Sequence:
1. Boiler water-level controller starts and stops pump to maintain boiler water-level set point.
 2. Visual indication of pump on **[and off]** status.
 3. Visual **[and audible]** alarm indication of pump failure.
- H. Feedwater Duplex-Pump Control Sequence:

1. Boiler water-level controller starts and stops lead pump to maintain boiler water-level set point.
 2. Lead and lag pumps alternate [**after each start**] [**to equalize run time**].
 3. Lead pump failure, lag pump [**automatically starts if lead pump cannot maintain set point**] [**is started manually**].
 4. Visual indication of pump on[**and off**] status.
 5. Visual indication of pump lead/lag status.
 6. Visual[**and audible**] alarm indication of pump failure.
- I. Feedwater Duplex-Pump Control Sequence:
1. Pump runs continuously while boiler operates. Electric interlock with boiler control starts lead pump when boiler starts.
 2. Boiler water-level controller modulates feedwater control valve to maintain boiler water-level set point. Valve closes when boiler is off.
 3. Lead and lag pumps alternate [**after each start**] [**to equalize run time**].
 4. Lead pump failure automatically starts lag pump.
 5. Feedwater pressure controller starts and stops lag pump to maintain feedwater pressure set point.
 6. Visual indication of pump on[**and off**] status.
 7. Visual indication of pump lead/lag status.
 8. Visual[**and audible**] alarm indication of pump failure.
- J. Receiver Makeup Water Control Sequence:
1. Electric level controller operates electric control valve to maintain receiver water-level set point.
 2. Mechanical float operates integral valve to maintain water-level set point.
 3. Visual[**and audible**] alarm indication of low[**and high**] receiver-water level.
- K. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.
1. Hardwired Monitoring Points: On/off status for each pump[, **failure alarm for each pump**] [, **receiver low-water-level alarm**] [, **receiver high-water-level alarm**] [, **feedwater temperature**] <Insert monitoring>.
- L. Capacities and Characteristics:
1. Condensate Receiver:
 - a. Volume: <Insert gal. (L).>
 - b. Diameter: <Insert inches (mm).>
 - c. Length: <Insert inches (mm).>
 - d. Height to Condensate Inlet: <Insert inches (mm).>
 - e. Condensate Return Minimum Inlet Size: <Insert NPS (DN).>
 - f. Makeup Water Minimum Inlet Size: <Insert NPS (DN).>
 - g. Sparge-Tube Steam Supply: <Insert lb/h (kW).>
 2. Feedwater Pumps:

- a. No. of Pumps: [**Simplex**] [**Duplex**] <Insert number>.
- b. Flow Rate: <Insert **gpm** (L/s).>
- c. NPSH Required: <Insert **psig** (kPa).>
- d. Rated Operating Temperature: <Insert **deg F** (deg C).>
- e. Head Pressure: <Insert **psig** (kPa).>
- f. Horsepower: <Insert **horsepower**.>
- g. Speed: <Insert **value**> RPM.
- h. Volts: [**115**] [**208**] [**230**] [**460**] <Insert **value**> V.
- i. Phase: [**Single**] [**Three**].
- j. Hertz: 60.

2.2 FEEDWATER UNIT WITH VACUUM PRODUCER

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Alyan Pump.](#)
2. [Domestic Pump; a unit of ITT Fluid Technology.](#)
3. [Flotronics, Inc.](#)
4. [Lockwood Products, Inc.; Sub. of John L. Underwood Co., Inc.](#)
5. [MEPCO \(Marshall Engineered Products Co.\).](#)
6. [Shippensburg Pump Co., Inc.](#)
7. [Skidmore.](#)
8. [U.S. Deaerator Co.](#)
9. <Insert **manufacturer's name**.>
10. or approved equal.

- B. Description: Receiver mounted, consisting of multijet vacuum producer, centrifugal pump and motor assembly mounted on separation chamber, and automatic pressure and water temperature controls. Include the following accessories:

1. [**Liquid-filled industrial**] [**Bimetal dial-type**] thermometer graduated in [**Fahrenheit**] [**Celsius**] [**both Fahrenheit and Celsius**].
2. Vacuum Gage: Dial-type register in **inches of mercury** (kPa).
3. Level Gage Glass: Stops top and bottom.
4. Air-suction check valve.
5. Lifting eyes.
6. Companion flanges.
7. Low-water cutoff switch.
8. Cooling-Water Control: Aquastat, inlet strainer, and electric valve.
9. Air vent.
10. Overflow drain from vacuum-producer receiver.
11. Factory-Installed Pipe, **NPS 2-1/2** (DN 65) and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule [**40**] [**80**]; with threaded joints and fittings.
 - a. Cast-Iron Threaded Fittings: ASME B16.4; Class [**125**] [**250**].
 - b. Malleable-Iron Threaded Fittings: ASME B16.3, Class [**150**] [**300**].
 - c. Forged-Steel Fittings: ASME B16.11, Class 3000.

- d. Malleable-Iron Unions: ASME B16.39; Class [150] [300].
 - e. Forged-Steel Unions: MSS SP-83, Class 3000.
12. Factory-Installed Pipe, NPS 3 (DN 80) and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule [40] [80]; with welded joints and carbon-steel fittings and flanges.
- a. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
 - b. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class [150] [300], including bolts, nuts, and gaskets.
- C. Vacuum-Producer Reservoir and Vacuum Receiver:
1. Material: [Close-grain cast iron] [Welded carbon steel] [Welded carbon steel galvanized after fabrication] [Stainless steel].
 2. Additional corrosion protection:
 - a. [0.07-inch (1.8-mm)] [0.13-inch (3.3-mm)] [0.19-inch (4.8-mm)] <Insert thickness> thickness allowance.
 - b. Electrolytic corrosion-inhibitor anode.
- First option is most common.
3. Finish: [Primer] [Primer under enamel topcoat] [Primer under epoxy topcoat].
- Consult manufacturer.
4. Factory-Applied Insulation and Jacket: Minimum thickness of [2 inches (50 mm)] <Insert thickness> for mineral-fiber pipe and tank insulation. Cover insulation with [painted steel] [stucco-embossed aluminum] [stainless-steel] jacket.
 5. Mounting Arrangement: [Recessed below floor] [Floor mounted].
 6. Mounting Frame: Structural-steel stand to support receiver and pumps.[Fabricate stand with bracing adequate for seismic forces according to authorities having jurisdiction and to allow anchoring mounting frame to floor.]
- D. Vertical Vacuum-Producer Pump: Flange-mounted, close-coupled, single-stage, radially split-case-design centrifugal pump; rated for [175-psig (1205-kPa)] <Insert pressure> minimum working pressure and a continuous water temperature of at least [225 deg F (107 deg C)] <Insert temperature>; with the following features:
1. Impeller: Bronze.
 2. Shaft: Stainless steel.
 3. Seals: Mechanical.
- Some pump configurations may exclude the third option and necessitate the second.
4. Motor: [Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled] enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

- E. Horizontal Vacuum-Producer Pump: Base-mounted, single-stage, radially split-case-design centrifugal pump; rated for [175-psig (1205-kPa)] <Insert pressure> minimum working pressure and a continuous water temperature of at least [225 deg F (107 deg C)] <Insert temperature>; with the following features:
1. Impeller: Bronze.
 2. Shaft: Stainless steel.
 3. Coupling: [Close] [Flexible].
 4. Seals: Mechanical.

Some pump configurations may exclude the third option and necessitate the second.

5. Motor: [Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled] enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- F. Vertical Feedwater Pump: Flange-mounted, close-coupled, [single-stage,] [multistage,] radially split-case-design centrifugal pump; rated for [175-psig (1205-kPa)] <Insert pressure> minimum working pressure and a continuous water temperature of at least [225 deg F (107 deg C)] <Insert temperature>; with the following features:
1. Impeller: [Bronze] [Stainless steel].
 2. Seals: Mechanical.

Some pump configurations may exclude the third option and necessitate the second.

3. Motor: [Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled] enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- G. Horizontal Feedwater Pump: Base-mounted, [single-stage,] [multistage,] radially split-case-design centrifugal pump; rated for [175-psig (1205-kPa)] <Insert pressure> minimum working pressure and a continuous water temperature of at least [225 deg F (107 deg C)] <Insert temperature>; with the following features:
1. Impeller: [Bronze] [Stainless steel].
 2. Coupling: [Close] [Flexible].
 3. Seals: Mechanical.

Some pump configurations may exclude the third option and necessitate the second.

4. Motor: [Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled] enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- H. Control panel shall be unit mounted and factory wired and include the following:
1. Vacuum Switches for Simplex Vacuum-Producer Pumps: Include pressure adjustment, and test push button. Factory set to operate pump between 3 and 6 inches of mercury (10.1 and 20.2 kPa).
 2. Vacuum Switches for Duplex Vacuum-Producer Pumps: Include pressure adjustment, and test push button. Factory set so one pump operates for 3 to 5

inches of mercury (10.1 to 16.9 kPa) and both pumps operate for 4 to 6 inches of mercury (13.5 to 20.2 kPa).

Type 12 is second most common. Type 4X is used primarily in corrosive environments.

3. NEMA 250, Type [1] [4] [4X] [12] <Insert type> enclosure.
 4. Single-point field power interface to [fused disconnect switch] [nonfused disconnect switch] [circuit breaker].
 - a. Branch power circuit to each motor and to controls[with a disconnect switch or circuit breaker].
 5. NEMA-rated motor controller for each motor and include a hand-off-auto switch and overcurrent protection.
 - a. Alternating control for units with intermittent operation as indicated by control sequence.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Wiring outside of an enclosure in a [metal]raceway. Make connections to motor with liquidtight conduit.
 8. Removable control mounting plate.
 9. Visual indication of status and alarm[with momentary test push button].
 10. Audible alarm and silence switch.
 11. Visual indication of elapsed run time, graduated in hours.
 12. Fused control-circuit transformer.
- I. Vacuum-Producer Control Sequence:
1. Cycle pumps to maintain vacuum-pressure set point.
 2. Visual indication of pump on[and off] status.
 3. Visual[and audible] alarm indication of pump failure.

Retain first for simplex feedwater system with single feedwater pump. Retain second for duplex-pump units with operating and standby pump. Retain third for duplex-pump units with continuous pump operation and modulating control valve. Coordinate with boiler operation and controls. See Evaluations for further discussion.

- J. Feedwater Simplex-Pump Control Sequence:
1. Boiler water-level controller starts and stops pump to maintain boiler water-level set point.
 2. Visual indication of pump on[and off] status.
 3. Visual[and audible] alarm indication of pump failure.
- K. Feedwater Duplex-Pump Control Sequence:
1. Boiler water-level controller starts and stops lead pump to maintain boiler water-level set point.
 2. Lead and lag pumps alternate [after each start] [to equalize run time].
 3. Lead pump failure, lag pump [automatically starts if lead pump cannot maintain set point] [is started manually].

4. Visual indication of pump on[**and off**] status.
5. Visual indication of pump lead/lag status.
6. Visual[**and audible**] alarm indication of pump failure.

L. Feedwater Duplex-Pump Control Sequence:

1. Pump runs continuously while boiler operates. Electric interlock with boiler control starts lead pump when boiler starts.
2. Boiler water-level controller modulates feedwater control valve to maintain boiler water-level set point. Valve closes when boiler is off.
3. Lead and lag pumps alternate [**after each start**] [**to equalize run time**].
4. Lead pump failure automatically starts lag pump.
5. Feedwater pressure controller starts and stops lag pump to maintain feedwater pressure set point.
6. Visual indication of pump on[**and off**] status.
7. Visual indication of pump lead/lag status.
8. Visual[**and audible**] alarm indication of pump failure.

M. Makeup Water Control Sequence:

1. Electric level controller operates electric control valve to maintain water temperature set point.
2. Visual[**and audible**] alarm indication of low[**and high**] water level.

N. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.

1. Hardwired Monitoring Points: On/off status for each pump[, **failure alarm for each pump**] [, **receiver low-water-level alarm**] [, **receiver high-water-level alarm**] [, **feedwater temperature**] <Insert monitoring>.

If retaining below, retain the "Basis-of-Design Product" Paragraph at the beginning of this Article and insert manufacturer's name and product name or designation there.

O. Capacities and Characteristics:

1. Vacuum-Producer Reservoir:
 - a. Volume: <Insert gal. (L).>
 - b. Diameter: <Insert inches (mm).>
 - c. Length: <Insert inches (mm).>
 - d. Cooling Makeup Water Supply: <Insert NPS (DN).>
 - e. Overflow Drain: <Insert NPS (DN).>
2. Vacuum-Producer Pumps:
 - a. No. of Pumps: [**Simplex**] [**Duplex**] <Insert number>.
 - b. Air Capacity: <Insert cfm (L/s).>
 - c. Head Pressure: <Insert inches of mercury (kPa).>
 - d. Horsepower: <Insert horsepower.>
 - e. Speed: <Insert value> RPM.

- f. Volts: [115] [208] [230] [460] <Insert value> V.
 - g. Phase: [Single] [Three].
 - h. Hertz: 60.
3. Vacuum Receiver:
- a. Volume: <Insert gal. (L).>
 - b. Diameter: <Insert inches (mm).>
 - c. Length: <Insert inches (mm).>
 - d. Height to Condensate Inlet: <Insert inches (mm).>
 - e. Condensate Return Minimum Inlet Size: <Insert NPS (DN).>
4. Feedwater Pumps:
- a. No. of Pumps: [Simplex] [Duplex] <Insert number>.
 - b. Flow Rate: <Insert gpm (L/s).>
 - c. NPSH Required: <Insert psig (kPa).>
 - d. Rated Operating Temperature: <Insert deg F (deg C).>
 - e. Head Pressure: <Insert psig (kPa).>
 - f. Horsepower: <Insert horsepower.>
 - g. Speed: <Insert value> RPM.
 - h. Volts: [115] [208] [230] [460] <Insert value> V.
 - i. Phase: [Single] [Three].
 - j. Hertz: 60.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before feedwater unit installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting feedwater unit performance, maintenance, and operations.
 - 1. Final feedwater unit locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
 - 2. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 - 1. Install feedwater units on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

- B. Install unit to permit access for maintenance.
- C. Support piping independent of pumps.
- D. Install base-mounted pumps on concrete bases with grouted base frames.
- E. Install parts and accessories shipped loose.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to machine to allow service and maintenance.
- C. Connect makeup water piping and cooling-water piping with reduced-pressure backflow preventers.
- D. Install overflow drain piping to nearest floor drain.
- E. Install vents and extend to outdoors; terminate with elbow turned down and an insect screen.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
- B. Perform tests and inspections and prepare test reports.
 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 1. Inspect field-assembled components, equipment installation, and piping and electrical connections for compliance with manufacturer's written instructions.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 3. Check bearing lubrication.
 4. Verify proper motor rotation.
 5. Start up service.

6. Report results in writing.

D. Remove and replace malfunctioning units and retest as specified above.

3.5 ADJUSTING

A. Adjust boiler water-level controls to properly stage unit.

B. Set field-adjustable, makeup water and cooling-water controls.

3.6 CLEANING

A. Clean equipment internally; remove coatings applied for protection during shipping and storage, foreign material, and oily residue according to manufacturer's written instructions.

B. Clean strainers.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain feedwater units. Refer to Section 017900 "Demonstration and Training."

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235313

SECTION 235316 - DEAERATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes packaged, factory-assembled deaerators.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. Feedwater Pump: Pump that moves feedwater from the deaerator to the boiler.
- B. Transfer Pump: Pump that moves feedwater from the surge tank to the deaerator.
- C. NPSH: Net-positive suction head.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated makeup water, feedwater, and steam flow rates; working pressure; tank capacities; storage capacity in minutes; temperature and NPSH required; pump performance curves with selection points clearly indicated; furnished specialties; and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For deaerators, signed and sealed by a qualified professional engineer; include plans, elevations, sections, details, dimensions, weights, loadings, required clearances, and attachments to other work.
 - 1. For installed products indicated to comply with design loads, include structural analysis data.
 - 2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing deaerator bases.
 - 3. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Manufacturer Seismic Qualification Certification: Submit certification that deaerators, accessories, and components will withstand seismic forces as indicated in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For deaerators to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- B. ASME Compliance: **[ASME B31.1, "Power Piping," for systems more than 15 psig (104 kPa)] [ASME B31.9, "Building Services Piping," for systems equal to or less than 15 psig (104 kPa)]**. Safety valves and pressure vessels shall bear the appropriate ASME label.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Protect flanges, pipe openings, nozzles, bearings, and couplings from damage during shipping and storage.

- B. Comply with manufacturer's written rigging instructions.
- C. Deliver deaerators as factory-assembled units with protective crating and covering.

1.9 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.10 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Gaskets: Furnish [**one (1)**] <Insert number> replacement gasket(s) for each gasketed opening.
 - 2. Gage Glass: Furnish [**one (1)**] <Insert number> replacement glass(es) for each gage glass.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [AESYS Technologies, LLC; York Shipley Global Div.](#)
 - 2. [Ambassador Heat Transfer Company.](#)
 - 3. [Bethlehem Corporation \(The\).](#)
 - 4. [Bryan Steam LLC.](#)
 - 5. [Cleaver-Brooks; Div. of Aqua-Chem Inc.](#)
 - 6. [Cochrane, Inc.; a Crane Co. Company.](#)
 - 7. [Deaerating Designs; a division of Precision Boilers, Inc.](#)
 - 8. [Eastern Industrial Products, Inc.; Smith-Koch, Inc., Div.](#)
 - 9. [Ecodyne Limited; Graver Water Conditioning Subsidiary.](#)
 - 10. [Enpro, Incorporated.](#)
 - 11. [Industrial Steam; Custom Steam and Pressure Vessel Systems.](#)
 - 12. [International Boiler Works Co. \(The\).](#)
 - 13. [Kansas City Deaerator Company.](#)

14. [Lockwood Products, Inc.; Sub. of John L. Underwood Co., Inc.](#)
15. [Nationwide Boiler Incorporated.](#)
16. [PVI Industries, LLC.](#)
17. [Sellers Engineering Co.](#)
18. [Skidmore.](#)
19. [Sterling Deaerator Co.](#)
20. [U.S. Deaerator Co.](#)
21. **<Insert manufacturer's name.>**
22. or approved equal.

2.2 MANUFACTURED UNITS

- A. **[Horizontal] [Vertical], [packed-column] [spray] [tray]**, single-compartment deaerator[, **and a separate packaged surge tank with transfer and feedwater pumps and controls to supply feedwater to deaerator**].
- B. **[Horizontal] [Vertical], [packed-column] [spray] [tray]**, two-compartment deaerator. One compartment for deaeration and one for surge volume, each with its own transfer and feedwater pumps and controls.
- C. **[Horizontal] [Vertical], [packed-column] [spray] [tray]**, single-compartment deaerator and separate surge tank, both mounted on same factory-fabricated stand with necessary transfer and feedwater pumps and controls.
- D. Material for Wetted Components: Components in contact with water that has not been deaerated shall be made of Type **[304] [316]** stainless steel.
- E. Adjustable Spray Valves: Type 316 stainless steel. Arrange spray valves for counterflow of steam and condensate and so corrosive gases being vented do not contact deaerator's head or shell.
- F. Vent Condenser: Stainless steel, with automatic and manual vent valves.
- G. Deaerator and Storage Tank:
 1. Material: **[Welded carbon steel] [Welded carbon steel galvanized after fabrication] [Stainless steel]**.
 2. Additional Corrosion Protection:
 - a. **[0.07-inch (1.8-mm)] [0.13-inch (3.3-mm)] [0.19-inch (4.8-mm)] <Insert thickness>** thickness allowance.
 - b. Electrolytic corrosion-inhibitor anode.
 3. Access: Manhole in deaerator and storage tank for access to internal components for inspection and service.
 4. Factory-Applied Insulation and Jacket: Minimum thickness of **[2 inches (50 mm)] <Insert thickness>** for mineral-fiber pipe and tank insulation. Cover insulation with **[painted steel] [stucco-embossed aluminum] [stainless-steel]** jacket.

5. Factory-Installed Pipe, **NPS 2-1/2 (DN 65)** and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule **[40] [80]**; with threaded joints and fittings.
 - a. Cast-Iron Threaded Fittings: ASME B16.4, Class **[125] [250]**.
 - b. Malleable-Iron Threaded Fittings: ASME B16.3, Class **[150] [300]**.
 - c. Forged-Steel Fittings: ASME B16.11, Class 3000.
 - d. Malleable-Iron Unions: ASME B16.39, Class **[150] [300]**.
 - e. Forged-Steel Unions: MSS SP-83, Class 3000.

6. Factory-Installed Pipe, **NPS 3 (DN 80)** and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule **[40] [80]**; with welded joints and carbon-steel fittings and flanges.
 - a. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
 - b. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class **[150] [300]**, including bolts, nuts, and gaskets.

H. Accessories:

1. Lifting eyes.
2. Companion flanges.
3. Pump suction piping with vortex breaker, isolation valve, strainer, and flexible connector.
4. Pump discharge piping with check valve, isolation valve, and liquid-filled pressure gage graduated in **[pounds force per square inch] [kilopascals] [both pounds force per square inch and kilopascals]**.
5. Pump-discharge bypass **[relief valve] [orifice plate] [relief valve with orifice plate]**.
6. Makeup Water Assembly:
 - a. Factory-mounted modulating valve with mechanical level control, external float cage, and stainless-steel float.
 - b. **[Factory] [Field]**-mounted, electric, **[pilot-operated, solenoid] [modulating]** valve with factory-mounted, **[probe-type]** water-level controller.
 - c. **[Factory] [Field]**-mounted, pneumatic modulating valve with factory-mounted water-level controller.
 - d. **[Factory] [Field]**-mounted, three-valve bypass and inlet strainer.
7. Steam Pressure-Reducing Valve(s): **[Steam] [Electric] [Pneumatic]** operated **[with three-valve bypass]**, and sized to reduce boiler outlet pressure to the deaerator design pressure.
8. Tank Overflow Drain: Sized to relieve full capacity at operating pressure.
9. Safety Valve(s): ASME labeled and sized to relieve full capacity of pressure-reducing valve.
10. Vents: Manual and automatic vent valves.
11. Vacuum breaker.
12. Meters and Gages:

- a. Full-height, water-level gage glass[, **reflex flat type**,] and stop valve set.
 - b. [**Liquid-filled industrial**] [**Bimetal dial-type**] thermometer graduated in [**Fahrenheit**] [**Celsius**] [**both Fahrenheit and Celsius**] mounted to measure temperature in storage [**and steam**] section of tank.
 - c. Pressure gage graduated in [**pounds force per square inch**] [**kilopascals**] [**both pounds force per square inch and kilopascals**] mounted to measure pressure in steam section of tank.
13. Provision for chemical injection quill.
 14. Chemical injection quill.
 15. Sampling connection with valve.
 16. Tank drain connection with valve.
 17. Oxygen test kit.
- I. Support Frame: Structural-steel frame for supporting tank and pumps. Weld or bolt to tank.
1. Fabricate support frame with bracing adequate for seismic forces according to authorities having jurisdiction and to allow installation by anchoring deaerators to floor only.
- J. Feedwater Pump : Cast-iron, [**flange**] [**base**]-mounted volute; with [**bronze**] [**stainless-steel**], [**multistage centrifugal**] [**turbine**] impeller, renewable bronze case ring, and stainless-steel shaft.
1. Seals: Mechanical, suitable for [**250 deg F (121 deg C)**] **<Insert temperature>**.
 2. Pump Motor: [**Vertical**] [**Horizontal**], [**open dripproof**] [**totally enclosed**] [**totally enclosed fan-cooled**] enclosure, [**close**] [**flexible**] coupled to pump. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- K. Feedwater Pump Control Panel: Factory mounted and wired and including the following:
1. NEMA 250, Type [**1**] [**4**] [**4X**] [**12**] **<Insert type>** enclosure.
 2. Single-point, field power connection to [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**].
 - a. Branch power circuit to each motor and to controls[**with a disconnect switch or circuit breaker**].
 3. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor.
 - a. Alternating control as indicated by control sequence for each pump.
 4. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 5. [**Metal raceway**] [**Raceway**] for factory-installed wiring outside of enclosures. Make connections to motor with liquidtight conduit.
 6. Removable control mounting plate.

7. Visual indication of status and alarm[**with momentary test push button**].
 8. Audible alarm and silence switch.
 9. Visual indication of elapsed run time, graduated in hours.
 10. Fusible, control-circuit transformer.
 11. Microprocessor-based controller.
- L. Feedwater Pump Start-Stop Control Sequence:
1. Boiler water-level controller starts and stops lead pump to maintain boiler water-level set point.
 2. Lead and lag pumps alternate [**after each start**] [**to equalize run time**].
 3. Lead pump failure, lag pump [**automatically starts if lead pump cannot maintain set point**] [**is started manually**].
 4. Visual indication of pump on[**and off**] status.
 5. Visual indication of pump lead/lag status.
 6. Visual[**and audible**] alarm indication of pump failure.
- M. Feedwater Pump Continuous Control Sequence:
1. Pump runs continuously while boiler operates. Electric interlock with boiler control starts lead pump when boiler starts.
 2. Boiler water-level controller modulates feedwater control valve to maintain boiler water-level set point. Valve closes when boiler is off.
 3. Lead and lag pumps alternate [**after each start**] [**to equalize run time**].
 4. Lead pump failure automatically starts lag pump.
 5. Feedwater pressure controller starts and stops lag pump to maintain feedwater pressure set point.
 6. Visual indication of pump on[**and off**] status.
 7. Visual indication of pump lead/lag status.
 8. Visual[**and audible**] alarm indication of pump failure.
- N. Makeup Water Control Sequence:
1. Electric level controller operates electric control valve to maintain tank water-level set point.
 2. Pneumatic level controller operates pneumatic control valve to maintain tank water-level set point.
 3. Mechanical float operates valve to maintain water-level set point.
 4. Visual[**and audible**] alarm indication of low[**and high**] tank water level.
- O. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.
1. Hardwired Monitoring Points: On/off status for each pump[, **failure alarm for each pump**] [, **low-water level alarm**] [, **high-water level alarm**] [, **feedwater temperature**] <Insert monitoring>.

2.3 SURGE TANK

- A. Description: Factory-assembled and -tested unit consisting of a condensate receiver, transfer pumps, and controls.
- B. Accessories:
1. **[Liquid-filled industrial] [Bimetal dial-type]** thermometer graduated in **[Fahrenheit] [Celsius] [both Fahrenheit and Celsius]**.
 2. Level gage glass[, **reflex flat type,**] with stops at top and bottom.
 3. Lifting eyes.
 4. Companion flanges.
 5. Pump suction piping with vortex breaker, isolation valve, strainer, and flexible connector.
 6. Pump discharge piping with check valve, isolation valve, and liquid-filled pressure gage graduated in **[pounds force per square inch] [kilopascals] [both pounds force per square inch and kilopascals]**.
 7. Pump-discharge bypass **[relief valve] [orifice plate] [relief valve with orifice plate]**.
- C. Factory-Installed Pipe, **NPS 2-1/2 (DN 65)** and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule **[40] [80]**; with threaded joints and fittings.
1. Cast-Iron Threaded Fittings: ASME B16.4, Class **[125] [250]**.
 2. Malleable-Iron Threaded Fittings: ASME B16.3, Class **[150] [300]**.
 3. Forged-Steel Fittings: ASME B16.11, Class 3000.
 4. Malleable-Iron Unions: ASME B16.39, Class **[150] [300]**.
 5. Forged-Steel Unions: MSS SP-83, Class 3000.
- D. Factory-Installed Pipe, **NPS 3 (DN 80)** and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule **[40] [80]**; with welded joints and carbon-steel fittings and flanges.
1. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
 2. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class **[150] [300]**, including bolts, nuts, and gaskets.
- E. Tank:
1. Material: **[Welded carbon steel] [Welded carbon steel galvanized after fabrication] [Stainless steel]**.
 2. Additional Corrosion Protection:
 - a. **[0.07-inch (1.8-mm)] [0.13-inch (3.3-mm)] [0.19-inch (4.8-mm)] <Insert thickness>** thickness allowance.
 - b. Electrolytic corrosion-inhibitor anode.
 3. Access: Manhole in tank for access to internal components for inspection and service.

4. Factory-Applied Insulation and Jacket: Minimum thickness of [2 inches (50 mm)] <Insert thickness> for mineral-fiber pipe and tank insulation. Cover insulation with [painted steel] [stucco-embossed aluminum] [stainless-steel] jacket.
- F. Support Frame: Structural-steel frame for supporting tank. Weld or bolt to tank.
1. Fabricate support frame with bracing adequate for seismic forces according to authorities having jurisdiction and to allow installation by anchoring deaerators to floor only.
- G. Transfer Pump: Vertical, flange-mounted, close-coupled, [single-stage] [multistage], radially split-case centrifugal pump; rated for [175-psig (1205-kPa)] <Insert pressure> minimum working pressure and a continuous water temperature of [225 deg F (107 deg C)] <Insert temperature>; with the following features:
1. Impeller: [Bronze] [Stainless steel].
 2. Seals: Mechanical.
 3. Motor: [Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled] enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- H. Transfer Pump: Horizontal, base-mounted, [single-stage] [multistage], radially split-case centrifugal pump; rated for [175-psig (1205-kPa)] <Insert pressure> minimum working pressure and a continuous water temperature of [225 deg F (107 deg C)] <Insert temperature>; with the following features:
1. Impeller: [Bronze] [Stainless steel].
 2. Coupling: [Close] [Flexible].
 3. Seals: Mechanical.
 4. Motor: [Open dripproof] [Totally enclosed] [Totally enclosed fan-cooled] enclosure. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- I. Transfer Pump Control Panel: Factory mounted and wired and including the following:
1. NEMA 250, Type [1] [4] [4X] [12] <Insert type> enclosure.
 2. Single-point, field power connection to [fused disconnect switch] [nonfused disconnect switch] [circuit breaker].
 - a. Branch power circuit to each motor and to controls [with a disconnect switch or circuit breaker].
 3. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor.
 - a. Alternating control indicated by control sequence for each pump.
 4. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 5. [Metal raceway] [Raceway] for factory-installed wiring outside of enclosures. Make connections to motor with liquidtight conduit.

6. Removable control mounting plate.
 7. Visual indication of on/off status and pump failure alarm[**with momentary test push button**].
 8. Audible alarm and silence switch.
 9. Visual indication of elapsed run time, graduated in hours.
 10. Fusible, control-circuit transformer.
 11. Microprocessor-based controller.
- J. Transfer Pump Start-Stop Control Sequence: Deaerator water-level controller controls lead pump; alternator switches lead and lag pump(s) [**after each start**] [**to equalize run time**]; failure of lead pump switches to lag pump[**and sounds audible alarm**].
- K. Transfer Pump Continuous-Run Control Sequence: Lead pump runs continuously while deaerator is operating; deaerator water-level controller modulates water-level-control valve; lead and lag pump(s) switch to equalize run time; lag pump operates if lead pump fails[; **pump failure sounds audible alarm**].
- L. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.
1. Hardwired Monitoring Points: On/off status for each pump[, **failure alarm for each pump**] [, **low-water level alarm**] [, **high-water level alarm**] <Insert monitoring>.
- 2.4 CAPACITIES AND CHARACTERISTICS
- A. Feedwater Flow Rate: <Insert **gpm** (L/s).>
 - B. Steam Flow Rate: <Insert **lb/h** (kg/h).>
 - C. Makeup Water Flow Rate: <Insert **gpm** (L/s).>
 - D. Makeup Water Temperature: <Insert **deg F** (deg C).>
 - E. Capacity: Capable of raising temperature of condensate and makeup water to within [**3 deg F** (2 deg C)] <Insert **temperature**> of saturated steam temperature.
 - F. Minimum Working Pressure: [**50 psig** (345 kPa)] <Insert **value**>.
 - G. Operating Pressure Range: [**Atmospheric**] [**From 2 to 15 psig** (14 to 104 kPa)] <Insert **pressure range**>.
 - H. Resultant Oxygen Content: Not more than [**0.03**] [**0.005**] **cc/L** through an operating range between [**0**] [**3**] [**5**] <Insert **value**> and 100 percent of full load.
 - I. Storage Tank:
 1. Tank Capacity to Overflow: <Insert **gal. (L)**.>
 2. Storage Time: [**10**] <Insert **number**> minutes.

J. Feedwater Pumps:

1. No. of Pumps: **[Duplex]** <Insert quantity>.
2. Flow Rate: <Insert gpm (L/s).>
3. NPSH Required: <Insert psig (kPa).>
4. Rated Operating Temperature: <Insert deg F (deg C).>
5. Head Pressure: <Insert psig (kPa).>
6. Horsepower: <Insert hp (kW).>
7. Speed: <Insert rpm.>
8. Volts: **[115] [208] [230] [460]** <Insert value> V.
9. Phase: **[Single] [Three]**.
10. Hertz: 60.

K. Surge Tank:

1. Tank Capacity to Overflow: <Insert gal. (L).>
2. Storage Time: <Insert number> minutes.

L. Transfer Pumps:

1. No. of Pumps: **[Duplex]** <Insert quantity>.
2. Flow Rate: <Insert gpm (L/s).>
3. NPSH Required: <Insert psig (kPa).>
4. Rated Operating Temperature: <Insert deg F (deg C).>
5. Head Pressure: <Insert psig (kPa).>
6. Horsepower: <Insert hp (kW).>
7. Speed: <Insert rpm.>
8. Volts: **[115] [208] [230] [460]** <Insert value> V.
9. Phase: **[Single] [Three]**.
10. Hertz: 60.

2.5 FACTORY FINISHES

- A. Manufacturer's standard prime-coat finish ready for field painting.
- B. Manufacturer's standard paint in standard colors, applied to factory-assembled and -tested unit before shipping.
- C. Do not paint aluminum, galvanized-steel, and stainless-steel surfaces.

2.6 SOURCE QUALITY CONTROL

- A. Fabricate and label deaerator tanks according to ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.
- B. Factory install and test piping that connects pumps to tanks according to **[ASME B31.1, "Power Piping] [ASME B31.9, "Building Services Piping]."**

- C. Factory test performance and certify test results on packaged deaerator units, according to ASME PTC 12.3, before shipping to Project.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before deaerator installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance, maintenance, and operations.
 - 1. Final deaerator locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
 - 2. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 - 1. Install deaerators on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Install deaerators to permit access for service and maintenance.
- C. Support piping independent of pumps.
- D. Install base-mounted pumps on concrete base with grouted base frame.
- E. Install all parts and materials not factory installed.
- F. Extend overflow drains to floor drains.
- G. Extend vent piping to outside and terminate with manufacturer-approved cap furnished with deaerator.
- H. Install piping adjacent to machine to allow service and maintenance.

3.3 CONNECTIONS

- A. Steam and condensate piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect steam and condensate piping to tank tappings with shutoff valves and unions or flanges at each connection.
- C. Connect condensate drains, pump-discharge piping, vents, overflow drains, makeup water, steam supply, and cooling water piping.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
- B. Perform tests and inspections and prepare test reports.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 - 1. Inspect field-assembled components and equipment installation, including piping and electrical connections, for compliance with requirements.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 3. Verify bearing lubrication.
 - 4. Verify proper motor rotation.
 - 5. Test Reports: Prepare a written report to record the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- D. Remove and replace malfunctioning equipment and retest as specified above.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
- B. Complete installation and startup checks according to manufacturer's written instructions and do the following:
 - 1. Set deaerator makeup water-level controls.

2. Verify bearing lubrication.
3. Verify proper motor rotation.
4. Start pumps according to manufacturer's written instructions.

3.6 ADJUSTING AND CLEANING

- A. Adjust initial temperature and pressure set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges.
- C. Clean strainers.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain deaerators. Refer to Section 017900 "Demonstration and Training."
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235316

SECTION 235413 - ELECTRIC-RESISTANCE FURNACES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Electric furnaces and accessories complete with controls.
 - 2. Air filters.
 - 3. Air cleaners.
 - 4. UV germicidal lights.
 - 5. Humidifiers.
 - 6. Ventilation heat exchangers.
 - 7. Refrigeration components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 - 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
 - 3. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.
 - 4. Laboratory Test Reports for Credit IEQ 4: For solvent cements and adhesive primers, documentation indicating that products comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing

and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Shop Drawings:

1. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each furnace to include in emergency, operation, and maintenance manuals:

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Furnace and accessories complete with controls.
 - b. Air filter.
 - c. Air cleaner.
 - d. UV germicidal light.
 - e. Humidifier.
 - f. Ventilation heat exchanger.
 - g. Refrigeration components.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Disposable Air Filters: Furnish **[two (2)] <Insert number>** complete sets.
2. Disposable Air-Cleaner Media: Furnish **[one (1)] <Insert number>** complete set(s).
3. Fan Belts: Furnish **[one (1)] <Insert number>** set(s) for each furnace fan.
4. Disposable Humidifier Media: Furnish **[one (1)] <Insert number>** set(s).

1.7 QUALITY ASSURANCE

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

- B. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- C. Comply with NFPA 70.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace the following components of furnaces that fail in materials or workmanship within specified warranty period:
 - 1. Warranty Period, Commencing on Date of Substantial Completion:
 - a. Furnace Heat Exchanger: Minimum **[ten (10) years] [twenty (20) years] [Lifetime] <Insert value>**.
 - b. Integrated Ignition and Blower Control Circuit Board: Minimum **[five (5) years] <Insert value>**.
 - c. Draft-Inducer Motor: Minimum **[five (5) years] <Insert value>**.
 - d. Refrigeration Compressors: Minimum **[ten (10) years] [Lifetime] <Insert value>**.
 - e. Evaporator and Condenser Coils: Minimum **[five (5)years] <Insert value>**.
 - f. **<Insert components requiring extended warranty>**.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Broan Nu-Tone Canada Inc.](#)
 - 2. [Fedders North America Inc.](#)
 - 3. [Intertherm Heating and Cooling.](#)
 - 4. [Wellman Furnaces, Inc.](#)
 - 5. [York International Corp.; a Johnson Controls company.](#)
 - 6. **<Insert manufacturer's name>**.
 - 7. or approved equal.

2.2 ASSEMBLY DESCRIPTION

- A. Factory assembled, piped, wired, and tested.

- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a qualified testing agency, and marked for intended location and application.

2.3 FURNACES

- A. Cabinet: Steel, with duct liner[**downstream from cooling coil**].
 - 1. Duct Liner: Fiberglass, minimum [1/2 inch (13 mm)] [3/4 inch (19 mm)] thick, complying with ASTM C 1071 and having a coated surface exposed to airstream complying with NFPA 90A or NFPA 90B and with NAIMA's "Fibrous Glass Duct Liner Standard."
 - a. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
 - 2. Factory paint external cabinets in manufacturer's standard color.
- B. Fan: Centrifugal, factory balanced, resilient mounted, direct drive.
 - 1. Fan Motors: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 2. Special Motor Features: Single speed, premium efficiency, as defined in Section 230513 "Common Motor Requirements for HVAC Equipment," and with internal thermal protection and permanent lubrication.
 - 3. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
 - 4. Special Motor Features: Electronically controlled motor (ECM) controlled by integrated furnace/blower control.
- C. Electric-Resistant Heating Elements: Helix-wound, nickel-chromium wire-heating elements in ceramic insulators mounted on steel supports.
- D. Heating-Element Control: Sequencer relay with relay for each element; switches elements on and off, with delay between each increment; initiates, stops, or changes fan speed.
- E. Summer Fan Switch: Connected to permit independent on-off switch of unit fan.
- F. Capacities and Characteristics:
 - 1. Airflow Configuration: [**Upflow**] [**Counterflow**] [**Horizontal**].
 - 2. Electric Heating Element:
 - a. Capacity: <Insert MBh (kW)>.
 - b. Number of Steps: <Insert number>.
 - c. Volts: <Insert value>.
 - d. Phase: <Insert value>.
 - e. Hertz: <Insert value>.
 - f. Full-Load Amperes: <Insert value>.

- g. Minimum Circuit Ampacity: **<Insert value>**.
 - h. Maximum Overcurrent Protection: **<Insert amperage>**.
3. Fan:
- a. Airflow: **<Insert cfm (L/s)>**.
 - b. External Static Pressure: **<Insert inches wg (Pa)>**.
 - c. Motor:
 - 1) Size: **<Insert horsepower>**.
 - 2) Speed: **<Insert rpm>**.
 - d. Volts: **<Insert value>**.
 - e. Phase: **<Insert value>**.
 - f. Hertz: **<Insert value>**.
 - g. Full-Load Amperes: **<Insert value>**.
 - h. Minimum Circuit Ampacity: **<Insert value>**.
 - i. Maximum Overcurrent Protection: **<Insert amperage>**.
4. Furnace Electrical Connection:
- a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 THERMOSTATS[**AND HUMIDISTATS**]

- A. Controls shall comply with requirements in ASHRAE/IES 90.1, "Controls."
- B. Solid-State Thermostat: [**Wall-mounted**] [**Freestanding**] [**Wireless**], programmable, microprocessor-based unit with [**automatic**] [**manual**] switching from heating to cooling, preferential rate control, seven-day programmability with minimum of four temperature presets per day, [**vacation mode**,]and battery backup protection against power failure for program settings.
- C. Single-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounted unit with fan on-automatic selector.
- D. Two-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounted unit with fan on-automatic selector.
- E. [**Single**] [**Two**]-Stage, Heating-Only Thermostat: Wall-mounted unit with fan on-automatic selector.
- F. Solid-State, Combination Thermostat and Humidistat: [**Wall-mounted**] [**Freestanding**] [**Wireless**], programmable, microprocessor-based unit with automatic switching from heating to cooling and humidifying to dehumidifying, preferential rate control,

seven-day programmability with minimum of four temperature presets per day, [**vacation mode**,]and battery backup protection against power failure for program settings.

G. Humidistat: Adjustable, [**wall**] [**duct**]-mounted unit.

H. Control Wiring: Unshielded twisted-pair cabling.

1. No. 24 AWG, 100 ohm, four pair.
2. Cable Jacket Color: [**Blue**] <Insert color>.

2.5 AIR FILTERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Aprilaire; a division of Research Products Corp.](#)
2. [Filtrete Home Filtration Products; a division of 3M.](#)
3. [General Filters, Inc.](#)
4. [Permatron Corporation.](#)
5. <Insert manufacturer's name>.
6. or approved equal.

B. Washable Filters: **1-inch-** (25-mm-) thick urethane pad.

C. Disposable Filters: [**1-inch-** (25-mm-)] <Insert dimension> thick fiberglass media[**with ASHRAE 52.2 MERV rating of 6 or higher,**] in sheet metal frame.

D. Charged Media Air Filters: Sheet metal housing arranged to be ducted in return-air duct connection to furnace; generates electrostatic charge; MERV 10 rating.

E. HEPA Air-Filter Units: Sheet metal housing with fan arranged to be ducted to return-air duct connection to furnace, with activated carbon prefilter[, **carbon VOC,**] and high-efficiency particulate air (HEPA) disposable filter. HEPA shall be as follows:

1. Standard: UL 586.
2. Rating: ASHRAE 52.2, 99.97 percent efficiency to 0.30-micrometer particle size.

2.6 AIR CLEANERS

A. Electronic Air Cleaners: Packaged system, including sheet metal housing, prefilter, power supply, and automatic control device, arranged for mounting in return-air duct at furnace; equip with on-off and test switches and pilot light.

1. Standard: UL 586.
2. Rating: ASHRAE 52.2, particle size to 0.01 micrometer.
3. Static Pressure Drop: Maximum **0.14-inch wg** (35 Pa) at **300-fpm** (1.52-m/s) air velocity.

B. Capacities and Characteristics:

1. Volts: **<Insert value>**.
2. Phase: **<Insert value>**.
3. Hertz: **<Insert value>**.
4. Minimum Circuit Ampacity: **<Insert value>**.
5. Maximum Overcurrent Protection: **<Insert amperage>**.

2.7 UV GERMICIDAL LIGHTS

- A. Description: Lighting unit in metal housing arranged for installation in supply-air duct and controlled to cycle on and off with furnace fan, with **[one]** **[two]** 75-W UV-light bulb(s).

2.8 HUMIDIFIERS

- A. Minimum capacity rating indicated according to AHRI 610.
- B. Media-wheel bypass type with bypass damper and motor-driven media wheel in reservoir with float-valve level control; arranged for mounting on return duct or plenum with bypass connection to supply duct.
- C. Wetted-pad, continuous-drain, bypass type with bypass damper and water-flow control orifice; arranged for mounting on return duct or plenum with bypass connection to supply duct.
- D. Fan-powered, wetted-pad, continuous-drain type with water-flow control orifice and motor; arranged for mounting on duct or plenum.
- E. Pumped, fan-powered, wetted-pad type with reservoir-level control and pump and fan motors; arranged for mounting on duct or plenum.
- F. Steam type with electric heating element in stainless-steel reservoir with float-valve level control; arranged for attachment to duct or plenum and for control by humidistat.
- G. Comply with applicable requirements in ASHRAE 62.1.
- H. Capacities and Characteristics:
1. Type: **[Steam]** **[Media wheel]** **[Wetted pad with reservoir]** **[Wetted pad with continuous drain]** **[Wetted-pad bypass]**.
 2. Steam Capacity: **<Insert lb/h (kg/h)>**.
 3. Water Connection Size: **<Insert NPS (DN)>**.
 4. Drain Connection Size: **<Insert NPS (DN)>**.
 5. Volts: **<Insert value>**.
 6. Phase: **<Insert value>**.
 7. Hertz: **<Insert value>**.
 8. Minimum Circuit Ampacity: **<Insert value>**.
 9. Maximum Overcurrent Protection: **<Insert amperage>**.

2.9 VENTILATION AIR HEAT EXCHANGERS

- A. Cabinet: Steel, with factory-installed interior insulation and manufacturer's standard factory finish. Fabricate with space for piping and electrical conduits.
- B. Heat-Recovery Device: Fixed-plate, polypropylene copolymer (high-density plastic) heat-exchanger plates evenly spaced and sealed and arranged for counter airflow.
- C. Supply and Exhaust Fans: Forward curved centrifugal with direct drive. Motors comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- D. Filters: **1-inch- (25-mm-)** thick disposable type[**with ASHRAE 52.2 MERV rating of 6 or higher**], in galvanized-steel frame, mounted upstream of unit in both supply and exhaust airstreams.
- E. Wiring: Wire motors and controls so only external connections are required during installation.

2.10 REFRIGERATION COMPONENTS

- A. General Refrigeration Component Requirements:
 - 1. Refrigeration compressor, coils, and specialties shall be designed to operate with CFC-free refrigerants.
 - 2. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IES 90.1.
- B. Refrigerant Coil: Copper tubes mechanically expanded into aluminum fins. Comply with AHRI 210/240. Match size with furnace. Include condensate drain pan with accessible drain outlet[**complying with ASHRAE 62.1**].
 - 1. Refrigerant Coil Enclosure: Steel, matching furnace and evaporator coil, with access panel and flanges for integral mounting at or on furnace cabinet and galvanized sheet metal drain pan coated with black asphaltic base paint.
- C. Refrigerant Line Kits: Annealed-copper suction and liquid lines factory cleaned, dried, pressurized with nitrogen, sealed, and with suction line insulated. Provide in standard lengths for installation without joints, except at equipment connections.
 - 1. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534/C 534M, Type I, [**1/2 inch (13 mm)**] [**1 inch (25 mm)**] **<Insert dimension>** thick.
- D. Refrigerant Piping: Comply with requirements in Section 232300 "Refrigerant Piping."
- E. Air-Cooled Compressor-Condenser Unit:
 - 1. Casing: Steel, finished with baked enamel, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.

2. Compressor: Hermetically sealed [**reciprocating**] [**or**] [**scroll**] type.
 - a. Crankcase heater.
 - b. [**Restrained vibration**] [**Vibration**] isolation mounts for compressor.
 - c. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - d. Two-speed compressor motors shall have manual-reset high-pressure switch and automatic-reset low-pressure switch.
 - e. Refrigerant Charge: [**R-22**] [**R-407C**] [**R-410A**] <Insert type>.
 - f. Refrigerant: R-407C or R-410A.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with AHRI 210/240, and with liquid subcooler.
4. Heat-Pump Components: Reversing valve and low-temperature air cutoff thermostat.
5. Fan: luminum-propeller type, directly connected to motor.
6. Motor: Permanently lubricated, with integral thermal-overload protection.
7. Low Ambient Kit: Permits operation down to 45 deg F (7 deg C).
8. Mounting Base: Polyethylene.

F. Capacities and Characteristics:

1. Refrigerant Coil:
 - a. Total Cooling Capacity: <Insert Btu/h (kW)>.
 - b. Sensible Cooling Capacity: <Insert Btu/h (kW)>.
 - c. Heating Capacity: <Insert Btu/h (kW)>.
 - d. Maximum Air Pressure Drop: <Insert inches wg (Pa)>.
 - e. Condensate Drain Size: <Insert NPS (DN)>.
2. Compressor-Condenser Unit:
 - a. Cooling Energy Efficiency[(**EER**)] [(**SEER**)]: <Insert value>.
 - b. Heating Coefficient of Performance: <Insert value>.
 - c. Volts: <Insert value>.
 - d. Phase: <Insert value>.
 - e. Hertz: <Insert value>.
 - f. Full-Load Amperes: <Insert value>.
 - g. Minimum Circuit Ampacity: <Insert value>.
 - h. Maximum Overcurrent Protection: <Insert amperage>.
 - i. Fan Motor Full-Load Amperes: <Insert value>.
 - j. Compressor Running-Load Amperes: <Insert value>.
 - k. Compressor Motor Full-Load Amperes: <Insert value>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine factory-installed insulation before furnace installation. Reject units that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Suspended Units: Suspend from structure using threaded rods, spring hangers, and building attachments. Secure rods to unit hanger attachments. Adjust hangers so unit is level and plumb.
 - 1. Install seismic restraints to limit movement of furnace by resisting code-required seismic acceleration.
- B. Base-Mounted Units: Secure units to substrate. Provide optional bottom closure base if required by installation conditions.
 - 1. Anchor furnace to substrate to resist code-required seismic acceleration.
- C. Controls: Install thermostats and humidistats at mounting height of **60 inches (1500 mm)** above floor.
- D. Wiring Method: Install control wiring in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Conceal control wiring except in unfinished spaces.
- E. Install ground-mounted, compressor-condenser components on **4-inch- (100-mm-)** thick, reinforced concrete base; **4 inches (100 mm)** larger on each side than unit. Concrete, reinforcement, and formwork are specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**] Coordinate anchor installation with concrete base.
- F. Install ground-mounted compressor-condenser components on polyethylene mounting base.
- G. Install roof-mounted compressor-condenser components on equipment supports specified in Section 077200 "Roof Accessories." Anchor units to supports with removable, cadmium-plated fasteners.

3.3 CONNECTIONS

- A. Install piping adjacent to equipment to allow service and maintenance.
- B. Water piping installation requirements are specified in Section 221116 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties. Connect water piping with union and ball valve.
- C. Connect ducts to furnace with flexible connector. Comply with requirements in Section 233300 "Air Duct Accessories."
- D. Connect refrigerant tubing kits to refrigerant coil in furnace and to air-cooled compressor-condenser unit.
 - 1. Flared Joints: Use ASME B16.26 fitting and flared ends, following procedures in CDA's "Copper Tube Handbook."
 - 2. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
 - 3. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.
- E. Comply with requirements in Section 232300 "Refrigerant Piping" for installation and joint construction of refrigerant piping.

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Perform electrical test and visual and mechanical inspection.
 - 2. Leak Test: After installation, charge systems with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation, product capability, and compliance with requirements.
 - 4. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
 - 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

3.5 STARTUP SERVICE

- A. Complete installation and startup checks according to manufacturer's written instructions and perform the following:

1. Inspect for physical damage to unit casings.
2. Verify that access doors move freely and are weathertight.
3. Clean units and inspect for construction debris.
4. Verify that all bolts and screws are tight.
5. Adjust vibration isolation and flexible connections.
6. Verify that controls are connected and operational.

B. Adjust fan belts to proper alignment and tension.

C. Start unit according to manufacturer's written instructions and complete manufacturer's operational checklist.

D. Measure and record airflows.

E. Verify proper operation of capacity control device.

F. After startup and performance test, lubricate bearings[**and adjust belt tension**].

3.6 ADJUSTING

A. Adjust initial temperature and humidity set points.

B. Set controls, burner, and other adjustments for optimum heating performance and efficiency. Adjust heat-distribution features, including shutters, dampers, and relays, to provide optimum heating performance and system efficiency.

3.7 CLEANING

A. After completing installation, clean furnaces internally according to manufacturer's written instructions.

B. Install new filters in each furnace within 14 days after Substantial Completion.

3.8 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain condensing units. Refer to Section 017900 "Demonstration and Training."

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235413

SECTION 235416.13 - GAS-FIRED FURNACES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Gas-fired, [**noncondensing**] [**condensing**] furnaces and accessories complete with controls.
 - 2. Air filters.
 - 3. Air cleaners.
 - 4. UV germicidal lights.
 - 5. Humidifiers.
 - 6. Ventilation heat exchangers.
 - 7. Refrigeration components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 - 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
 - 3. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.
 - 4. Laboratory Test Reports for Credit IEQ 4: For solvent cements and adhesive primers, documentation indicating that products comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing

and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Shop Drawings:

1. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Include diagrams for power, signal, and control wiring.
3. Prepare the following by or under the supervision of a qualified professional engineer:
 - a. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
 - b. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
 - c. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
 - d. Wiring Diagrams: Power, signal, and control wiring.
4. Startup service reports.

1.4 INFORMATIONAL SUBMITTALS

- A. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each furnace to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Furnace and accessories complete with controls.
 - b. Air filter.
 - c. Air cleaner.
 - d. UV germicidal light.
 - e. Humidifier.
 - f. Ventilation heat exchanger.
 - g. Refrigeration components.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Disposable Air Filters: Furnish **[two (2)] <Insert number>** complete sets.
 2. Disposable Air-Cleaner Media: Furnish **[one (1)] <Insert number>** complete set(s).
 3. Fan Belts: Furnish **[one (1)] <Insert number>** set(s) for each furnace fan.
 4. Disposable Humidifier Media: Furnish **[one (1)] <Insert number>** set(s).

1.7 QUALITY ASSURANCE

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- B. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- C. Comply with NFPA 70.

1.8 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace the following components of furnaces that fail in materials or workmanship within specified warranty period:
1. Warranty Period, Commencing on Date of Substantial Completion:
 - a. Furnace Heat Exchanger: Minimum **[ten (10) years] [twenty (20) years] [Lifetime] <Insert value>**.
 - b. Integrated Ignition and Blower Control Circuit Board: Minimum **[Five (5) years] <Insert value>**.
 - c. Draft-Inducer Motor: Minimum **[Five (5) years] <Insert value>**.
 - d. Refrigeration Compressors: Minimum **[ten (10) years] [Lifetime] <Insert value>**.
 - e. Evaporator and Condenser Coils: Minimum **[Five (5) years] <Insert value>**.
 - f. **<Insert components requiring extended warranty>**.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a qualified testing agency, and marked for intended location and application.
- B. General Requirements for Noncondensing Gas-Fired Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.47/CSA 2.3 and NFPA 54.

2.2 GAS-FIRED FURNACES, NONCONDENSING

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Adams Manufacturing Company.
 2. Amana Heating & Air Conditioning; under license to Goodman Company, L.P.
 3. Arcoaire Air Conditioning & Heating; an International Comfort Products brand; a unit of United Technologies Corp..
 4. Bard Manufacturing Company.
 5. Bryant Heating & Cooling Systems; a unit of United Technologies Corp.
 6. Carrier Corporation; a unit of United Technologies Corp.
 7. Comfort-Aire; a division of Heat Controller, Inc.
 8. Comfortmaker Air Conditioning & Heating; an International Comfort Products brand; a unit of United Technologies Corp.
 9. Dornback Furnace.
 10. Goodman Manufacturing Company, L.P.
 11. Heil Heating & Cooling Products; an International Comfort Products brand; a unit of United Technologies Corp.
 12. Lennox Industries Inc; Lennox International.
 13. Luxaire Corporation; a division of Unitary Products Group of Luxaire; a Johnson Controls company.
 14. Rheem Manufacturing Company; Heating and Cooling Products.
 15. Ruud Air Conditioning Division.
 16. Tempstar Heating & Cooling Products; an International Comfort Products brand; a unit of United Technologies Corp.
 17. Thermo Products, Inc.; a division of Burnham Holdings Inc.
 18. Trane.
 19. York International Corp.; a Johnson Controls Company.
 20. **<Insert manufacturer's name>.**

21. or approved equal.
- B. Cabinet: **[Steel]** **[Galvanized steel]**.
1. Cabinet interior around heat exchanger shall be factory-installed insulation.
 2. Lift-out panels shall expose burners and all other items requiring access for maintenance.
 3. Factory paint external cabinets in manufacturer's standard color.
 4. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- C. Fan: Centrifugal, factory balanced, resilient mounted, **[direct drive]** **[belt drive]** **[direct or belt drive]** **[drive type indicated on Drawings]**.
1. Fan Motors: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Special Motor Features: Single speed, premium efficiency, as defined in Section 230513 "Common Motor Requirements for HVAC Equipment," and with internal thermal protection and permanent lubrication.
 3. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
 4. Special Motor Features: Electronically controlled motor (ECM) controlled by integrated furnace/blower control.
- D. Type of Gas: **[Natural]** **[Propane]**.
- E. Heat Exchanger: **[Aluminized]** **[Stainless]** steel.
- F. Burner:
1. Gas Valve: 100 percent safety **[two-stage]** **[modulating]** main gas valve, main shutoff valve, pressure regulator, safety pilot with electronic flame sensor, limit control, transformer, and combination ignition/fan timer control board.
 2. Ignition: Electric pilot ignition, with hot-surface igniter or electric spark ignition.
- G. Gas-Burner Safety Controls:
1. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
 2. Flame Rollout Switch: Installed on burner box; prevents burner operation.
 3. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
- H. Combustion-Air Inducer: Centrifugal fan with thermally protected motor and sleeve bearings prepurges heat exchanger and vents combustion products; pressure switch prevents furnace operation if combustion-air inlet or flue outlet is blocked.
- I. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; and adjustable fan-on and fan-off timing; terminals for connection to accessories.

- J. Vent Materials: Comply with requirements in Section 235123 "Gas Vents" for Type B metal vents.
- K. Capacities and Characteristics:
1. Airflow Configuration: [**Upflow**] [**Counterflow**] [**Horizontal**].
 2. Gas:
 - a. Type: [**Natural**] [**Propane**].
 - b. Venting Type: [**Power venter**][**with combustion-air intake**].
 - c. Minimum Efficiency AFUE: <Insert number> percent.
 - d. Minimum Thermal Efficiency: <Insert number> percent.
 - e. Minimum Combustion Efficiency: <Insert number> percent.
 - f. Input: <Insert MBh (kW)>.
 - g. Heat Output: <Insert MBh (kW)>.
 - h. Gas Connection Size: <Insert NPS (DN)>.
 - i. Draft-Inducer Motor:
 - 1) Size: <Insert horsepower>.
 - 2) Speed: <Insert rpm>.
 - j. Combustion-Air Inlet Size: <Insert inches (mm)>.
 - k. Combustion-Air Inlet Material: [**Galvanized steel**] [**Stainless steel**] [**PVC**].
 - l. Heat-Exchanger Condensate Drain Size: <Insert NPS (DN)>.
 - m. Vent Size: <Insert inches (mm)>.
 3. Fan:
 - a. Airflow: <Insert cfm (L/s)>.
 - b. External Static Pressure: <Insert inches wg (Pa)>.
 - c. Motor:
 - 1) Size: <Insert horsepower>.
 - 2) Speed: <Insert rpm>.
 - d. Volts: <Insert value>.
 - e. Phase: <Insert value>.
 - f. Hertz: <Insert value>.
 - g. Full-Load Amperes: <Insert value>.
 - h. Minimum Circuit Ampacity: <Insert value>.
 - i. Maximum Overcurrent Protection: <Insert amperage>.
 4. Furnace Electrical Connection:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.3 GAS-FIRED FURNACES, CONDENSING

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. Adams Manufacturing Company.
2. Amana Heating & Air Conditioning; under license to Goodman Company, L.P.
3. Arcoaire Air Conditioning & Heating; an International Comfort Products brand; a unit of United Technologies Corp.
4. Bryant Heating & Cooling Systems; a unit of United Technologies Corp.
5. Carrier Corporation; Div. of United Technologies Corp.
6. Comfort-Aire; a division of Heat Controller, Inc.
7. Comfortmaker Air Conditioning & Heating; an International Comfort Products brand; a unit of United Technologies Corp.
8. Dornback Furnace.
9. Goodman Manufacturing Company, L.P.
10. Heil Heating & Cooling Products; an International Comfort Products brand; a unit of United Technologies Corp.
11. Lennox Industries Inc; Lennox International.
12. Luxaire Corporation; a division of Unitary Products Group of Luxaire; a Johnson Controls company.
13. Rheem Manufacturing Company; Heating and Cooling Products.
14. Ruud Air Conditioning Division.
15. Tempstar Heating & Cooling Products; an International Comfort Products brand; a unit of United Technologies Corp.
16. Thermo Products, Inc.; a division of Burnham Holdings Inc.
17. Trane.
18. York International Corp.; a Johnson Controls Company.
19. **<Insert manufacturer's name>.**
20. or approved equal.

B. Cabinet: **[Steel] [Galvanized steel]**.

1. Cabinet interior around heat exchanger shall be factory-installed insulation.
2. Lift-out panels shall expose burners and all other items requiring access for maintenance.
3. Factory paint external cabinets in manufacturer's standard color.
4. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Fan: Centrifugal, factory balanced, resilient mounted, direct drive.

1. Fan Motors: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Special Motor Features: Single speed, premium efficiency, as defined in Section 230513 "Common Motor Requirements for HVAC Equipment," and with internal thermal protection and permanent lubrication.
3. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.

4. Special Motor Features: Electronically controlled motor (ECM) controlled by integrated furnace/blower control.
- D. Type of Gas: **[Natural]** **[Propane]**.
- E. Heat Exchanger:
1. Primary: **[Aluminized]** **[Stainless]** steel.
 2. Secondary: **[Polyethylene-coated]** **[Stainless]** steel.
- F. Burner:
1. Gas Valve: 100 percent safety **[two-stage]** **[modulating]** main gas valve, main shutoff valve, pressure regulator, safety pilot with electronic flame sensor, limit control, transformer, and combination ignition/fan timer control board.
 2. Ignition: Electric pilot ignition, with hot-surface igniter or electric spark ignition.
- G. Gas-Burner Safety Controls:
1. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
 2. Flame Rollout Switch: Installed on burner box; prevents burner operation.
 3. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
- H. Combustion-Air Inducer: Centrifugal fan with thermally protected motor and sleeve bearings prepurges heat exchanger and vents combustion products; pressure switch prevents furnace operation if combustion-air inlet or flue outlet is blocked.
- I. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; adjustable fan-on and fan-off timing; terminals for connection to accessories[; **diagnostic light with viewport**].
- J. Accessories:
1. Combination Combustion-Air Intake and Vent: PVC plastic fitting to combine combustion-air inlet and vent through **[outside wall]** **[roof]**.
 2. CPVC Plastic Vent Materials:
 - a. CPVC Plastic Pipe: Schedule 40, complying with ASTM F 441/F 441M.
 - b. CPVC Plastic Fittings: Schedule 40, complying with ASTM F 438, socket type.
 - c. CPVC Solvent Cement: ASTM F 493.
 - 1) CPVC solvent cement shall have a VOC content of 490 g/L or less.
 - 2) Adhesive primer shall have a VOC content of 550 g/L or less.
 - 3) Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic

Chemical Emissions from Indoor Sources Using Environmental Chambers."

3. PVC Plastic Vent Materials:
 - a. PVC Plastic Pipe: Schedule 40, complying with ASTM D 1785.
 - b. PVC Plastic Fittings: Schedule 40, complying with ASTM D 2466, socket type.
 - c. PVC Solvent Cement: ASTM D 2564.
 - 1) PVC solvent cement shall have a VOC content of 510 g/L or less.
 - 2) Adhesive primer shall have a VOC content of 550 g/L or less.
 - 3) Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

K. Capacities and Characteristics:

1. Airflow Configuration: **[Upflow]** **[Counterflow]** **[Horizontal]**.
2. Gas:
 - a. Type: **[Natural]** **[Propane]**.
 - b. Venting Type: **[Power venter]** **[Power venter with combustion-air intake]**.
 - c. Minimum Efficiency AFUE: **<Insert number>** percent.
 - d. Minimum Thermal Efficiency: **<Insert number>** percent.
 - e. Minimum Combustion Efficiency: **<Insert number>** percent.
 - f. Input: **<Insert MBh (kW)>**.
 - g. Heat Output: **<Insert MBh (kW)>**.
 - h. Gas Connection Size: **<Insert NPS (DN)>**.
 - i. Draft-Inducer Motor:
 - 1) Size: **<Insert horsepower>**.
 - 2) Speed: **<Insert rpm>**.
 - j. Combustion-Air Inlet Size: **<Insert inches (mm)>**.
 - k. Combustion-Air Inlet Material: **[CPVC]** **[PVC]**.
 - l. Heat-Exchanger Condensate Drain Size: **<Insert NPS (DN)>**.
 - m. Vent Size: **<Insert inches (mm)>**.
 - n. Vent Material: **[CPVC]** **[PVC]**.
3. Fan:
 - a. Airflow: **<Insert cfm (L/s)>**.
 - b. External Static Pressure: **<Insert inches wg (Pa)>**.
 - c. Motor:

- 1) Size: **<Insert horsepower>**.
- 2) Speed: **<Insert rpm>**.

- d. Volts: **<Insert value>**.
- e. Phase: **<Insert value>**.
- f. Hertz: **<Insert value>**.
- g. Full-Load Amperes: **<Insert value>**.
- h. Minimum Circuit Ampacity: **<Insert value>**.
- i. Maximum Overcurrent Protection: **<Insert amperage>**.

4. Furnace Electrical Connection:

- a. Volts: **<Insert value>**.
- b. Phase: **<Insert value>**.
- c. Hertz: **<Insert value>**.
- d. Full-Load Amperes: **<Insert value>**.
- e. Minimum Circuit Ampacity: **<Insert value>**.
- f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 THERMOSTATS[**AND HUMIDISTATS**]

- A. Controls shall comply with requirements in ASHRAE/IES 90.1, "Controls."
- B. Solid-State Thermostat: [**Wall-mounted**] [**Freestanding**] [**Wireless**], programmable, microprocessor-based unit with [**automatic**] [**manual**] switching from heating to cooling, preferential rate control, seven-day programmability with minimum of four temperature presets per day, [**vacation mode**,]and battery backup protection against power failure for program settings.
- C. Single-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounted unit with fan on-automatic selector.
- D. Two-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounted unit with fan on-automatic selector.
- E. [**Single**] [**Two**]-Stage, Heating-Only Thermostat: Wall-mounted unit with fan on-automatic selector.
- F. Solid-State, Combination Thermostat and Humidistat: [**Wall-mounted**] [**Freestanding**] [**Wireless**], programmable, microprocessor-based unit with automatic switching from heating to cooling and humidifying to dehumidifying, preferential rate control, seven-day programmability with minimum of four temperature presets per day, [**vacation mode**,]and battery backup protection against power failure for program settings.
- G. Humidistat: Adjustable, [**wall**] [**duct**]-mounted unit.
- H. Control Wiring: Unshielded twisted-pair cabling.
 1. No. 24 AWG, 100 ohm, four pair.

2. Cable Jacket Color: **[Blue]** <Insert color>.

2.5 AIR FILTERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Aprilaire; a division of Research Products Corp.](#)
 2. [Filtrete Home Filtration Products; a division of 3M.](#)
 3. [General Filters, Inc.](#)
 4. [Permatron Corporation.](#)
 5. <Insert manufacturer's name>.
 6. or approved equal.
- B. Washable Filters: **1-inch-** (25-mm-) thick urethane pad.
- C. Disposable Filters: [**1-inch-** (25-mm-)] <Insert dimension> thick fiberglass media[**with ASHRAE 52.2 MERV rating of 6 or higher,**] in sheet metal frame.
- D. Charged Media Air Filters: Sheet metal housing arranged to be ducted in return-air duct connection to furnace; generates electrostatic charge; MERV 10 rating.
- E. HEPA Air Filter Units: Sheet metal housing with fan arranged to be ducted to return-air duct connection to furnace, with activated carbon prefilter[, **carbon VOC,**] and high-efficiency particulate air (HEPA) disposable filter. HEPA shall be as follows:
1. Standard: UL 586.
 2. Rating: ASHRAE 52.2, 99.97 percent efficiency to 0.30-micrometer particle size.

2.6 AIR CLEANERS

- A. Electronic Air Cleaners: Packaged system, including sheet metal housing, prefilter, power supply, and automatic control device, arranged for mounting in return-air duct at furnace; equip with on-off and test switches and pilot light.
1. Standard: UL 586.
 2. Rating: ASHRAE 52.2, particle size to 0.01 micrometer.
 3. Static Pressure Drop: Maximum **0.14-inch wg** (35 Pa) at **300-fpm** (1.52-m/s) air velocity.
- B. Capacities and Characteristics:
1. Volts: <Insert value>.
 2. Phase: <Insert value>.
 3. Hertz: <Insert value>.
 4. Minimum Circuit Ampacity: <Insert value>.
 5. Maximum Overcurrent Protection: <Insert amperage>.

2.7 UV GERMICIDAL LIGHTS

- A. Description: Lighting unit in metal housing arranged for installation in supply-air duct and controlled to cycle on and off with furnace fan, with **[one]** **[two]** 75-W UV-light bulb(s).

2.8 HUMIDIFIERS

- A. Minimum capacity rating indicated according to AHRI 610.
- B. Media-wheel bypass type with bypass damper and motor-driven media wheel in reservoir with float-valve level control; arranged for mounting on return duct or plenum with bypass connection to supply duct.
- C. Wetted-pad, continuous-drain, bypass type with bypass damper and water-flow control orifice; arranged for mounting on return duct or plenum with bypass connection to supply duct.
- D. Fan-powered, wetted-pad, continuous-drain type with water-flow control orifice and motor; arranged for mounting on duct or plenum.
- E. Pumped, fan-powered, wetted-pad type with reservoir-level control and pump and fan motors; arranged for mounting on duct or plenum.
- F. Steam type with electric heating element in stainless-steel reservoir with float-valve level control; arranged for attachment to duct or plenum and for control by humidistat.
- G. Comply with applicable requirements in ASHRAE 62.1.
- H. Capacities and Characteristics:
1. Type: **[Steam]** **[Media wheel]** **[Wetted pad with reservoir]** **[Wetted pad with continuous drain]** **[Wetted-pad bypass]**.
 2. Steam Capacity: **<Insert lb/h (kg/h)>**.
 3. Water Connection Size: **<Insert NPS (DN)>**.
 4. Drain Connection Size: **<Insert NPS (DN)>**.
 5. Volts: **<Insert value>**.
 6. Phase: **<Insert value>**.
 7. Hertz: **<Insert value>**.
 8. Minimum Circuit Ampacity: **<Insert value>**.
 9. Maximum Overcurrent Protection: **<Insert amperage>**.

2.9 VENTILATION AIR HEAT EXCHANGERS

- A. Cabinet: Steel, with factory-installed interior insulation and manufacturer's standard factory finish. Fabricate with space for piping and electrical conduits.
- B. Heat-Recovery Device: Fixed-plate, polypropylene copolymer (high-density plastic) heat-exchanger plates evenly spaced and sealed and arranged for counter airflow.

- C. Supply and Exhaust Fans: Forward curved centrifugal with direct drive. Motors comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- D. Filters: 1-inch- (25-mm-) thick disposable type[**with ASHRAE 52.2 MERV rating of 6 or higher**], in galvanized-steel frame, mounted upstream of unit in both supply and exhaust airstreams.
- E. Wiring: Wire motors and controls so only external connections are required during installation.

2.10 REFRIGERATION COMPONENTS

- A. General Refrigeration Component Requirements:
 - 1. Refrigeration compressor, coils, and specialties shall be designed to operate with CFC-free refrigerants.
 - 2. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IES 90.1.
- B. Refrigerant Coil: Copper tubes mechanically expanded into aluminum fins. Comply with AHRI 210/240. Match size with furnace. Include condensate drain pan with accessible drain outlet[**complying with ASHRAE 62.1**].
 - 1. Refrigerant Coil Enclosure: Steel, matching furnace and evaporator coil, with access panel and flanges for integral mounting at or on furnace cabinet and galvanized sheet metal drain pan coated with black asphaltic base paint.
- C. Refrigerant Line Kits: Annealed-copper suction and liquid lines factory cleaned, dried, pressurized with nitrogen, sealed, and with suction line insulated. Provide in standard lengths for installation without joints, except at equipment connections.
 - 1. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534/C 534M, Type I, [1/2 inch (13 mm)] [1 inch (25 mm)] <Insert dimension> thick.
- D. Refrigerant Piping: Comply with requirements in Section 232300 "Refrigerant Piping."
- E. Air-Cooled Compressor-Condenser Unit:
 - 1. Casing: Steel, finished with baked enamel, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
 - 2. Compressor: Hermetically sealed [**reciprocating**] [**or**] [**scroll**] type.
 - a. Crankcase heater.
 - b. [**Restrained vibration**] [**Vibration**] isolation mounts for compressor.
 - c. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - d. Two-speed compressor motors shall have manual-reset high-pressure switch and automatic-reset low-pressure switch.

- e. Refrigerant Charge: **[R-22] [R-407C] [R-410A] <Insert type>**.
 - f. Refrigerant: R-407C or R-410A.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with AHRI 210/240, and with liquid subcooler.
 4. Heat-Pump Components: Reversing valve and low-temperature air cut-off thermostat.
 5. Fan: Aluminum-propeller type, directly connected to motor.
 6. Motor: Permanently lubricated, with integral thermal-overload protection.
 7. Low Ambient Kit: Permits operation down to **45 deg F (7 deg C)**.
 8. Mounting Base: Polyethylene.
- F. Capacities and Characteristics:
1. Refrigerant Coil:
 - a. Total Cooling Capacity: **<Insert Btu/h (kW)>**.
 - b. Sensible Cooling Capacity: **<Insert Btu/h (kW)>**.
 - c. Heating Capacity: **<Insert Btu/h (kW)>**.
 - d. Maximum Air Pressure Drop: **<Insert inches wg (Pa)>**.
 - e. Condensate Drain Size: **<Insert NPS (DN)>**.
 2. Compressor-Condenser Unit:
 - a. Cooling Energy Efficiency[**(EER)**] [**(SEER)**]: **<Insert value>**.
 - b. Heating Coefficient of Performance: **<Insert value>**.
 - c. Volts: **<Insert value>**.
 - d. Phase: **<Insert value>**.
 - e. Hertz: **<Insert value>**.
 - f. Full-Load Amperes: **<Insert value>**.
 - g. Minimum Circuit Ampacity: **<Insert value>**.
 - h. Maximum Overcurrent Protection: **<Insert amperage>**.
 - i. Fan Motor Full-Load Amperes: **<Insert value>**.
 - j. Compressor Running-Load Amperes: **<Insert value>**.
 - k. Compressor Motor Full-Load Amperes: **<Insert value>**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine factory-installed insulation before furnace installation. Reject units that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for gas[**and refrigerant**] piping systems to verify actual locations of piping connections before equipment installation.

- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install gas-fired furnaces and associated fuel and vent features and systems according to NFPA 54.
- B. Suspended Units: Suspend from structure using threaded rods, spring hangers, and building attachments. Secure rods to unit hanger attachments. Adjust hangers so unit is level and plumb.
1. Install seismic restraints to limit movement of furnace by resisting code-required seismic acceleration.
- C. Base-Mounted Units: Secure units to substrate. Provide optional bottom closure base if required by installation conditions.
1. Anchor furnace to substrate to resist code-required seismic acceleration.
- D. Controls: Install thermostats and humidistats at mounting height of **60 inches** (1500 mm) above floor.
- E. Wiring Method: Install control wiring in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Conceal control wiring except in unfinished spaces.
- F. Install ground-mounted, compressor-condenser components on **4-inch-** (100-mm-) thick, reinforced concrete base; **4 inches** (100 mm) larger on each side than unit. Concrete, reinforcement, and formwork are specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**] Coordinate anchor installation with concrete base.
- G. Install ground-mounted compressor-condenser components on polyethylene mounting base.
- H. Install roof-mounted compressor-condenser components on equipment supports specified in Section 077200 "Roof Accessories." Anchor units to supports with removable, cadmium-plated fasteners.

3.3 CONNECTIONS

- A. Gas piping installation requirements are specified in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Drawings indicate general arrangement of piping, fittings, and specialties. Connect gas piping with union or flange and appliance connector valve.
- B. Install piping adjacent to equipment to allow service and maintenance.

- C. Water piping installation requirements are specified in Section 221116 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties. Connect water piping with union and ball valve.
- D. Vent Connection, Noncondensing, Gas-Fired Furnaces: Connect Type B vents to furnace vent connection and extend outdoors. Type B vents and their installation requirements are specified in Section 235123 "Gas Vents."
- E. Vent and Outside-Air Connection, Condensing, Gas-Fired Furnaces: Connect plastic piping vent material to furnace connections and extend outdoors. Terminate vent outdoors with a cap and in an arrangement that will protect against entry of birds, insects, and dirt.
1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
 2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
 3. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
 - a. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
 - b. CPVC Piping: Join according to ASTM D 2846/D 2846M, Appendix.
 - c. PVC Pressure Piping: Join schedule number ASTM D 1785 PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule-number PVC pipe and socket fittings according to ASTM D 2855.
 - d. Requirements for Low-Emitting Materials:
 - 1) CPVC solvent cement shall have a VOC content of 490 g/L or less.
 - 2) PVC solvent cement shall have a VOC content of 510 g/L or less.
 - 3) Adhesive primer shall have a VOC content of 550 g/L or less.
 - 4) Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
 4. Slope pipe vent back to furnace or to outside terminal.
- F. Connect ducts to furnace with flexible connector. Comply with requirements in Section 233300 "Air Duct Accessories."
- G. Connect refrigerant tubing kits to refrigerant coil in furnace and to air-cooled compressor-condenser unit.
1. Flared Joints: Use ASME B16.26 fitting and flared ends, following procedures in CDA's "Copper Tube Handbook."
 2. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's

- "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
3. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.
- H. Comply with requirements in Section 232300 "Refrigerant Piping" for installation and joint construction of refrigerant piping.

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
1. Perform electrical test and visual and mechanical inspection.
 2. Leak Test: After installation, charge systems with refrigerant and test for leaks. Repair leaks, replace lost refrigerant, and retest until no leaks exist.
 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation, product capability, and compliance with requirements.
 4. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

3.5 STARTUP SERVICE

- A. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
1. Inspect for physical damage to unit casings.
 2. Verify that access doors move freely and are weathertight.
 3. Clean units and inspect for construction debris.
 4. Verify that all bolts and screws are tight.
 5. Adjust vibration isolation and flexible connections.
 6. Verify that controls are connected and operational.
- B. Adjust fan belts to proper alignment and tension.
- C. Start unit according to manufacturer's written instructions and complete manufacturer's operational checklist.
- D. Measure and record airflows.
- E. Verify proper operation of capacity control device.
- F. After startup and performance test, lubricate bearings[**and adjust belt tension**].

3.6 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Set controls, burner, and other adjustments for optimum heating performance and efficiency. Adjust heat-distribution features, including shutters, dampers, and relays, to provide optimum heating performance and system efficiency.

3.7 CLEANING

- A. After completing installation, clean furnaces internally according to manufacturer's written instructions.
- B. Install new filters in each furnace within 14 days after Substantial Completion.

3.8 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain condensing units. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235416.13

SECTION 235416.16 - OIL-FIRED FURNACES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Oil-fired furnaces and accessories complete with controls.
 - 2. Air filters.
 - 3. Air cleaners.
 - 4. UV germicidal lights.
 - 5. Humidifiers.
 - 6. Ventilation heat exchangers.
 - 7. Refrigeration components.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 - 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
 - 3. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.
 - 4. Laboratory Test Reports for Credit IEQ 4: For solvent cements and adhesive primers, documentation indicating that products comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing

and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Shop Drawings:

1. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Include diagrams for power, signal, and control wiring.
3. Prepare the following by or under the supervision of a qualified professional engineer:
 - a. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
 - b. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
 - c. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
 - d. Wiring Diagrams: Power, signal, and control wiring.
4. Startup service reports.

1.4 INFORMATIONAL SUBMITTALS

- A. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each furnace to include in emergency, operation, and maintenance manuals.
1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Furnace and accessories complete with controls.
 - b. Air filter.
 - c. Air cleaner.
 - d. UV germicidal light.
 - e. Humidifier.
 - f. Ventilation heat exchanger.
 - g. Refrigeration components.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Disposable Air Filters: Furnish **[two (2)] <Insert number>** complete sets.
 2. Disposable Air-Cleaner Media: Furnish **[one (1)] <Insert number>** complete set(s).
 3. Fan Belts: Furnish **[one (1)] <Insert number>** set(s) for each furnace fan.
 4. Disposable Humidifier Media: Furnish **[one (1)] <Insert number>** set(s).

1.7 QUALITY ASSURANCE

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- B. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- C. Comply with NFPA 70.

1.8 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace the following components of furnaces that fail in materials or workmanship within specified warranty period:
1. Warranty Period, Commencing on Date of Substantial Completion:
 - a. Furnace Heat Exchanger: Minimum **[ten (10) years] [twenty (20) years] [Lifetime] <Insert value>**.
 - b. Integrated Ignition and Blower Control Circuit Board: Minimum **[five (5) years] <Insert value>**.
 - c. Draft-Inducer Motor: Minimum **[five (5) years] <Insert value>**.
 - d. High-Efficiency Oil Furnace Burner: Minimum **[three (3) years] <Insert value>**.
 - e. Refrigeration Compressors: Minimum **[ten (10) years] [Lifetime] <Insert value>**.
 - f. Evaporator and Condenser Coils: Minimum **[five (5) years] <Insert value>**.
 - g. **<Insert components requiring extended warranty>**.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. Adams Manufacturing Company.
2. Arcoaire Air Conditioning & Heating; an International Comfort Products brand; a unit of United Technologies Corp.
3. Bard Manufacturing Company.
4. Carrier Corporation; Div. of United Technologies Corp.
5. Comfort-Aire a division of Heat Controller, Inc.
6. Comfortmaker Air Conditioning & Heating; a division of International Comfort Products, LLC.
7. Dornback Furnace.
8. Heil Heating & Cooling Products; a division of International Comfort Products, LLC.
9. Lennox Industries Inc.
10. Luxaire Corporation; a division of Unitary Products Group.
11. Rheem Manufacturing Company; Air Conditioning Division.
12. Ruud Air Conditioning Division.
13. Thermo Products, Inc.; a division of Burnham Holdings Inc.
14. York International Corp.; a Johnson Controls Company.
15. **<Insert manufacturer's name>.**
16. or approved equal.

2.2 ASSEMBLY DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a qualified testing agency, and marked for intended location and application.
- B. Manufactured Units: Factory assembled, piped, wired, and tested; complying with UL 727 and with NFPA 31.

2.3 FURNACES

- A. Cabinet: **[Steel] [Galvanized steel]**.
1. Cabinet interior around heat exchanger shall be factory-installed insulation.

2. Lift-out panels shall expose burners and all other items requiring access for maintenance.
 3. Factory paint external cabinets in manufacturer's standard color.
 4. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- B. Fan: Centrifugal, factory balanced, resilient mounted, **[direct drive] [belt drive] [direct or belt drive] [drive type indicated on Drawings]**.
1. Fan Motors: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Special Motor Features: Single speed, premium efficiency, as defined in Section 230513 "Common Motor Requirements for HVAC Equipment," and with internal thermal protection and permanent lubrication.
 3. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
- C. Heat Exchanger: Welded steel with **[ceramic-fiber liner] [refractory insert]** at the burner in the combustion chamber. Minimum **2-inch- (50-mm-)** diameter access ports in heat exchanger to permit access for cleaning.
- D. Burner: High-pressure atomizing type, with rubber-mounted, adjustable, combustion-air blower; integrated fuel pump; hinged, flame-inspection port; cadmium-sulfide flame sensor; electrodes; ignition transformer; and oil nozzle.
1. Time-Delay Relay: Limits time for establishing main flame.
 2. Flame Sensor: Monitors flame and stops burner on flame failure.
 3. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
- E. Barometric Draft Regulator: Match furnace; for mounting in flue.
- F. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; and adjustable fan-on and fan-off timing; terminals for connection to accessories.
- G. Vent Materials: Comply with requirements in Section 235123 "Gas Vents" for Type B metal vents.
- H. Capacities and Characteristics:
1. Airflow Configuration: **[Upflow] [Counterflow] [Horizontal]**.
 2. Minimum Efficiency AFUE: **<Insert number>** percent.
 3. Minimum Thermal Efficiency: **<Insert number>** percent.
 4. Oil:
 - a. Input: **<Insert gph (L/s)>**.
 - b. Heat Output: **<Insert MBh (kW)>**.
 - c. Burner Motor:
 - 1) Size: **<Insert horsepower>**.

- 2) Speed: **<Insert rpm>**.
- d. Vent Size: **<Insert inches (mm)>**.
5. Fan:
 - a. Airflow: **<Insert cfm (L/s)>**.
 - b. External Static Pressure: **<Insert inches wg (Pa)>**.
 - c. Motor:
 - 1) Size: **<Insert horsepower>**.
 - 2) Speed: **<Insert rpm>**.
 - d. Volts: **<Insert value>**.
 - e. Phase: **<Insert value>**.
 - f. Hertz: **<Insert value>**.
 - g. Full-Load Amperes: **<Insert value>**.
 - h. Minimum Circuit Ampacity: **<Insert value>**.
 - i. Maximum Overcurrent Protection: **<Insert amperage>**.
6. Furnace Electrical Connection:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 THERMOSTATS[**AND HUMIDISTATS**]

- A. Controls shall comply with requirements in ASHRAE/IES 90.1, "Controls."
- B. Solid-State Thermostat: [**Wall-mounted**] [**Freestanding**] [**Wireless**], programmable, microprocessor-based unit with [**automatic**] [**manual**] switching from heating to cooling, preferential rate control, seven-day programmability with minimum of four temperature presets per day, [**vacation mode**,]and battery backup protection against power failure for program settings.
- C. Single-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounted unit with fan on-automatic selector.
- D. Two-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounted unit with fan on-automatic selector.
- E. [**Single**] [**Two**]-Stage, Heating-Only Thermostat: Wall-mounted unit with fan on-automatic selector.
- F. Solid-State, Combination Thermostat and Humidistat: [**Wall-mounted**] [**Freestanding**] [**Wireless**], programmable, microprocessor-based unit with automatic switching from

heating to cooling and humidifying to dehumidifying, preferential rate control, seven-day programmability with minimum of four temperature presets per day, [**vacation mode**,]and battery backup protection against power failure for program settings.

- G. Humidistat: Adjustable, [**wall**] [**duct**]-mounted unit.
- H. Control Wiring: Unshielded twisted-pair cabling.
 - 1. No. 24 AWG, 100 ohm, four pair.
 - 2. Cable Jacket Color: [**Blue**] <**Insert color**>.

2.5 AIR FILTERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Aprilaire; a division of Research Products Corp.](#)
 - 2. [Filtrete Home Filtration Products; a division of 3M.](#)
 - 3. [General Filters, Inc.](#)
 - 4. [Permatron Corporation.](#)
 - 5. <**Insert manufacturer's name**>.
 - 6. or approved equal.

Retain one or more of paragraphs below. If Project has more than one filter type, indicate filter type for each unit on Drawings.

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, in which a MERV rating of 6 or higher is required. "Washable Filters" Paragraph below does not comply; "Disposable Filters" Paragraph complies.

- B. Washable Filters: **1-inch-** (25-mm-) thick urethane pad.
- C. Disposable Filters: [**1-inch-** (25-mm-)] <**Insert dimension**> thick fiberglass media[**with ASHRAE 52.2 MERV rating of 6 or higher,**] in sheet metal frame.
- D. Charged Media Air Filters: Sheet metal housing arranged to be ducted in return-air duct connection to furnace; generates electrostatic charge; MERV 10 rating.
- E. HEPA Air Filter Units: Sheet metal housing with fan arranged to be ducted to return-air duct connection to furnace, with activated carbon prefilter[, **carbon VOC,**] and high-efficiency particulate air (HEPA) disposable filter. HEPA shall be as follows:
 - 1. Standard: UL 586.
 - 2. Rating: ASHRAE 52.2, 99.97 percent efficiency to 0.30-micrometer particle size.

2.6 AIR CLEANERS

If Project uses both air filters and air cleaners, indicate type for each unit on Drawings.

- A. Electronic Air Cleaners: Packaged system, including sheet metal housing, prefilter, power supply, and automatic control device, arranged for mounting in return-air duct at furnace; equip with on-off and test switches and pilot light.
1. Standard: UL 586.
 2. Rating: ASHRAE 52.2, particle size to 0.01 micrometer.
 3. Static Pressure Drop: Maximum **0.14-inch wg (35 Pa)** at **300-fpm (1.52-m/s)** air velocity.
- B. Capacities and Characteristics:
1. Volts: **<Insert value>**.
 2. Phase: **<Insert value>**.
 3. Hertz: **<Insert value>**.
 4. Minimum Circuit Ampacity: **<Insert value>**.
 5. Maximum Overcurrent Protection: **<Insert amperage>**.

2.7 UV GERMICIDAL LIGHTS

- A. Description: Lighting unit in metal housing arranged for installation in supply-air duct and controlled to cycle on and off with furnace fan, with **[one]** **[two]** 75-W UV light bulb(s).

2.8 HUMIDIFIERS

- A. Minimum capacity rating indicated according to AHRI 610.
- B. Media-wheel bypass type with bypass damper and motor-driven media wheel in reservoir with float-valve level control; arranged for mounting on return duct or plenum with bypass connection to supply duct.
- C. Wetted-pad, continuous-drain, bypass type with bypass damper and water-flow control orifice; arranged for mounting on return duct or plenum with bypass connection to supply duct.
- D. Fan-powered, wetted-pad, continuous-drain type with water-flow control orifice and motor; arranged for mounting on duct or plenum.
- E. Pumped, fan-powered, wetted-pad type with reservoir-level control and pump and fan motors; arranged for mounting on duct or plenum.
- F. Steam type with electric heating element in stainless-steel reservoir with float-valve level control; arranged for attachment to duct or plenum and for control by humidistat.
- G. Comply with applicable requirements in ASHRAE 62.1.
- H. Capacities and Characteristics:

1. Type: [**Steam**] [**Media wheel**] [**Wetted pad with reservoir**] [**Wetted pad with continuous drain**] [**Wetted-pad bypass**].
2. Steam Capacity: <Insert lb/h (kg/h)>.
3. Water Connection Size: <Insert NPS (DN)>.
4. Drain Connection Size: <Insert NPS (DN)>.
5. Volts: <Insert value>.
6. Phase: <Insert value>.
7. Hertz: <Insert value>.
8. Minimum Circuit Ampacity: <Insert value>.
9. Maximum Overcurrent Protection: <Insert amperage>.

2.9 VENTILATION AIR HEAT EXCHANGERS

- A. Cabinet: Steel, with factory-installed interior insulation and manufacturer's standard factory finish. Fabricate with space for piping and electrical conduits.
- B. Heat-Recovery Device: Fixed-plate, polypropylene copolymer (high-density plastic) heat-exchanger plates evenly spaced and sealed and arranged for counter airflow.
- C. Supply and Exhaust Fans: Forward curved centrifugal with direct drive. Motors comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- D. Filters: 1-inch- (25-mm-) thick disposable type[**with ASHRAE 52.2 MERV rating of 6 or higher**], in galvanized-steel frame, mounted upstream of unit in both supply and exhaust airstreams.
- E. Wiring: Wire motors and controls so only external connections are required during installation.

2.10 REFRIGERATION COMPONENTS

- A. General Refrigeration Component Requirements:

Also, LEED Prerequisite EA 3 requires using CFC-free refrigerants in new HVAC&R systems.

1. Refrigeration compressor, coils, and specialties shall be designed to operate with CFC-free refrigerants.

Also, LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1.

2. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IES 90.1.

- B. Refrigerant Coil: Copper tubes mechanically expanded into aluminum fins. Comply with AHRI 210/240. Match size with furnace. Include condensate drain pan with accessible drain outlet[**complying with ASHRAE 62.1**].

1. Refrigerant Coil Enclosure: Steel, matching furnace and evaporator coil, with access panel and flanges for integral mounting at or on furnace cabinet and galvanized sheet metal drain pan coated with black asphaltic base paint.

- C. Refrigerant Line Kits: Annealed-copper suction and liquid lines factory cleaned, dried, pressurized with nitrogen, sealed, and with suction line insulated. Provide in standard lengths for installation without joints, except at equipment connections.
1. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534/C 534M, Type I, [1/2 inch (13 mm)] [1 inch (25 mm)] <Insert dimension> thick.
- D. Refrigerant Piping: Comply with requirements in Section 232300 "Refrigerant Piping."
- E. Air-Cooled Compressor-Condenser Unit:
1. Casing: Steel, finished with baked enamel, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
 2. Compressor: Hermetically sealed [reciprocating] [or] [scroll] type.
 - a. Crankcase heater.
 - b. [Restrained vibration] [Vibration] isolation mounts for compressor.
 - c. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - d. Two-speed compressor motors shall have manual-reset high-pressure switch and automatic-reset low-pressure switch.
 - e. Refrigerant Charge: [R-22] [R-407C] [R-410A] <Insert type>.
 - f. Refrigerant: R-407C or R-410A.
 3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with AHRI 210/240, and with liquid subcooler.
 4. Heat-Pump Components: Reversing valve and low-temperature air cut-off thermostat.
 5. Fan: Aluminum-propeller type, directly connected to motor.
 6. Motor: Permanently lubricated, with integral thermal-overload protection.
 7. Low Ambient Kit: Permits operation down to 45 deg F (7 deg C).
 8. Mounting Base: Polyethylene.
- F. Capacities and Characteristics:
1. Refrigerant Coil:
 - a. Total Cooling Capacity: <Insert Btu/h (kW)>.
 - b. Sensible Cooling Capacity: <Insert Btu/h (kW)>.
 - c. Heating Capacity: <Insert Btu/h (kW)>.
 - d. Maximum Air Pressure Drop: <Insert inches wg (Pa)>.
 - e. Condensate Drain Size: <Insert NPS (DN)>.
 2. Compressor-Condenser Unit:
 - a. Cooling Energy Efficiency[(EER)] [(SEER)]: <Insert value>.
 - b. Heating Coefficient of Performance: <Insert value>.
 - c. Volts: <Insert value>.

- d. Phase: **<Insert value>**.
- e. Hertz: **<Insert value>**.
- f. Full-Load Amperes: **<Insert value>**.
- g. Minimum Circuit Ampacity: **<Insert value>**.
- h. Maximum Overcurrent Protection: **<Insert amperage>**.
- i. Fan Motor Full-Load Amperes: **<Insert value>**.
- j. Compressor Running-Load Amperes: **<Insert value>**.
- k. Compressor Motor Full-Load Amperes: **<Insert value>**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine factory-installed insulation before furnace installation. Reject units that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for oil[**and refrigerant**] piping systems to verify actual locations of piping connections before equipment installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install oil-fired furnaces and associated fuel and vent piping according to NFPA 31.
- B. Suspended Units: Suspend from structure using threaded rods, spring hangers, and building attachments. Secure rods to unit hanger attachments. Adjust hangers so unit is level and plumb.
 - 1. Install seismic restraints to limit movement of furnace by resisting code-required seismic acceleration.
- C. Base-Mounted Units: Secure units to substrate. Provide optional bottom closure base if required by installation conditions.
 - 1. Anchor furnace to substrate to resist code-required seismic acceleration.
- D. Controls: Install thermostats and humidistats at mounting height of **60 inches (1500 mm)** above floor.
- E. Wiring Method: Install control wiring in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Conceal control wiring except in unfinished spaces.

- F. Install ground-mounted, compressor-condenser components on 4-inch- (100-mm-) thick, reinforced concrete base; 4 inches (100 mm) larger on each side than unit. Concrete, reinforcement, and formwork are specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."] Coordinate anchor installation with concrete base.
- G. Install ground-mounted compressor-condenser components on polyethylene mounting base.
- H. Install roof-mounted compressor-condenser components on equipment supports specified in Section 077200 "Roof Accessories." Anchor units to supports with removable, cadmium-plated fasteners.

3.3 CONNECTIONS

- A. Oil piping installation requirements are specified in Section 231113 "Facility Fuel-Oil Piping." Drawings indicate general arrangement of piping, fittings, and specialties. Connect oil piping with union or flange and [ball] [gate] valve.
- B. Install piping adjacent to equipment to allow service and maintenance.
- C. Water piping installation requirements are specified in Section 221116 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties. Connect water piping with union and ball valve.
- D. Vent Connections: Connect Type L vents to furnace vent connection and extend outdoors. Type L vents and their installation requirements are specified in Section 235123 "Gas Vents."
- E. Connect ducts to furnace with flexible connector. Comply with requirements in Section 233300 "Air Duct Accessories."
- F. Connect refrigerant tubing kits to refrigerant coil in furnace and to air-cooled, compressor-condenser unit.
 - 1. Flared Joints: Use ASME B16.26 fitting and flared ends, following procedures in CDA's "Copper Tube Handbook."
 - 2. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
 - 3. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.
- G. Comply with requirements in Section 232300 "Refrigerant Piping" for installation and joint construction of refrigerant piping.

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
1. Perform electrical test and visual and mechanical inspection.
 2. Leak Test: After installation, charge systems with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation, product capability, and compliance with requirements.
 4. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

3.5 STARTUP SERVICE

- A. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
1. Inspect for physical damage to unit casings.
 2. Verify that access doors move freely and are weathertight.
 3. Clean units and inspect for construction debris.
 4. Verify that all bolts and screws are tight.
 5. Adjust vibration isolation and flexible connections.
 6. Verify that controls are connected and operational.
- B. Adjust fan belts to proper alignment and tension.
- C. Start unit according to manufacturer's written instructions and complete manufacturer's operational checklist.
- D. Measure and record airflows.
- E. Verify proper operation of capacity control device.
- F. After startup and performance test, lubricate bearings[**and adjust belt tension**].

3.6 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Set controls, burner, and other adjustments for optimum heating performance and efficiency. Adjust heat-distribution features, including shutters, dampers, and relays, to provide optimum heating performance and system efficiency.

3.7 CLEANING

- A. After completing installation, clean furnaces internally according to manufacturer's written instructions.
- B. Install new filters in each furnace within 14 days after Substantial Completion.

3.8 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain condensing units. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235416.16

SECTION 235513.16 - GAS-FIRED DUCT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes gas-fired duct heaters.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of gas-fired duct heater.
 - 1. Include rated capacities, operating characteristics, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For gas-fired duct heaters[; **signed and sealed by a qualified professional engineer**]. Include plans, elevations, sections, and attachment details.
 - 1. Prepare by or under the supervision of a qualified professional engineer detailing fabrication and assembly of gas-fired duct heaters, as well as procedures and diagrams.
 - 2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
 - 3. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
 - 4. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
 - 5. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 6. Startup service reports.
 - 7. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Structural members to which equipment will be attached.
 2. Items penetrating roof and the following:
 - a. Duct, vent, and gas piping rough-ins and connections.
 - b. **<Insert item>**.
- B. Seismic Qualification Certificates: For gas-fired duct heaters, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.
- D. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For gas-fired duct heaters to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.7 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace heat exchanger of gas-fired duct heater that fails in materials or workmanship within specified warranty period.
1. Warranty Period: Minimum **[two (2)] [five (5)] <Insert number>** years from date of Substantial Completion.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Lennox Industries, Inc.; Lennox International.](#)
 2. [Modine Manufacturing Company.](#)
 3. [Reznor/Thomas & Betts Corporation.](#)
 4. [Sterling HVAC Products; Div. of Mestek Technology Inc.](#)
 5. **<Insert manufacturer's name>.**
 6. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. **Seismic Performance:** Gas-fired duct heaters shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] **<Insert requirement>.**
1. **Seismic Fabrication Requirements:** Fabricate and reinforce suspension attachments of gas-fired duct heaters, accessories mountings, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when gas-fired duct heater is anchored to building structure.
 2. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
 3. **<Insert requirements for Component Amplification Factor and Component Response Modification Factor>.**
- B. **Electrical Components, Devices, and Accessories:** Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. **Capacities and Characteristics:**
1. Heat Exchanger: **[Aluminized] [Stainless]** steel.
 2. Burner Material: **[Aluminized steel with stainless-steel inserts] [Stainless steel]**.
 3. Venting: **[Gravity] [Power]** vented.
 4. Venting: Indoor, separated combustion, power vented.

- a. Concentric, Terminal Vent Assembly: Combined combustion-air inlet and power-vent outlet with wall or roof caps. Include adapter assembly for connection to inlet and outlet pipes, and flashing for wall or roof penetration.
5. Flue Outlet: <Insert inches (mm)> in diameter.
6. Gas Input: <Insert Btu/h (kW)>.
7. Gas Output: <Insert Btu/h (kW)>.
8. Gas Control Valve: [**Single stage**] [**Two stage**] [**Modulating**].
9. Annual Fuel Utilization Efficiency: [**80**] <Insert number> percent.
10. Minimum Airflow: <Insert cfm (L/s)>.
11. External Static Pressure: <Insert inches wg (kPa)>.

2.3 MANUFACTURED UNITS

- A. Description: Factory assembled, piped, and wired; and complying with ANSI Z83.8/CSA 2.6.
- B. Fuel Type: Design burner for [**natural**] [**propane**] gas having characteristics same as those of gas available at Project site.
- C. Indoor External Housing: Steel cabinet with integral support inserts and removable bottom arranged to serve as drain pan.
 1. External Casings and Cabinets: [**Baked enamel**] [**Powder coating**] over corrosion-resistant-treated surface.
- D. Outdoor External Housing: Weatherproof steel cabinet with integral support inserts and removable bottom arranged to serve as drain pan.
 1. External Casings and Cabinets: [**Baked enamel**] [**Powder coating**] over corrosion-resistant-treated surface.
- E. Internal Casing: Aluminized steel, arranged to contain airflow, with duct flanges at inlet and outlet.
- F. Power Venter: Integral, motorized centrifugal fan interlocked with gas valve.
- G. Controls: Regulated redundant gas valve containing pilot solenoid valve, electric gas valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
 1. Ignition: [**Standing pilot**] [**Electronically controlled electric spark with flame sensor**].
 2. Fan Thermal Switch: Operates fan on heat-exchanger temperature.
 3. Vent Flow Verification: [**Flame rollout switch**] [**Differential pressure switch to verify open vent**].
 4. Control transformer.
 5. High Limit: Thermal switch or fuse to stop burner.
 6. Thermostat: Devices and wiring are specified in Section 230923.27 "Temperature Instruments."

7. Thermostat: Single-stage, wall-mounted type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
8. Thermostat: Two-stage, wall-mounted type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
9. Thermostat: Single-stage type with duct-mounted sensor and 50 to 90 deg F (10 to 32 deg C) operating range.
10. Thermostat: Two-stage type with duct-mounted sensor and 50 to 90 deg F (10 to 32 deg C) operating range.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install and connect gas-fired duct heaters and associated fuel and vent features and systems according to [NFPA 54] [CSA B149.1], applicable local codes and regulations, and manufacturer's written instructions.
- B. Suspended Units: Suspend from substrate using threaded rods, spring hangers, and building attachments. Secure rods to unit hanger attachments. Adjust hangers so unit is level and plumb.
 1. Spring hangers are specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
 2. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for spring hangers and seismic restraints.
 3. Restrain the unit to resist code-required horizontal acceleration.

3.2 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to gas-fired duct heaters, allow space for service and maintenance.
- C. Gas Piping: Comply with [Section 231123 "Facility Natural-Gas Piping."] [Section 231126 "Facility Liquefied-Petroleum Gas Piping."] Connect gas piping to gas train inlet; provide union with enough clearance for burner removal and service.
- D. Vent Connections: Comply with Section 235123 "Gas Vents."
- E. Duct Connections: Comply with [Section 233113 "Metal Ducts."] [Section 233116 "Nonmetal Ducts."]
- F. Electrical Connections: Comply with applicable requirements in electrical Sections.
 1. Install electrical devices furnished with heaters but not specified to be factory mounted.

3.3 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 2. Verify bearing lubrication.
 - 3. Verify proper motor rotation.
 - 4. Test Reports: Prepare a written report to record the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- C. Gas-fired duct heater will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.4 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Adjust burner and other unit components for optimum heating performance and efficiency.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain gas-fired duct heaters.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235513.16

SECTION 235523.13 - LOW-INTENSITY, GAS-FIRED, RADIANT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes low-intensity, gas-fired, [**forced-draft**] [**draft-induced**] [**multiple-burner**] radiant heaters.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include manufacturer's literature and data indicating rated capacities, operating characteristics, electrical characteristics and wiring diagrams, weights, electrical nameplate data, and furnished specialties and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Signed, sealed, and prepared by or under the supervision of a qualified professional engineer.
 - 2. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.
 - 3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 4. Detail fabrication and assembly of high-intensity, gas-fired, radiant heaters, as well as procedures and diagrams.
 - 5. Include diagrams for power[, **signal, and control**] wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Structural members to which equipment will be attached.
2. Gas piping to heater installations
3. Thermostats and wiring to heaters.
4. Heater locations and clearance requirements.
5. Other suspended ceiling components including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Sprinklers.
 - d. **<Insert item>**.

B. Field quality-control reports.

C. Sample Warranty: For manufacturer's special warranties.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For gas-fired, radiant heaters to include in emergency, operation, and maintenance manuals.

1. Include manufacturer's descriptive literature, operating instructions, maintenance and repair data, and parts listing.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Igniter: Provide **[One (1)] <Insert number>** hot-surface burner igniter(s) for each style of high-intensity, gas-fired, radiant heater furnished.

1.7 WARRANTY

A. Manufacturer's Special Warranty: Manufacturer agrees to repair or replace components of radiant heaters that fail in materials or workmanship within specified warranty period.

1. Warranty Period: All warranty periods listed below are from date of Substantial Completion.
 - a. Burner Assembly: Minimum **[three (3)] [five (5)] [ten (10)] <Insert number>** years.
 - b. Combustion and Emitter Tubes: Minimum **[two (2)] [three (3)] [five (5)] <Insert number>** years.

- c. Heater Controls: One (1) <Insert number> year(s).

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. CSA certified, with CSA Seal and certification number clearly visible on units indicating compliance with ANSI Z83.20/CSA 2.34.
- B. UL listed and labeled, with UL label clearly visible on units indicating compliance with ANSI Z83.20/CSA 2.34.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 FORCED-DRAFT HEATERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Calcana Industries Ltd.](#)
 2. [Combustion Research Corporation.](#)
 3. [Detroit Radiant Products Company.](#)
 4. [Roberts-Gordon, LLC.](#)
 5. [Schwank Inc.](#)
 6. [Solaronics, Inc.](#)
 7. [Space-Ray; Division of Gas Fired Products, Inc.](#)
 8. [Sterling HVAC Products; a Mestek company.](#)
 9. [Thomas & Betts Corporation; a member of the ABB Group.](#)
 10. <Insert manufacturer's name>.
 11. or approved equal.
- B. Description: Factory-assembled, [**indoor**] [**outdoor**], overhead-mounted, electrically controlled, low-intensity, infrared radiant heating units using gas combustion. Heater to have all necessary factory-installed wiring and piping required prior to field installation and startup.
- C. Fuel Type: Design burner for [**natural**] [**propane**] gas having characteristics same as those of gas available at Project site.

D. Burner Assembly:

1. Combustion-Air Inlet: Non-ducted, unvented.
2. Combustion-Air Inlet: Ducted horizontal to outdoors through sidewall with vent caps.
3. Combustion-Air Inlet: Ducted vertical to outdoors through roof with vent caps.
4. Burner Control Housing: **[Stainless steel] [Corrosion-resistant, aluminized steel] [Steel]**.
 - a. Totally enclosed with **[stainless-steel] [steel]** access cover.
 - b. Sight glass for visual inspection of burner.
 - c. Finish: **[Enameled finish] [or] [powder-coated finish]**.
5. Burner: **[Stainless steel] [One-piece cast iron]**.
6. Ignition System: **[Silicon carbide hot-surface igniter] [Direct spark] [24/25-V ac] [115/120-V ac]** with flame rod sensing capabilities[**and self-diagnostic control module**].
7. Combustion Blower Fan: Dynamically balanced, direct-driven, forward-curved fan with **[cast-aluminum-alloy] [stainless-steel]** <Insert material> impeller and **[aluminized-]steel** housing, with a minimum temperature rating of **450 deg F** (232 deg C).
8. Motors: General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor: Resilient-mounted, capacitor-start-capacitor-run type with sealed ball bearings; totally enclosed, nonventilated type with internal thermal protection.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

E. Combustion Chamber: **4-inch-** (100-mm-) diameter, **[12] [16]**-gage, **[aluminized] [titanium-coated aluminized] [stainless] [hot-rolled]**-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish. Chambers shall be equipped with sight glass for burner and pilot flame observation.

F. Emitter Tube: **4-inch-** (100-mm-) **[3-inch-** (76-mm-)] diameter, **[12] [16]**-gage, **[aluminized] [hot-rolled] [stainless] [titanium-coated aluminized]**-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish.**[Emitter tubing shall be equipped with baffles to maximize heating efficiency.]**

1. Tubing Connections: **[Stainless-steel threaded couplings] [Interlocking flare joints with stainless-steel draw bolts] [Compression couplings made from aluminized or stainless steel]**.
2. **[90] [180]**-degree-bend emitter steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish.
3. Exhaust Vent Termination: **[Vertical through roof] [Horizontal though side wall]** with vent caps.

- G. Reflector: **[Polished aluminum] [Polished stainless steel] [High-grade steel with a heat- and corrosion-resistant, hot-bonded, aluminum-silicon alloy coating]**, with end caps. Shape to control radiation from tubing for uniform intensity at floor level with 100 percent cutoff above centerline of tubing. Reflectors or entire heater shall accommodate rotational adjustment from horizontal to a minimum 30-degree tilt from vertical.
- H. Accessories:
1. Reflector Extension Shields: Same material as reflectors, arranged for fixed connection to lower reflector lip and rigid support to provide 100 percent cutoff of direct radiation from tubing at angles greater than 30 degrees from vertical.
 2. Protective grilles mounted to reflectors to protect emitter tubing.
 3. Stainless-steel flexible connector with manual valve for gas supply.
 4. Hanger chain with "S" hooks.
 5. **3/16-inch- (5-mm-)** diameter, **[galvanized][aluminized]**-steel wire tubing hangers and reflector supports.
 6. Rigid mounting kits.
 7. Outdoor use conversion kit.
 8. Clearance warning plaque.
- I. Capacities and Characteristics:
1. Gas Input: **<Insert Btu/h (kW)>**.
 2. Gas Output: **<Insert Btu/h (kW)>**.
 3. Fuel-Supply Connection: **<Insert inches (mm)>**.
 4. Combustion-Air Fan Motor Size: **<Insert value>** hp.
 - a. Volts: **[120] [208] [230] <Insert value>** V.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 DRAFT-INDUCED HEATERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Combustion Research Corporation](#).
 2. [Detroit Radiant Products Company](#).
 3. [Roberts-Gordon, Inc.](#)
 4. [Schwank Inc.](#)
 5. [Solaronics, Inc.](#)
 6. [Space-Ray; Division of Gas Fired Products, Inc.](#)
 7. **<Insert manufacturer's name>**.
 8. or approved equal.

- B. Description: Factory-assembled, [**indoor**] [**outdoor**], overhead-mounted, electrically controlled, low-intensity, infrared radiant heating units using gas combustion. Heater to have all necessary factory-installed wiring and piping required prior to field installation and startup.
- C. Fuel Type: Design burner for [**natural**] [**propane**] gas having characteristics same as those of gas available at Project site.
- D. Burner Assembly:
1. Combustion-Air Inlet: Non-ducted, unvented.
 2. Combustion-Air Inlet: Ducted horizontal to outdoors through sidewall with vent caps.
 3. Combustion-Air Inlet: Ducted vertical to outdoors through roof with vent caps.
 4. Burner Control Housing: [**Stainless steel**] [**Corrosion-resistant, aluminized steel**] [**Steel**].
 - a. Totally enclosed with [**stainless-steel**] [**steel**] access cover.
 - b. Sight glass for visual inspection of burner.
 - c. Finish: [**Enameled finish**] [**or**] [**powder-coated finish**].
 5. Burner: [**Stainless steel**] [**One-piece cast iron**].
 6. Ignition System: [**Silicon carbide hot-surface igniter**] [**Direct spark**] [**24/25-V ac**] [**115/120-V ac**] with flame rod sensing capabilities[**and self-diagnostic control module**].
 7. Combustion Blower Fan: Dynamically balanced, direct-driven, forward-curved fan with [**cast-aluminum-alloy**] [**stainless-steel**] <Insert material> impeller and [**aluminized-**]steel housing, with a minimum temperature rating of 450 deg F (232 deg C).
 8. Motors: General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor: Resilient-mounted, capacitor-start-capacitor-run type with sealed ball bearings; totally enclosed, nonventilated type with internal thermal protection.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- E. Combustion Chamber: 4-inch- (100-mm-) diameter, [**12**] [**16**]-gage, [**aluminized**] [**titanium-coated aluminized**] [**stainless**] [**hot-rolled**]-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish. Chambers shall be equipped with sight glass for burner and pilot flame observation.
- F. Emitter Tube: [4-inch- (100-mm-)] [3-inch- (76-mm-)] diameter, [**12**] [**16**]-gage, [**aluminized**] [**hot-rolled**] [**stainless**] [**titanium-coated aluminized**]-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish.[**Emitter tubing shall be equipped with baffles to maximize heating efficiency.**]

1. Tubing Connections: [**Stainless-steel threaded couplings**] [**Interlocking flare joints with stainless-steel draw bolts**] [**Compression couplings made from aluminized or stainless steel**].
 2. [**90**] [**180**]-degree-bend emitter steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish.
- G. Vacuum Exhaust Fan: Dynamically balanced, direct-driven, [**cast-aluminum-alloy**] [**stainless-steel**] impeller in aluminized-steel housing, isolated from emitter tubing exhaust system by high-temperature flexible vibration isolation connector. Fan and connector to have a minimum temperature rating of **450 deg F** (**232 deg C**).
1. Motors: General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor: Resilient-mounted, capacitor-start-capacitor-run type with sealed ball bearings; totally enclosed, nonventilated type with internal thermal protection.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Balancing Dampers: Plate type, mounted in cast, double-flange fitting with vacuum test plug.
 3. Filter: Cartridge type for mounting on burner housing.
 4. Exhaust Vent Termination: [**Vertical through roof**] [**Horizontal though side-wall**] with vent caps.
- H. Reflector: [**Polished aluminum**] [**Polished stainless steel**] [**High-grade steel with a heat- and corrosion-resistant, hot-bonded, aluminum-silicon alloy coating**], with end caps. Shape to control radiation from tubing for uniform intensity at floor level with 100 percent cutoff above centerline of tubing. Reflectors or entire heater shall accommodate rotational adjustment from horizontal to a minimum 30-degree tilt from vertical.
- I. Accessories:
1. Reflector Extension Shields: Same material as reflectors, arranged for fixed connection to lower reflector lip and rigid support to provide 100 percent cutoff of direct radiation from tubing at angles greater than 30 degrees from vertical.
 2. Protective grilles mounted to reflectors to protect emitter tubing.
 3. Stainless-steel flexible connector with manual valve for gas supply.
 4. Hanger chain with "S" hooks.
 5. **3/16-inch-** (**5-mm-**) diameter, [**galvanized**][**aluminized**]-steel wire tubing hangers and reflector supports.
 6. Rigid mounting kits.
 7. Outdoor use conversion kit.
 8. Clearance warning plaque.
- J. Capacities and Characteristics:

1. Gas Input: <Insert Btu/h (kW)>.
2. Gas Output: <Insert Btu/h (kW)>.
3. Fuel-Supply Connection: <Insert inches (mm)>.
4. Combustion-Air Fan Motor Size: <Insert value> hp.
 - a. Volts: [120] [208] [230] <Insert value> V.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.
5. Vacuum Exhaust Fan Motor Size: <Insert value> hp.
 - a. Volts: [120] [208] [230] <Insert value> V.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.4 MULTIPLE-BURNER HEATERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Combustion Research Corporation](#).
 2. [Detroit Radiant Products Company](#).
 3. [Roberts-Gordon, Inc.](#)
 4. <Insert manufacturer's name>.
 5. or approved equal.
- B. Description: Factory-assembled, [indoor] [outdoor], overhead-mounted, electrically controlled, low-intensity, infrared radiant heating units using gas combustion. Heater to have all necessary factory-installed wiring and piping required prior to field installation and startup.
- C. Fuel Type: Design burner for [natural] [propane] gas having characteristics same as those of gas available at Project site.
- D. Burner Assembly: <Insert drawing designation>.
1. Combustion-Air Inlet: Non-ducted, unvented.
 2. Combustion-Air Inlet: Ducted horizontal to outdoors through sidewall with vent caps.
 3. Combustion-Air Inlet: Ducted vertical to outdoors through roof with vent caps.
 4. Burner Control Housing: [Stainless steel] [Corrosion-resistant, aluminized steel] [Steel].

- a. Totally enclosed with **[stainless-steel]** **[steel]** access cover.
 - b. Sight glass for visual inspection of burner.
 - c. Finish: **[Enameled finish]** **[or]** **[powder-coated finish]**.
5. Burner: **[Stainless steel]** **[One-piece cast iron]**.
6. Ignition System: **[Silicon carbide hot-surface igniter]** **[Direct spark]** **[24/25-V ac]** **[115/120-V ac]** with flame rod sensing capabilities **[and self-diagnostic control module]**.
7. Combustion Blower Fan: Dynamically balanced, direct-driven, forward-curved fan with **[cast-aluminum-alloy]** **[stainless-steel]** **<Insert material>** impeller and **[aluminized-]**steel housing, with a minimum temperature rating of **450 deg F (232 deg C)**.
8. Motors: General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- a. Motor: Resilient-mounted, capacitor-start-capacitor-run type with sealed ball bearings; totally enclosed, nonventilated type with internal thermal protection.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- E. Combustion Chamber: **4-inch- (100-mm-)** diameter, **[12]** **[16]**-gage, **[aluminized]** **[titanium-coated aluminized]** **[stainless]** **[hot-rolled]**-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish. Chambers shall be equipped with sight glass for burner and pilot flame observation.
- F. Emitter Tube: **[4-inch- (100-mm-)]** **[3-inch- (76-mm-)]** diameter, **[12]** **[16]**-gage, **[aluminized]** **[hot-rolled]** **[stainless]** **[porcelain-lined]** **[titanium-coated aluminized]**-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish. **[Emitter tubing shall be equipped with baffles to maximize heating efficiency.]**
1. Tubing Connections: **[Stainless-steel threaded couplings]** **[Interlocking flare joints with stainless-steel draw bolts]** **[Compression couplings made from aluminized or stainless steel]**.
 2. **[90-degree bends]** **[180-degree bends]** **[Tee fittings]** **[Cross fittings]** made from **[stainless steel]** with corrosion-resistant, high-temperature black coating.
 3. Condensing Tubing: **4-inch- (100-mm-)** diameter, stainless-steel tubing with high-emissivity, high-temperature, corrosion-resistant external finish.
- G. Vacuum Exhaust Fan: Dynamically balanced, direct-driven, **[cast-aluminum-alloy]** **[stainless-steel]** impeller in aluminized-steel housing, isolated from emitter tubing exhaust system by high-temperature flexible vibration isolation connector. Fan and connector to have a minimum temperature rating of **450 deg F (232 deg C)**.
1. See **[Section 230548 "Vibration and Seismic Controls for HVAC"]** **[Section 230548.13 "Vibration Controls for HVAC"]** for mounting vacuum exhaust fan.
 2. Motors: General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- a. Motor: Resilient-mounted, capacitor-start-capacitor-run type with sealed ball bearings; totally enclosed, nonventilated type with internal thermal protection.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Balancing Dampers: Plate type, mounted in cast, double-flange fitting with vacuum test plug.
 4. Filter: Cartridge type for mounting on burner housing.
 5. Exhaust Vent Termination: **[Vertical through roof] [Horizontal though side wall]** with vent caps.
- H. Reflector: **[Polished aluminum] [Polished stainless steel] [High-grade steel with a heat- and corrosion-resistant, hot-bonded, aluminum-silicon alloy coating]**, with end caps. Shape to control radiation from tubing for uniform intensity at floor level with 100 percent cutoff above centerline of tubing. Reflectors shall accommodate rotational adjustment from horizontal to a minimum 30-degree tilt from vertical.
- I. Accessories:
1. Reflector Extension Shields: Same material as reflectors, arranged for fixed connection to lower reflector lip and rigid support to provide 100 percent cutoff of direct radiation from tubing at angles greater than 30 degrees from vertical.
 2. Protective grilles mounted to reflectors to protect emitter tubing.
 3. Stainless-steel flexible connector with manual valve for gas supply.
 4. Hanger chain with "S" hooks.
 5. **3/16-inch- (5-mm-)** diameter, **[galvanized][aluminized]**-steel wire tubing hangers and reflector supports.
 6. Rigid mounting kits.
 7. Outdoor use conversion kit.
 8. Clearance warning plaque.
- J. Capacities and Characteristics:
1. Gas Input: **<Insert Btu/h (kW)>**.
 2. Gas Output: **<Insert Btu/h (kW)>**.
 3. Fuel-Supply Connection: **<Insert inches (mm)>**.
 4. Combustion-Air Fan Motor Size: **<Insert value>** hp.
 - a. Volts: **[120] [208] [230] <Insert value>** V.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
 5. Vacuum Exhaust Fan Motor Size: **<Insert value>** hp.
 - a. Volts: **[120] [208] [230] <Insert value>** V.

- b. Phase: [**Single**] [**Three**].
- c. Hertz: 60.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.5 CONTROLS AND SAFETIES

- A. Gas Control Valve: [**Single**] [**Two**]-stage, regulated redundant 24-V ac gas valve that contains pilot solenoid valve, electric gas valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
- B. Failure Safeguards: 100 percent shutoff of gas flow in the event of flame or power failure.
- C. Prepurge of [**15**] [**30**] [**45**] seconds of air control system prior to burner ignition.
- D. Safety lockout of burner after [**three consecutive ignition failures**] [**flame is not reestablished within trial ignition period**].
- E. Blocked Vent Safety: Differential pressure switch in burner safety circuit to stop burner operation with high discharge or suction pressure.
- F. Control Panel Interlock: Stops burner if panel is open.
- G. Indicator Lights: ["**Airflow-on**"] [**and**] ["**burner-on**"] indicator lights.
- H. Thermostat: Devices and wiring are specified in Section 230923.27 "Temperature Instruments."
- I. Thermostat: Single-stage, wall-mounted type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
 - 1. Control Transformer: Integrally mounted.
- J. Thermostat: Two-stage, wall-mounted type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
 - 1. Control Transformer: Integrally mounted.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that space is ready for installation of systems and openings are as indicated on shop drawings.
- B. Verify that proper power supply is available.

- C. Examine structures, substrates, areas and conditions, with Installer present, for compliance with requirements for installation tolerances, required clearances, and other conditions affecting performance of the Work.
- D. Examine roughing-in for fuel-gas piping to verify actual locations of piping connections before equipment installation.
- E. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- F. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Installation: Install gas-fired, radiant heaters and associated gas features and systems according to **[NFPA 54] [CSA B149.1]**.
- B. Suspended Units: **[Suspend from substrate using chain hanger kits and building attachments] [Mount to substrate using manufacturer's rigid mounting kits or custom fabricated brackets]**.
 - 1. Restrain the unit to resist seismic acceleration. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- C. Maintain manufacturers' recommended clearances for combustibles.

3.3 CONNECTIONS

- A. Gas Piping: Comply with **[Section 231123 "Facility Natural-Gas Piping."]** **[Section 231126 "Facility Liquefied-Petroleum Gas Piping."]** Connect gas piping to gas train inlet; provide union with enough clearance for burner removal and service.
 - 1. Gas Connections: Connect gas piping to radiant heaters according to **[NFPA 54] [CSA B149.1]**.
- B. Where installing piping adjacent to gas-fired, radiant heaters, allow space for service and maintenance.
- C. Vent Connections: Comply with Section 233113 "Metal Ducts" and with Section 235123 "Gas Vents."
- D. Electrical Connections: Comply with applicable requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
 - 1. Install electrical devices furnished with heaters but not specified to be factory mounted.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 2. Verify bearing lubrication.
 - 3. Verify proper motor rotation.
 - 4. Test Reports: Prepare a written report to record the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- C. Gas-fired, radiant heaters will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Adjust initial-temperature set points.
- B. Adjust burner and other unit components for optimum heating performance and efficiency.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain gas-fired, radiant heaters.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235523.13

SECTION 235523.16 - HIGH-INTENSITY, GAS-FIRED, RADIANT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. High-intensity, infrared, gas-fired, radiant heaters.
 - 2. Gas-fired, outdoor, infrared patio heaters.
- B. Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.
- D. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Signed, sealed, and prepared by or under the supervision of a qualified professional engineer.
 - 2. Include plans, elevations, sections, and [mounting] [attachment] details.
 - 3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 4. Detail fabrication and assembly of high-intensity, gas-fired, radiant heaters, as well as procedures and diagrams.
 - 5. Include diagrams for power[, **signal, and control**] wiring.

- C. Delegated-Design Submittal: For gas-fired, radiant heaters.
 - 1. Include design calculations for seismic restraints.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Structural members to which equipment will be attached.
 - 2. Gas piping to heater installations
 - 3. Thermostats and wiring to heaters.
 - 4. Heater locations and clearance requirements.
 - 5. Other suspended ceiling components:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Sprinklers.
 - d. <Insert item>.
- B. Field quality-control reports.
- C. Sample Warranty: For manufacturer's special warranties.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For gas-fired, radiant heaters to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Igniter: Provide [**One (1)**] <Insert number> hot-surface burner igniter(s) for each style of high-intensity, gas-fired, radiant heater furnished.

1.7 WARRANTY

- A. Manufacturer's Special Warranty: Manufacturer agrees to repair or replace components of radiant heaters that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods.

1. Warranty Period: All warranty periods listed below are from date of Substantial Completion.
 - a. Ceramic Tiles: Minimum **[three (3)] [five (5)] [ten (10)] [fifteen (15)] <Insert number>** years.
 - b. Heater Components: Minimum **[one (1)] [three (3)] [five (5)] [ten (10)] <Insert number>** year(s).

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Comply with **[ANSI Z83.19A/CSA 2.35A] [ANSI Z83.26/CSA 2.37]**.
 1. CSA certified, with CSA Seal and certification number clearly visible on units.
 2. UL listed and labeled, with UL label clearly visible on units.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 HIGH-INTENSITY, INFRARED, GAS-FIRED, RADIANT HEATERS **<Insert drawing designation>**

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Combustion Research Corporation.](#)
 2. [Detroit Radiant Products Company.](#)
 3. [Roberts-Gordon Inc.](#)
 4. [Schwank Inc.](#)
 5. [Solaronics, Inc.](#)
 6. [Space-Ray; Division of Gas Fired Products, Inc.](#)
 7. [Sterling HVAC Products; a Mestek company.](#)
 8. [Thomas & Betts Corporation.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.

- B. Factory-assembled, [**indoor**] [**outdoor**], overhead-mounted, electrically controlled, high-intensity, infrared, radiant heating units using gas combustion. Heater to have all necessary factory-installed wiring and piping required prior to field installation and startup.
- C. Fuel Type: Design burner for [**natural**] [**propane**] gas having characteristics same as those of gas available at Project site.
- D. Main Housing: Continuous, one-piece, [**aluminized**] [**stainless**]-steel unit without gaps between housing and reflectors.
- E. Burner Assembly:

Either material may be obtained with or without third option.

- 1. Modular, [**aluminized steel with powder-coat or similar finish**] [**stainless-steel**] plenum chamber [**coated with ceramic fiber insulation**] secured with stainless-steel retainers.
- F. Emitter: Perforated ceramic tiles.
- G. Reflector: [**One-sided, bright-polished aluminum**] [**High-grade steel with cold-bonded, polished-aluminum layer**] [**Aluminized steel**].
- H. Ignition:
 - 1. Manual Pilot: Self-energizing with no external power connection.
 - 2. Direct Spark: [**24/25**] [**115/120**]-V ac, solid-state ignition module with spark electrode and flame sensor.

Consult manufacturers for applications in environments with high humidity or moisture levels.

- 3. Potted circuitry.
- I. Accessories:
 - 1. [**Parabolic reflector**] [**Reflector extensions**].
 - 2. Wire grid or expanded metal secondary emitter for increased efficiency.
 - 3. Protective screen and heat-deflector shield.
 - 4. Stainless-steel flexible connector with manual valve for gas supply.
 - 5. Hanger chain with "S" hooks.
 - 6. Preassembled chain suspension kit.
 - 7. Rigid mounting kits.
 - 8. Clearance warning plaque.
 - 9. Two-stage operation.
- J. Capacities and Characteristics:
 - 1. Gas Input: <Insert Btu/h (kW)>.
 - 2. Gas Output: <Insert Btu/h (kW)>.
 - 3. Electrical Characteristics:

- a. Volts: [**Millivolt**] [24/25] [115/120] <Insert value>.
- b. Phase: Single.
- c. Hertz: 60.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

Delete paragraph if angle is indicated on Drawings. Heaters can be mounted horizontal or to any angle up to and including 35 degrees from horizontal.

- K. Mounting Angle: <Insert value> degrees.

2.3 GAS-FIRED, OUTDOOR, INFRARED PATIO HEATERS <Insert drawing designation>

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Combustion Research Corporation.](#)
2. [Detroit Radiant Products Company.](#)
3. [Roberts-Gordon, Inc.](#)
4. [Schwank Inc.](#)
5. [Solaronics, Inc.](#)
6. [Space-Ray; Division of Gas Fired Products, Inc.](#)
7. [Sterling HVAC Products; a Mestek company.](#)
8. [Thomas & Betts Corporation.](#)
9. <Insert manufacturer's name>.
10. or approved equal.

- B. Factory-assembled, [**indoor**] [**outdoor**], overhead-mounted, electrically controlled, high-intensity, infrared, radiant heating units using gas combustion. Heater to have all necessary factory-installed wiring and piping required prior to field installation and startup.

- C. Fuel Type: Design burner for [**natural**] [**propane**] gas having characteristics same as those of gas available at Project site.

- D. Main Housing: Continuous, one-piece, [**aluminized**] [**stainless**]-steel unit without gaps between housing and reflectors.

1. Air vents with cooling channels.
2. Air louvers.
3. Decorative grill.

- E. Burner Assembly:

Either material may be obtained with or without third option.

1. Modular, [**aluminized-steel with powder-coat or similar finish**]
[**stainless-steel**] plenum chamber [**coated with ceramic fiber insulation**]
]secured with stainless-steel retainers.

F. Emitter: Perforated ceramic tiles.

G. Reflector: [**Polished stainless steel**] <Insert material>.

H. Ignition:

1. Direct Spark: [**24/25**] [**115/120**]-V ac, solid-state ignition module with spark electrode and flame sensor.

Consult manufacturers for applications in environments with high humidity or moisture levels.

2. Potted circuitry.

I. Accessories:

1. Wire grid or expanded metal secondary emitter for increased efficiency.
2. Protective screen and heat-deflector shield.
3. Stainless-steel flexible connector with manual valve for gas supply.
4. Hanger chain with "S" hooks.
5. Preassembled chain suspension kit.
6. Rigid mounting kits.
7. Clearance warning plaque.

J. Capacities and Characteristics:

1. Gas Input: <Insert Btu/h (kW)>.
2. Gas Output: <Insert Btu/h (kW)>.
3. Electrical Characteristics:
 - a. Volts: [**24/25**] [**115/120**] <Insert value>.
 - b. Phase: Single.
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

K. Mounting Angle: <Insert value> degrees.

2.4 CONTROLS AND SAFETIES

A. Failure Safeguards: 100 percent main gas shutoff on [**pilot**] [**pilot or power**] failure.

B. Thermostat: Devices and wiring are specified in Section 230923.27 "Temperature Instruments."

C. Thermostat: Single-stage, wall-mounted type with **50 to 90 deg F** (10 to 32 deg C) operating range and fan on switch.

1. Control Transformer: Integrally mounted.
- D. Thermostat: Two-stage, wall-mounted type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
1. Control Transformer: Integrally mounted.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine structures, substrates, areas and conditions, with Installer present, for compliance with requirements for installation tolerances, required clearances, and other conditions affecting performance of the Work.
- B. Examine roughing-in for fuel-gas piping to verify actual locations of piping connections before equipment installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting: Install gas-fired, infrared heaters with continuous-thread hanger rods and spring hangers[**with vertical-limit stop**] of size required to support weight of heaters.

Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

1. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
 3. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Equipment Installation: Install gas-fired, radiant heaters and associated gas features and systems according to **[NFPA 54] [CSA B149.1]**.
- C. Suspended Units: **[Suspend from substrate using chain hanger kits and building attachments] [Mount to substrate using rigid mounting kits or brackets, supplied by manufacturer or manufactured].**

1. Restrain the unit to resist seismic acceleration. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- D. Maintain manufacturers' recommended clearances for combustibles.

3.3 CONNECTIONS

If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Gas Piping: Comply with [Section 231123 "Facility Natural-Gas Piping."] [Section 231126 "Facility Liquefied-Petroleum Gas Piping."] Connect gas piping to gas train inlet; provide union with enough clearance for burner removal and service.
1. Gas Connections: Connect gas piping to radiant heaters according to [NFPA 54] [CSA B149.1].
- B. Where installing piping adjacent to gas-fired, radiant heaters, allow space for service and maintenance.
- C. Electrical Connections: Comply with applicable requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
1. Install electrical devices furnished with heaters but not specified to be factory mounted.

3.4 ADJUSTING

- A. Adjust initial-temperature set points.
- B. Adjust burner and other unit components for optimum heating performance and efficiency.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 2. Verify bearing lubrication.
 3. Verify proper motor rotation.

4. Test Reports: Prepare a written report to record the following:

- a. Test procedures used.
- b. Test results that comply with requirements.
- c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.

C. Gas-fired, radiant heaters will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

3.6 ADJUSTING

A. Adjust initial-temperature set points.

B. Adjust burner and other unit components for optimum heating performance and efficiency.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain gas-fired, radiant heaters.

- 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235523.16

SECTION 235700 - HEAT EXCHANGERS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes [**shell-and-tube**] [**and**] [**plate**] heat exchangers.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. TEMA: Tubular Exchanger Manufacturers Association.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product. Provide data with dimensions, locations, and size of tapings and performance data.
 - 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Signed and sealed by a qualified professional engineer. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Design Calculations: Calculate requirements for selecting seismic restraints and for designing bases.
 - 2. Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment.
 - 3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

4. Test Reports: Indicate tube bundle pressure tests.

C. Delegated-Design Submittal: Details and design calculations for seismic restraints for heat exchangers.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Equipment room, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Tube-removal space.
2. Structural members to which heat exchangers will be attached.

B. Seismic Qualification Certificates: For heat exchanger, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Heat Exchanger: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of heat exchanger anchorage devices on which certification is based and their installation requirements.

C. Product Certificates: For each type of shell-and-tube heat exchanger. Documentation that shell-and-tube heat exchangers comply with "TEMA Standards."

1. Certificates: Certify that [**Products**] <Insert item> meet or exceed [**specified requirements.**]

D. Source quality-control reports.

E. Field quality-control reports.

F. Sample Warranty: For manufacturer's warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For heat exchangers to include in emergency, operation, and maintenance manuals.

1. Include start up and shut down instructions, assembly drawings, and spare parts lists.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Protect internals from entry of foreign material by temporary caps on flanged openings.

1.8 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of domestic-water heat exchangers that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

- a. Structural failures including heat exchanger, storage tank, and supports.
- b. Faulty operation of controls.
- c. Deterioration of metals, metal finishes, and other materials beyond normal use.

2. Warranty Periods: From date of Substantial Completion.

a. Shell-and-Tube, Domestic-Water Heat Exchangers:

- 1) Tube Coil: Minimum **[one (1)] <Insert number>** year(s).
- 2) Other Components: Minimum **[one (1)] <Insert number>** year(s).

b. Plate, Domestic-Water Heat Exchangers:

- 1) Brazed-Plate Type: Minimum **[one] <Insert number>** year(s).
- 2) Plate-and-Frame Type: Minimum **[one] <Insert number>** year(s).

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design seismic restraints for heat exchangers.
- B. Seismic Performance: Heat exchangers shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
2. Component Importance Factor is [**1.5**] [**1.0**].
3. **<Insert requirements for Component Amplification Factor and Component Response Modification Factor>**.

2.2 SHELL-AND-TUBE HEAT EXCHANGERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [API Heat Transfer Inc.](#)
2. [Armstrong Pumps, Inc.](#)
3. [ITT Corporation; Bell & Gossett.](#)
4. [TACO Incorporated.](#)
5. [Thrush Company, Inc.](#)
6. **<Insert manufacturer's name>**.
7. or approved equal.

B. Description: Packaged assembly of tank, heat-exchanger coils, and specialties.

C. Construction:

1. Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1.
2. Fabricate and label shell-and-tube heat exchangers to comply with "TEMA Standards."

D. Configuration: [**U-tube with removable**] [**Straight tube with removable**] [**Straight tube with fixed**] bundle.

E. Shell Materials: [**Steel**] [**Stainless steel**].

F. Head:

1. Materials: [**Cast iron**] [**Cast stainless steel**] [**Fabricated steel**] [**Fabricated steel with removable cover**] [**Fabricated stainless steel**] [**Fabricated stainless steel with removable cover**].
2. Flanged and bolted to shell.

G. Tube:

1. [**Seamless copper**] [**Steel**] [**Stainless-steel**] [**Cupronickel**] [**Admiralty-metal**] tubes.
2. Tube diameter is determined by manufacturer based on service.

H. Tubesheet Materials: [**Steel**] [**Stainless steel**].

I. Baffles: [**Steel**] [**Stainless steel**].

- J. Piping Connections: Factory fabricated of materials compatible with heat-exchanger shell. Attach tapings to shell before testing and labeling.
1. NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1.
 2. NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
- K. Support Saddles:
1. Fabricated of material similar to shell.
 2. Fabricate foot mount with provision for anchoring to support.
 3. Fabricate attachment of saddle supports to pressure vessel with reinforcement strong enough to resist heat-exchanger movement during seismic event when heat-exchanger saddles are anchored to building structure.
- L. Capacities and Characteristics:
1. General:
 - a. Shell Diameter: <Insert NPS (DN)>.
 - b. Heat-Exchanger Length: <Insert inches (mm)>.
 - c. Heat-Exchanger Surface Area: <Insert sq. ft. (sq. m)>.
 - d. Number of Passes: <Insert number>.
 - e. Heat Exchanged: <Insert Btu/h (kW)>.
 - f. Operating Weight: <Insert lb (kg)>.
 2. Shell Side:
 - a. Fluid: [Water] [Steam] <Insert type>.
 - b. Working Pressure: <Insert psig (kPa)>.
 - c. Supply Pressure: <Insert psig (kPa)>.
 - d. Steam Flow Rate: <Insert lb/h (kg/h)>.
 - e. Water Flow Rate: <Insert gpm (L/s)>.
 - f. Pressure Drop: <Insert psig (kPa)>.
 - g. Inlet Temperature: <Insert deg F (deg C)>.
 - h. Outlet Temperature: <Insert deg F (deg C)>.
 - i. Fouling Factor: <Insert value>.
 - j. Inlet Size: <Insert NPS (DN)>.
 - k. Outlet Size: <Insert NPS (DN)>.
 3. Tube Side:
 - a. Fluid: [Water] [Steam] <Insert type>.
 - b. Working Pressure: <Insert psig (kPa)>.
 - c. Supply Pressure: <Insert psig (kPa)>.
 - d. Steam Flow Rate: <Insert lb/h (kg/h)>.
 - e. Water Flow Rate: <Insert gpm (L/s)>.
 - f. Pressure Drop: <Insert psig (kPa)>.
 - g. Inlet Temperature: <Insert deg F (deg C)>.

- h. Outlet Temperature: <Insert deg F (deg C)>.
- i. Fouling Factor: <Insert value>.
- j. Inlet Size: <Insert NPS (DN)>.
- k. Outlet Size: <Insert NPS (DN)>.

2.3 GASKETED-PLATE HEAT EXCHANGERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Alfa Laval Inc.](#)
 - 2. [API Heat Transfer Inc.](#)
 - 3. [APV; a brand of SPX Corporation.](#)
 - 4. [Armstrong Pumps, Inc.](#)
 - 5. [Delta T Heat Exchangers.](#)
 - 6. [ITT Corporation; Bell & Gossett.](#)
 - 7. [Mueller, Paul, Company.](#)
 - 8. [Polaris Plate Heat Exchangers.](#)
 - 9. [SEC Heat Exchangers.](#)
 - 10. [TACO Incorporated.](#)
 - 11. [Thermo Dynamics Ltd.](#)
 - 12. [Tranter, Inc.](#)
 - 13. <Insert manufacturer's name>.
 - 14. or approved equal.
- B. Configuration: Freestanding assembly consisting of frame support, top and bottom carrying and guide bars, fixed and movable end plates, tie rods, individually removable plates, and one-piece gaskets.
- C. Construction: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1.
- D. Frame:
 - 1. Capacity to accommodate [20] <Insert number> percent additional plates.
 - 2. Painted carbon steel with provisions for anchoring to support.
- E. Top and Bottom Carrying and Guide Bars: Painted carbon steel, aluminum, or stainless steel.
 - 1. Fabricate attachment of heat-exchanger carrying and guide bars with reinforcement strong enough to resist heat-exchanger movement during seismic event when heat-exchanger carrying and guide bars are anchored to building structure.
- F. End-Plate Material: Painted carbon steel.
- G. Tie Rods and Nuts: Steel or stainless steel.

- H. Plate Material: [0.024 inch (0.6 mm)] [0.031 inch (0.8 mm)] [0.039 inch (1 mm)] <Insert thickness> thick before stamping; [Type 304] [Type 304L] [Type 316] [Type 316L] stainless steel.
- I. Gasket Materials: [Glued] [Glue free] [Nitrile rubber] [EPDM rubber] <Insert material>.
1. Glue: Chlorine free.
- J. Piping Connections: Factory fabricated of materials compatible with heat-exchanger shell. Attach tapings to shell before testing and labeling.
1. NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1.
 2. NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
- K. Enclose plates in solid [aluminum] [stainless-steel] removable shroud.
- L. Capacities and Characteristics:
1. General:
 - a. Heat-Exchanger Surface Area: <Insert sq. ft. (sq. m)>.
 - b. Number of Plates: <Insert number>.
 - c. Number of Passes: [One] <Insert number>.
 - d. Heat Exchanged: <Insert Btu/h (kW)>.
 - e. Operating Weight: <Insert lb (kg)>.
 2. Hot Side:
 - a. Fluid: [Water] [Steam] <Insert type>.
 - b. Working Pressure: <Insert psig (kPa)>.
 - c. Supply Pressure: <Insert psig (kPa)>.
 - d. Steam Flow Rate: <Insert lb/h (kg/h)>.
 - e. Water Flow Rate: <Insert gpm (L/s)>.
 - f. Pressure Drop: <Insert psig (kPa)>.
 - g. Inlet Temperature: <Insert deg F (deg C)>.
 - h. Outlet Temperature: <Insert deg F (deg C)>.
 - i. Fouling Factor: <Insert value>.
 - j. Inlet Size: <Insert NPS (DN)>.
 - k. Outlet Size: <Insert NPS (DN)>.
 3. Cold Side:
 - a. Fluid: [Water] [Steam] <Insert type>.
 - b. Working Pressure: <Insert psig (kPa)>.
 - c. Supply Pressure: <Insert psig (kPa)>.
 - d. Steam Flow Rate: <Insert lb/h (kg/h)>.
 - e. Water Flow Rate: <Insert gpm (L/s)>.

- f. Pressure Drop: **<Insert psig (kPa)>**.
- g. Inlet Temperature: **<Insert deg F (deg C)>**.
- h. Outlet Temperature: **<Insert deg F (deg C)>**.
- i. Fouling Factor: **<Insert value>**.
- j. Inlet Size: **<Insert NPS (DN)>**.
- k. Outlet Size: **<Insert NPS (DN)>**.

2.4 BRAZED-PLATE HEAT EXCHANGERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Alfa Laval Inc.](#)
2. [API Heat Transfer Inc.](#)
3. [APV; a brand of SPX Corporation.](#)
4. [Armstrong Pumps, Inc.](#)
5. [GEA PHE Systems North America Inc.](#)
6. [ITT Corporation; Bell & Gossett.](#)
7. [Mueller, Paul, Company.](#)
8. [Polaris Plate Heat Exchangers.](#)
9. [Tranter, Inc.](#)
10. **<Insert manufacturer's name>**.
11. or approved equal.

- B. Configuration: Brazed assembly consisting of embossed or pressed stainless-steel plates brazed together and two end plates, one with threaded nozzles and one with pattern-embossed plates.

- C. Construction: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1.

- D. End-Plate Material: Type 316 stainless steel.

- E. Threaded Nozzles: Type 316 stainless steel.

- F. Plate Material: Type 316 stainless steel.

- G. Brazing Material: **[Copper] [or] [nickel]**.

- H. Capacities and Characteristics:

1. General:

- a. Heat-Exchanger Surface Area: **<Insert sq. ft. (sq. m)>**.
- b. Heat Exchanged: **<Insert Btu/h (kW)>**.
- c. Operating Weight: **<Insert lb (kg)>**.

2. Hot Side:

- a. Fluid: **[Water] [Steam] <Insert type>**.

- b. Working Pressure: <Insert psig (kPa)>.
- c. Supply Pressure: <Insert psig (kPa)>.
- d. Steam Flow Rate: <Insert lb/h (kg/h)>.
- e. Water Flow Rate: <Insert gpm (L/s)>.
- f. Pressure Drop: <Insert psig (kPa)>.
- g. Inlet Temperature: <Insert deg F (deg C)>.
- h. Outlet Temperature: <Insert deg F (deg C)>.
- i. Fouling Factor: <Insert value>.
- j. Inlet Size: <Insert NPS (DN)>.
- k. Outlet Size: <Insert NPS (DN)>.

3. Cold Side:

- a. Fluid: **[Water] [Steam]** <Insert type>.
- b. Working Pressure: <Insert psig (kPa)>.
- c. Supply Pressure: <Insert psig (kPa)>.
- d. Steam Flow Rate: <Insert lb/h (kg/h)>.
- e. Water Flow Rate: <Insert gpm (L/s)>.
- f. Pressure Drop: <Insert psig (kPa)>.
- g. Inlet Temperature: <Insert deg F (deg C)>.
- h. Outlet Temperature: <Insert deg F (deg C)>.
- i. Fouling Factor: <Insert value>.
- j. Inlet Size: <Insert NPS (DN)>.
- k. Outlet Size: <Insert NPS (DN)>.

2.5 ACCESSORIES

A. Hangers and Supports:

- 1. Custom, steel **[supports] [cradles]** for mounting on **[floor] [wall] [structural steel]**.
 - a. Minimum Number of Cradles: <Insert number>.
- 2. **[Factory] [Field]**-fabricated steel **[supports] [cradles]** to ensure both horizontal and vertical support of heat exchanger. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Shroud: **[Steel] [Stainless-steel] [Aluminum]** sheet.

C. Miscellaneous Components for High-Temperature Hot-Water Unit: Control valve, valves, and piping. **[Include components fitted for pneumatic control.]**

D. Miscellaneous Components for Steam Unit: Strainers, steam-control valve, steam trap, valves, pressure gage, thermometer, and piping. **[Include components fitted for pneumatic control.]**

E. Pressure Relief Valves: **[Cast iron] [Steel] [Bronze] [Brass]**, <Insert NPS (DN)>, ASME rated and stamped.

1. Pressure relief valve setting: <Insert psig (kPa)>.

2.6 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect heat exchangers according to ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1. Affix ASME label.
- B. Hydrostatically test heat exchangers to minimum of one and one-half times pressure rating before shipment.
- C. Heat exchangers will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas for compliance with requirements for installation tolerances and for structural rigidity, strength, anchors, and other conditions affecting performance of heat exchangers.
- B. Examine roughing-in for heat-exchanger piping to verify actual locations of piping connections before equipment installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SHELL-AND-TUBE HEAT-EXCHANGER INSTALLATION

- A. Install in accordance with manufacturers instructions.
- B. Install to permit removal of tube bundle with minimum disturbance to installed equipment and piping.
- C. Equipment Mounting:
 1. Install heat exchangers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Install heat exchangers on saddle supports.

- E. Heat-Exchanger Supports: Use factory-fabricated steel cradles and supports specifically designed for each heat exchanger.

3.3 GASKETED-PLATE HEAT-EXCHANGER INSTALLATION

- A. Install in accordance with manufacturers instructions.
- B. Install to permit removal of plates with minimum disturbance to installed equipment and piping.
- C. Install gasketed-plate heat exchanger on custom-designed wall supports anchored to structure as indicated on Drawings.
- D. Install metal shroud over installed gasketed-plate heat exchanger according to manufacturer's written instructions.

3.4 BRAZED-PLATE HEAT-EXCHANGER INSTALLATION

- A. Install in accordance with manufacturers instructions.
- B. Install brazed-plate heat exchanger on custom-designed wall supports anchored to structure as indicated on Drawings.

3.5 CONNECTIONS

- A. Comply with requirements for piping specified in other Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements for steam and condensate piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties."
- C. Maintain manufacturer's recommended clearances for tube removal, service, and maintenance.
- D. Install piping adjacent to heat exchangers to allow space for service and maintenance of heat exchangers. Arrange piping for easy removal of heat exchangers.
- E. Install shutoff valves at heat-exchanger inlet and outlet connections.
- F. Install relief valves on heat-exchanger heated-fluid connection and install pipe relief valves, full size of valve connection, to floor drain.
- G. Install vacuum breaker at heat-exchanger steam inlet connection.
- H. Install hose end valve to drain shell.

- I. Install thermometer on heat-exchanger and[**inlet and**] outlet piping, and install thermometer on heating-fluid[**inlet and**] outlet piping. Comply with requirements for thermometers specified in Section 230519 "Meters and Gages for HVAC Piping."
- J. Install pressure gages on heat-exchanger and heating-fluid piping. Comply with requirements for pressure gages specified in Section 230519 "Meters and Gages for HVAC Piping."

3.6 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Heat exchanger will be considered defective if it does not pass tests and inspections.
- C. Prepare test and inspection reports.

3.7 CLEANING

- A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain heat exchangers.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 235700

SECTION 236200 - PACKAGED COMPRESSOR AND CONDENSER UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes packaged, refrigerant compressor and condenser units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Compressor and condenser units shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each compressor and condenser unit. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1.
 - 2. Product Data for Credit EA 4: Documentation indicating that compressor and condenser units and refrigerants comply.
- C. Shop Drawings: For compressor and condenser units. Include plans, elevations, sections, details, and attachments to other work.

1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
 2. Wiring Diagrams: For power, signal, and control wiring.
- D. Delegated-Design Submittal: For compressor and condenser units indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
1. Structural members to which compressor and condenser units will be attached.
 2. Liquid and vapor pipe sizes.
 3. Refrigerant specialties.
 4. Piping including connections, oil traps, and double risers.
 5. Compressors.
 6. Evaporators.
- B. Seismic Qualification Certification: For compressor and condenser units, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.
- D. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For compressor and condenser units to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 EXTRA MATERIALS

- A. Provide [**two (2)**] <Insert number> sets of fan belts.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Fabricate and label refrigeration system according to ASHRAE 15, "Safety Standard for Refrigeration Systems."
- C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6, "Heating, Ventilating, and Air-Conditioning."
- D. ASME Compliance: Fabricate and label water-cooled compressor and condenser units to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

1.9 COORDINATION

- A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 033000 "Cast-In-Place Concrete" and Section 033053 "Miscellaneous Cast-In-Place Concrete."
- B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 077200 "Roof Accessories."
- C. Coordinate location of piping and electrical rough-ins.

1.10 DELIVERY, STORAGE, AND PROTECTION

- A. Section 230400 "Basic HVAC Requirements" and Division 1: Transportation, delivery, handling, storage, and protection of products.
- B. Comply with manufacturer's installation instruction for rigging, unloading and transporting units.

- C. Protect units on site from physical damage. Protect coils.

1.11 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of compressor and condenser units that fail in materials or workmanship within specified warranty period.
1. Failures include, but are not limited to, the following:
 - a. Compressor failure.
 - b. Condenser coil leak.
 2. Warranty Period: Minimum **[five (5)] [ten 10] <Insert number>** years from date of Substantial Completion.
 3. Warranty Period (Compressor Only): Minimum **[five (5)] [seven (7)] [ten (10)] <Insert number>** years from date of Substantial Completion.
 4. Warranty Period (Components Other Than Compressor): Minimum **[five (5)] [ten 10] <Insert number>** years from date of Substantial Completion.
 5. Warranty Period (Condenser Coil Only): Minimum **[five (5)] <Insert number>** years from date of Substantial Completion.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 COMPRESSOR AND CONDENSER UNITS, AIR COOLED, 1 TO 5 TONS (3.5 TO 17.6 kW)

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation; Commercial HVAC Systems.](#)
 2. [Lennox International Inc.](#)
 3. [Rheem Air Conditioning Division.](#)
 4. [Ruud Air Conditioning Division.](#)
 5. [Trane; a business of American Standard Companies.](#)
 6. [YORK; a Johnson Controls company.](#)
 7. **<Insert manufacturer's name>.**
 8. or approved equal.
- B. Description: Factory assembled and tested; consisting of compressor, condenser coil, fan, motors, refrigerant reservoir, and operating controls.

- C. Compressor: Scroll, hermetically sealed, with rubber vibration isolators.
1. Motor: [**Single**] [**Two**] speed, and includes thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 2. Two-Speed Compressor: Include manual-reset, high-pressure switch and automatic-reset, low-pressure switch.
 3. Accumulator: Suction tube.
- D. Refrigerant: [**R-22**] [**R-407C**] [**R-410A**] <Insert type>.
- E. Refrigerant: R-407C or R-410A.
- F. Condenser Coil: Seamless copper-tube, aluminum-fin coil; circuited for integral liquid subcooler, with removable drain pan and brass service valves with service ports.
- G. Condenser Fan: Direct-drive, aluminum propeller fan; with permanently lubricated, totally enclosed fan motor with thermal-overload protection[**and ball bearings**].
- H. Accessories:
1. Coastal Filter: Mesh screen to protect condenser coil from salt damage.
 2. Crankcase heater.
 3. Cycle Protector: Automatic-reset timer to prevent rapid compressor cycling.
 4. [**Electronic programmable thermostat**] [**Low-voltage thermostat and subbase**] to control compressor and condenser unit and evaporator fan.
 5. Evaporator Freeze Thermostat: Temperature-actuated switch that stops unit when evaporator reaches freezing temperature.
 6. Filter-dryer.
 7. High-Pressure Switch: Automatic-reset switch cycles compressor off on high refrigerant pressure.
 8. Liquid-line solenoid.
 9. Low-Ambient Controller: Cycles condenser fan to permit operation down to [**30 deg F (minus 1 deg C)**] [**0 deg F (minus 18 deg C)**] [**with time-delay relay to bypass low-pressure switch**].
 10. Low-Ambient Controller: Controls condenser fan speed to permit operation down to **minus 20 deg F (minus 29 deg C)**[**with time-delay relay to bypass low-pressure switch**].
 11. Low-Pressure Switch: Automatic-reset switch cycles compressor off on low refrigerant pressure.
 12. PE mounting base.
 13. Precharged and insulated suction and liquid tubing.
 14. Sound Hood: Wraps around sound attenuation cover for compressor.
 15. Thermostatic expansion valve.
 16. Time-Delay Relay: Continues operation of evaporator fan after compressor shuts off.
 17. Reversing valve.
 18. <Insert accessories>.

- I. Unit Casing: Galvanized steel, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Mount service valves, fittings, and gage ports on exterior of casing.
 - J. Capacities and Characteristics:
 1. Compressor and Condenser Unit:
 - a. Full-Load Cooling Capacity: <Insert MBh (kW)>.
 - b. Energy-Efficiency Ratio (EER): <Insert value>.
 - c. Seasonal Energy-Efficiency Ratio (SEER): <Insert value>.
 - d. Coefficient of Performance (COP): <Insert value>.
 - e. Compressor Suction Temperature: <Insert deg F (deg C)>.
 - f. Capacity Steps: <Insert number>.
 2. Refrigerant Connections:
 - a. Liquid Pipe Size: <Insert NPS (DN)>.
 - b. Suction Pipe Size: <Insert NPS (DN)>.
 3. Compressor:
 - a. Rated-Load Amperes: <Insert value>.
 - b. Locked-Rotor Amperes: <Insert value>.
 - c. Power Input: <Insert kilowatts>.
 4. Air-Cooled Condenser:
 - a. Ambient-Air Temperature: <Insert deg F (deg C)>.
 - b. Airflow: <Insert cfm (L/s)>.
 - c. Number of Condenser Fans: <Insert number>.
 - d. Condenser Fan Motor Size: <Insert horsepower>.
 5. Electrical Characteristics:
 - a. Kilowatt Input: <Insert value>.
 - b. Volts: <Insert value>.
 - c. Phase: <Insert value>.
 - d. Hertz: <Insert value>.
 - e. Maximum Circuit Amperes: <Insert value>.
 - f. Maximum Instantaneous Current Flow during Startup: <Insert value>.
 - g. Maximum Overcurrent Protection: <Insert amperage>.
- 2.2 COMPRESSOR AND CONDENSER UNITS, AIR COOLED, 6 TO 120 TONS (21 TO 422 kW)
- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Carrier Corporation: Commercial HVAC Systems.](#)

2. [Continental Products.](#)
 3. [Dunham-Bush, Inc.](#)
 4. [Engineered Air.](#)
 5. [Lennox International Inc.](#)
 6. [McQuay International.](#)
 7. [Rheem Air Conditioning Division.](#)
 8. [Ruud Air Conditioning Division.](#)
 9. [Trane; a business of American Standard Companies.](#)
 10. [YORK; a Johnson Controls company.](#)
 11. **<Insert manufacturer's name>.**
 12. or approved equal.
- B. Description: Factory assembled and tested, air cooled; consisting of casing, compressors, condenser coils, condenser fans and motors, and unit controls.
- C. Compressor: Hermetic scroll compressor designed for service with crankcase sight glass, crankcase heater, and backseating service access valves on suction and discharge ports.
1. Capacity Control: [**On-off compressor cycling**] [**Hot-gas bypass**].
- D. Compressor: Hermetic or semihermetic rotary screw compressor designed for service with crankcase sight glass, crankcase heater, and backseating service access valves on suction and discharge ports.
1. Capacity Control: [**On-off compressor cycling**] [**Modulating slide-valve assembly or port unloaders**] [**Variable-frequency controller**] [**Hot-gas bypass**].
- E. Refrigerant: [**R-22**] [**R-407C**] [**R-410A**] [**R-134a**] **<Insert type>.**
- F. Refrigerant: R-407C, R-410A, or R-134a.
- G. Condenser Coil: Seamless copper-tube, aluminum-fin coil, including subcooling circuit and backseating liquid-line service access valve. Factory pressure test coils, then dehydrate by drawing a vacuum and fill with a holding charge of nitrogen or refrigerant.
- H. Condenser Fans: Propeller-type vertical discharge; either directly or belt driven. Include the following:
1. Permanently lubricated, ball-bearing[**totally enclosed**] motors.
 2. Separate motor for each fan.
 3. Dynamically and statically balanced fan assemblies.
- I. Operating and safety controls include the following:
1. Manual-reset, high-pressure cutout switches.
 2. Automatic-reset, low-pressure cutout switches.
 3. Low-oil-pressure cutout switch.
 4. Compressor-winding thermostat cutout switch.

5. Three-leg, compressor-overload protection.
6. Control transformer.
7. Magnetic contactors for compressor and condenser fan motors.
8. Timer to prevent excessive compressor cycling.

J. Accessories:

1. **[Electronic programmable thermostat] [Low-voltage thermostat and subbase]** to control compressor and condenser unit and evaporator fan.
2. Low-Ambient Controller: Cycles condenser fan to permit operation down to **0 deg F** (minus 18 deg C) **[with time-delay relay to bypass low-pressure switch]**.
3. Low-Ambient Controller: Controls condenser fan speed to permit operation down to **minus 20 deg F** (minus 29 deg C) **[with time-delay relay to bypass low-pressure switch]**.
4. Gage Panel: Package with refrigerant circuit suction and discharge gages.
5. Hot-gas bypass kit.
6. Part-winding-start timing relay, circuit breakers, and contactors.
7. Reversing valve.
8. **<Insert accessories>**.

K. Unit Casings: Designed for outdoor installation with weather protection for components and controls and with removable panels for required access to compressors, controls, condenser fans, motors, and drives. Additional features include the following:

1. Steel, galvanized or zinc coated, for exposed casing surfaces; treated and finished with manufacturer's standard paint coating.
2. Perimeter base rail with forklift slots and lifting holes to facilitate rigging.
3. Gasketed control panel door.
4. Nonfused disconnect switch, factory mounted and wired, for single external electrical power connection.
5. Condenser coil **[hail guard] [grille]**.

L. Capacities and Characteristics:

1. Compressor and Condenser Unit:
 - a. Full-Load Cooling Capacity: **<Insert MBh (kW)>**.
 - b. Energy-Efficiency Ratio (EER): **<Insert value>**.
 - c. Seasonal Energy-Efficiency Ratio (SEER): **<Insert value>**.
 - d. Coefficient of Performance (COP): **<Insert value>**.
 - e. Compressor Suction Temperature: **<Insert deg F (deg C)>**.
 - f. Capacity Steps: **<Insert number>**.
2. Refrigerant Connections:
 - a. Liquid Pipe Size: **<Insert NPS (DN)>**.
 - b. Suction Pipe Size: **<Insert NPS (DN)>**.
3. Compressors:

- a. Number of Compressors: **<Insert number>**.
 - b. Rated-Load Amperes: **<Insert value>**.
 - c. Locked-Rotor Amperes: **<Insert value>**.
 - d. Power Input: **<Insert kilowatts>**.
4. Air-Cooled Condenser:
- a. Ambient-Air Temperature: **<Insert deg F (deg C)>**.
 - b. Airflow: **<Insert cfm (L/s)>**.
 - c. Number of Condenser Fans: **<Insert number>**.
 - d. Condenser Fan Motor Size: **<Insert horsepower>**.
5. Electrical Characteristics:
- a. Kilowatt Input: **<Insert value>**.
 - b. Volts: **<Insert value>**.
 - c. Phase: **<Insert value>**.
 - d. Hertz: **<Insert value>**.
 - e. Maximum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Instantaneous Current Flow during Startup: **<Insert value>**.
 - g. Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 COMPRESSOR AND CONDENSER UNITS, WATER COOLED

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Carrier Corporation; Commercial HVAC Systems.
 2. McQuay International.
 3. Trane; a business of American Standard Companies.
 4. YORK; a Johnson Controls company.
 5. **<Insert manufacturer's name>**.
 6. or approved equal.
- B. Description: Factory assembled and tested, consisting of compressors, water-cooled condensers, bases, and unit controls.
- C. Compressor: Hermetic or serviceable hermetic type; with oil pump, operating oil charge, and suction and discharge shutoff valves. Factory mounted on base using spring isolators. Include the following:
1. Thermally protected compressor motor.
 2. Crankcase heater.
 3. Capacity control using cylinder unloading, suction pressure controlled and discharge pressure operated, designed for unloaded start.
- D. Refrigerant: **[R-22] [R-407C] [R-410A] [R-134a] <Insert type>**.
- E. Refrigerant: R-407C, R-410A, or R-134a.

- F. Condenser: Single-pass, tube-in-tube, coaxial type; with seamless, integral-finned, copper tube and steel outer shell with water-regulating valve.
- G. Condenser: Multipass, shell-and-tube type; with replaceable, seamless, integral-finned copper tubes; positive-liquid subcooling circuit; pressure relief device; liquid-level test cock; purge connection; liquid-line shutoff valve; and angle valve for connection of water-regulating valve.
1. Unit Construction: ASME stamped for refrigerant-side working pressure of **385 psig** (2650 kPa) and water-side working pressure of **250 psig** (1720 kPa).
- H. Condenser: Plate type, with brazed assembly of two end plates, one with threaded nozzles and pattern-embossed plates.
- I. Accessories:
1. Discharge-line muffler.
 2. Gage panel containing gages for suction, discharge, and oil pressure.
 3. Electric solenoid cylinder unloaders.
 4. Pump-down relay package.
 5. Crankcase cover plates with equalizer connections.
- J. Controls: Factory-mounted and -wired panel with the following:
1. Timer to prevent short cycling.
 2. High- and low-refrigerant-pressure safety controls.
 3. Power- and control-circuit terminal blocks.
 4. Compressor motor starter.
 5. Control-circuit on-off switch.
 6. Control-circuit fuse.
- K. Unit Casings: Galvanized steel, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Mount service valves, fittings, and gage ports on exterior of casing.
- L. Capacities and Characteristics:
1. Compressor and Condenser Unit:
 - a. Full-Load Cooling Capacity: **<Insert MBh (kW)>**.
 - b. Energy-Efficiency Ratio (EER): **<Insert value>**.
 - c. Seasonal Energy-Efficiency Ratio (SEER): **<Insert value>**.
 - d. Coefficient of Performance (COP): **<Insert value>**.
 - e. Compressor Suction Temperature: **<Insert deg F (deg C)>**.
 - f. Capacity Steps: **<Insert number>**.
 2. Refrigerant Connections:
 - a. Liquid Pipe Size: **<Insert NPS (DN)>**.
 - b. Suction Pipe Size: **<Insert NPS (DN)>**.

3. Compressors:
 - a. Number of Compressors: **<Insert number>**.
 - b. Rated-Load Amperes: **<Insert value>**.
 - c. Locked-Rotor Amperes: **<Insert value>**.
 - d. Power Input: **<Insert kilowatts>**.

4. Water-Cooled Condenser:
 - a. Condenser Temperature: **<Insert deg F (deg C)>**.
 - b. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - c. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 - d. Water Flow: **<Insert gpm (L/s)>**.
 - e. Water Pressure Drop: **<Insert feet of water (kPa)>**.
 - f. Fouling Factor: **<Insert number>**.
 - g. Pipe Connection Size: **<Insert NPS (DN)>**.

5. Electrical Characteristics:
 - a. Kilowatt Input: **<Insert value>**.
 - b. Volts: **<Insert value>**.
 - c. Phase: **<Insert value>**.
 - d. Hertz: **<Insert value>**.
 - e. Maximum Circuit Amperes: **<Insert value>**.
 - f. Maximum Instantaneous Current Flow during Startup: **<Insert value>**.
 - g. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

2.5 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate compressor and condenser units according to **[ARI 206/110] [ARI 306/110]**.
- B. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IESNA 90.1, "Energy Efficient Design of New Buildings except Low-Rise Residential Buildings," Section 6, "Heating, Ventilating, and Air-Conditioning."
- C. Test and inspect shell and tube condensers according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

- D. Testing Requirements: Factory test sound-power-level ratings according to **[ARI 270]** **[ARI 370]**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of compressor and condenser units.
- B. Examine roughing-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.
- C. Examine walls, floors, and roofs for suitable conditions where compressor and condenser units will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install units level and plumb, firmly anchored in locations indicated.
- C. Install roof-mounting units on equipment supports specified in Section 077200 "Roof Accessories."
- D. Equipment Mounting:
1. Install compressor and condenser units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete. "] [Section 033053 "Miscellaneous Cast-in-Place Concrete. "]**
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- E. Maintain manufacturer's recommended clearances for service and maintenance.
- F. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.3 CONNECTIONS

- A. Comply with requirements for piping in other Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
- C. Connect precharged refrigerant tubing to unit's quick-connect fittings. Install tubing so it does not interfere with access to unit. Install furnished accessories.
- D. Connect refrigerant piping to air-cooled compressor and condenser units; maintain required access to unit. Install furnished field-mounted accessories. Refrigerant piping and specialties are specified in Section 232300 "Refrigerant Piping."
- E. Connect refrigerant and condenser-water piping to water-cooled compressor and condenser units. [**Maintain clear tube removal space.**] Refrigerant piping and specialties are specified in Section 232300 "Refrigerant Piping" and condenser-water piping and specialties are specified in [**Section 221116 "Domestic Water Piping."**] [**Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties.**] Install shutoff valve and union or flange at each water supply connection; install balancing valve and union or flange at each return connection.

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. Perform each visual and mechanical inspection and electrical test. Certify compliance with test parameters.
 - 2. Leak Test: After installation, charge system with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor operation and unit operation, product capability, and compliance with requirements.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 5. Verify proper airflow over coils.
- C. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
- D. Compressor and condenser units will be considered defective if they do not pass tests and inspections.

- E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - a. Inspect for physical damage to unit casing.
 - b. Verify that access doors move freely and are weathertight.
 - c. Clean units and inspect for construction debris.
 - d. Verify that all bolts and screws are tight.
 - e. Adjust vibration isolation and flexible connections.
 - f. Verify that controls are connected and operational.
- B. Lubricate bearings on fan motors.
- C. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
- D. Adjust fan belts to proper alignment and tension.
- E. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.
- F. Measure and record airflow and air temperature rise over coils.
- G. Verify proper operation of condenser capacity control device.
- H. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
- I. After startup and performance test, lubricate bearings.
- J. Provide cooling season start-up, winter season shut-down service, for first year of operation.
- K. Shut-down system if initial start-up and testing takes place in winter and machines are to remain inoperative. Repeat start-up and testing operation at beginning of first cooling season.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain compressor and condenser units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven

(7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236200

SECTION 236313 - AIR-COOLED REFRIGERANT CONDENSERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes packaged, air-cooled refrigerant condensers for [outdoor] [indoor] installation.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Air-cooled refrigerant condensers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each air-cooled refrigerant condenser. Include rated capacities, operating characteristics, furnished specialties, and accessories. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1.
 - 2. Product Data for Credit EA 4: Documentation indicating that air-cooled refrigerant condensers and refrigerants comply.
- C. Shop Drawings: For air-cooled refrigerant condensers. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
 3. Wiring Diagrams: For power, signal, and control wiring.
- D. Delegated-Design Submittal: For air-cooled refrigerant condensers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
1. Structural members to which air-cooled refrigerant condensers will be attached.
 2. Liquid and vapor pipe sizes.
 3. Refrigerant specialties.
 4. Piping including connections, oil traps, and double risers.
 5. Evaporators.
- B. Seismic Qualification Certificates: For air-cooled refrigerant condensers, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-cooled refrigerant condensers to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 EXTRA MATERIALS

- A. Provide [**two (2)**] <Insert number> sets of fan belts.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Fabricate and label refrigeration system according to ASHRAE 15, "Safety Standard for Refrigeration Systems."
- C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.9 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
- B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 077200 "Roof Accessories."
- C. Coordinate location of refrigerant piping and electrical rough-ins.

1.10 DELIVERY, STORAGE, AND PROTECTION

- A. Section 230400 "Basic HVAC Requirements" and Division 1: Transportation, delivery, handling, storage, and protection of products.
- B. Comply with manufacturer's installation instruction for rigging, unloading and transporting units.
- C. Protect units on site from physical damage. Protect coils.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Carrier Corporation; Commercial HVAC Systems.](#)
2. [Colmac Coil Manufacturing, Inc.](#)
3. [Coolenheat Inc.](#)
4. [Dunham-Bush, Inc.](#)
5. [Engineered Air.](#)
6. [Heatcraft Refrigeration Products LLC.](#)
7. [McQuay International.](#)
8. [Trane; a business of American Standard Companies.](#)
9. [USA Coil & Air.](#)
10. [YORK; a Johnson Controls company.](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

2.2 MANUFACTURED UNITS

- A. Description: Factory assembled and tested; consisting of casing, condenser coils, condenser fans and motors, and unit controls.
- B. Refrigerant: [R-22] [R-407C] [R-410A] **<Insert type>.**
- C. Refrigerant: R-407C or R-410A.
- D. Condenser Coil: Factory tested at 425 psig (2930 kPa).
1. Tube: [1/2-inch- (13-mm-) diameter seamless copper.] [3/8-inch- (10-mm-) diameter seamless copper.] [5/8-inch- (16-mm-) diameter seamless copper.] [5/8-inch- (16-mm-) diameter steel.]
 2. Coil Fin: [Aluminum] [Steel].
 3. Coating: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; **<Insert manufacturer's name; trade name>.**
 4. Circuit: To match compressors[**with liquid subcooling coil**].
- E. Condenser Fans and Drives: Propeller fans with [aluminum or galvanized-steel] [galvanized-steel] [stainless-steel] fan blades, for [vertical] [horizontal] air

discharge; directly driven with **[permanently lubricated]** **[grease-lubricated]** ball-bearing motors with integral current- and thermal-overload protection.

1. Weather-proof motors with rain shield and shaft slinger.
2. Extend grease lines to outside of casing.

F. Condenser Fans and Drives: Forward-curved centrifugal fans for **[vertical]** **[horizontal]** air discharge.

1. Fan on steel shaft with self-aligning ball bearings.
2. V-belt drive with minimum of two belts; variable pitch drive pulley.
3. Motor mounted on adjustable slide base.

G. Operating and Safety Controls: Include condenser fan motor thermal and overload cutouts; 115-V control transformer, if required; magnetic contactors for condenser fan motors and a nonfused factory-mounted and -wired disconnect switch for single external electrical power connection.

1. Fan Cycling Control: **[Head pressure switches]** **[Ambient thermostats]**.

H. Casings: **[Galvanized or zinc-coated steel treated and finished with manufacturer's standard paint coating]** **[Aluminum]** **[Stainless steel]**, designed for **outdoor installation with weather protection for components and controls**, and with the following:

1. Removable panels for access to controls, condenser fans, motors, and drives.
2. **[Plated]** **[Stainless]**-steel fan guards.
3. Lifting eyes.
4. Removable legs, **[20 inches (500 mm)]** **[30 inches (760 mm)]** **[36 inches (910 mm)]** **[42 inches (1060 mm)]** high.

2.3 CAPACITIES AND CHARACTERISTICS

A. Heat-Rejection Capacity: **<Insert MBh (kW)>**.

B. Condensing Temperature:

1. Saturated Discharge Temperature: **<Insert deg F (deg C)>**.
2. Saturated Suction Temperature: **<Insert deg F (deg C)>**.
3. Subcooling Temperature: **<Insert deg F (deg C)>**.

C. Ambient-Air Temperature: **<Insert deg F (deg C)>**.

D. Refrigerant Pipe Connections:

1. Number of Connections: **<Insert number>**.
2. Liquid Pipe Size: **<Insert NPS (DN)>**.
3. Suction Pipe Size: **<Insert NPS (DN)>**.

E. Coils:

1. Arrangement: **<Insert description>**.
2. Number of Rows: **<Insert number>**.
3. Fin Spacing: [12 fins/inch (2 mm)] **<Insert value>**.
4. Total Face Area: **<Insert sq. ft. (sq. m)>**.

F. Fans:

1. Number of Condenser Fans: **<Insert number>**.
2. Diameter: **<Insert inches (mm)>**.
3. RPM: **<Insert number>**.
4. Total Airflow: **<Insert cfm (L/s)>**.
5. Condenser Fan Motor Size: **<Insert horsepower>**.

G. Electrical Characteristics:

1. Kilowatts: **<Insert value>**.
2. Volts: **<Insert value>**.
3. Phase: **<Insert value>**.
4. Hertz: **<Insert value>**.
5. Maximum Circuit Ampacity: **<Insert value>**.
6. Maximum Instantaneous Current Flow during Startup: **<Insert value>**.
7. Maximum Overcurrent Protection: **<Insert amperage>**.

2.4 MOTORS

A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Mount unit-mounted disconnect switches on [exterior] [interior] of unit.
4. **<Insert unique motor characteristics>**.

2.5 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate air-cooled refrigerant condensers according to ARI 460.
- B. Testing Requirements: Factory test sound-power-level ratings according to ARI 270.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of air-cooled refrigerant condensers.
- B. Examine roughing-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.
- C. Examine walls, floors, and roofs for suitable conditions where air-cooled condensers will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install units level and plumb, firmly anchored in locations indicated; maintain manufacturer's recommended clearances.
- B. Equipment Mounting:
 - 1. Install air-cooled condenser refrigerant condensers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- C. Maintain manufacturer's recommended clearances for service and maintenance.
- D. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to machine to allow service and maintenance.
- C. Refrigerant Piping: Connect piping to unit with pressure relief, service valve, filter-dryer, and moisture indicator on each refrigerant-circuit liquid line. Refrigerant piping and specialties are specified in Section 232300 "Refrigerant Piping."

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect, test, and adjust components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. Perform electrical test and visual and mechanical inspection.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Complete manufacturer's starting checklist.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 5. Verify proper airflow over coils.
- C. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
- D. Air-cooled refrigerant condensers will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - a. Inspect for physical damage to unit casing.
 - b. Verify that access doors move freely and are weathertight.
 - c. Clean units and inspect for construction debris.
 - d. Verify that all bolts and screws are tight.
 - e. Adjust vibration isolation and flexible connections.
 - f. Verify that controls are connected and operational.
 - 2. Lubricate bearings on fan motors.
 - 3. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
 - 4. Adjust fan belts to proper alignment and tension.
 - 5. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.
 - 6. Measure and record airflow and air temperature rise over coils.

7. Verify proper operation of capacity control device.
8. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
9. After startup and performance test, lubricate bearings.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air-cooled refrigerant condensers.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236313

SECTION 236333 - EVAPORATIVE REFRIGERANT CONDENSERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes: Factory-assembled and -tested, **[forced]** **[induced]**-draft evaporative refrigerant condensers.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. DDC: Direct digital control.

1.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design evaporative refrigerant condenser support structure[**and seismic restraints**] [**and wind restraints**], including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Structural Performance: Evaporative refrigerant condenser support structure shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated according to **[ASCE/SEI 7] <Insert requirement>**.
 - 1. Dead Loads: **<Insert loads>**.
 - 2. Live Loads: **<Insert loads>**.
 - 3. Roof Loads: **<Insert loads>**.
 - 4. Snow Loads: **<Insert loads>**.
 - 5. Seismic Loads: **<Insert loads>**.
 - 6. Wind Loads: **<Insert loads>**.
 - 7. **<Insert loads or load combinations>**.
 - 8. Deflection Limits: Design system to withstand design loads without deflections greater than the following:
 - a. **<Insert deflection limits>**.

C. Wind-Restraint Performance:

1. Basic Wind Speed: <Insert value>.
2. Building Classification Category: [I] [II] [III] [IV].
3. Minimum 10 lb/sq. ft. (48.8 kg/sq. m) multiplied by the maximum area of the mechanical component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

D. Seismic Performance: Evaporative refrigerant condenser shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.5 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, pressure drop, fan performance data, installation instructions, furnished specialties, and accessories.

1. Maximum flow rate.
2. Minimum flow rate.
3. Drift loss as percent of design flow rate.
4. Volume of water in suspension for purposes of sizing a remote storage tank.
5. Sound power levels in eight octave bands for operation with fans off, fans at minimum speed, and fans at design speed.
6. Performance curves for the following:
 - a. Varying entering-water temperatures from design to minimum.
 - b. Varying ambient wet-bulb temperatures from design to minimum.
 - c. Varying water flow rates from design to minimum.
 - d. Varying fan operation (off, minimum speed, and design speed).
7. Fan airflow, brake horsepower, and drive losses.
8. Pump flow rate, head, brake horsepower, and efficiency.
9. Motor amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
10. Electrical power requirements for each evaporative refrigerant condenser component requiring power.
11. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

C. Shop Drawings: For evaporative refrigerant condensers. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, required clearances, method of field assembly, components, and location and size of each field piping and wiring connection.
 2. Wiring Diagrams: Power, signal, and control wiring.
 3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
- D. Delegated-Design Submittal: For evaporative refrigerant condensers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Detail mounting, securing, and flashing of roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
 2. **[Wind-] [and] [Seismic-]Restraint Details:** Detail fabrication and attachment of restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.
 3. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include handrails, ladders, and equipment mounting frame.
 4. Design Calculations: Calculate requirements for selecting vibration isolators **[and seismic restraints]** and for designing vibration isolation bases.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved.
1. Structural supports.
 2. Piping and wiring roughing-in requirements (determine spaces reserved for electrical equipment).
 3. Access requirements for service and maintenance.
- B. Seismic Qualification Certificates: For evaporative refrigerant condensers, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- C. Warranties: Sample of special warranties.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For evaporative refrigerant condensers to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 EXTRA MATERIALS

- A. Provide [**two (2)**] <Insert number> sets of fan belts.

1.9 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label heat-exchanger coils to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- C. Comply with NFPA 70.
- D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning" and Section 10 - "Other Equipment."

1.10 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.11 DELIVERY, STORAGE, AND PROTECTION

- A. Section 230400 "Basic HVAC Requirements" and Division 1: Transportation, delivery, handling, storage, and protection of products.

- B. Comply with manufacturer's installation instruction for rigging, unloading, and transporting units.
- C. Protect units on site from physical damage. Protect coils.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of evaporative refrigerant condensers that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Fan, motor, drive shaft, bearings, and motor supports.
 - b. Tube bundle.
 - c. External-circuit circulating pump.
 - d. **<Insert failure modes>**.
 - 2. Warranty Period: Minimum **[five (5)] <Insert number>** years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 FORCED-DRAFT EVAPORATIVE REFRIGERANT CONDENSERS

- A. **Products:** Subject to compliance with requirements, provide one of the following:
 - 1. [Baltimore Aircoil Company](#); Series V.
 - 2. [EVAPCO, Inc](#); Models LSCB.
 - 3. [Recold](#); Series JC.
 - 4. **<Insert manufacturer's name; product name or designation>**.
 - 5. or approved equal.
- B. Fabricate evaporative refrigerant condenser mounting base with reinforcement strong enough to resist evaporative refrigerant condenser movement during a seismic event when evaporative refrigerant condenser is anchored to field support structure.
- C. Evaporative refrigerant condenser designed to resist wind load of **[30 lbf/sq. ft. (1.44 kPa)] <Insert value>**.
- D. Casing and Frame:

1. Casing[**and Frame**] Material: [**FRP with UV inhibitors**] [**Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating**] [**Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating**] [**Polymer-coated galvanized steel**] [**Stainless steel**].
 2. Frame Material: [**FRP with UV inhibitors**] [**Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating**] [**Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating**] [**Polymer-coated galvanized steel**] [**Stainless steel**].
 3. Fasteners: [**Galvanized**] [**Stainless**] steel.
 4. Joints and Seams: Sealed watertight.
 5. Welded Connections: Continuous and watertight.
- E. Collection Basin: Configure evaporative refrigerant condenser for installation with a field-constructed collection basin.
- F. Collection Basin:
1. Material: [**FRP with UV inhibitors**] [**Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating**] [**Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating**] [**Polymer-coated galvanized steel**] [**Stainless steel**].
 2. Strainer: Removable[**stainless-steel**] strainer with openings smaller than nozzle orifices.
 3. Overflow and drain connections.
 4. Makeup water connection.

Not all listed manufacturers offer basin sweeper distribution piping. Consult evaporative refrigerant condenser manufacturers.

5. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: [**PVC**] <Insert material>.
 - b. Nozzle Material: [**Plastic**] <Insert material>.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, [**Type 4**] [**Type 4X**] <Insert type>.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [**control of water makeup valve**] [**control of water makeup valve and low-level alarm**] [**control of water makeup valve and low- and high-level alarms**] [**control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level**].
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: [**Corrosion-resistant material**] [**FRP**] [**Galvanized steel**] [**PVC pipe**] [**Stainless steel**].
 5. Solenoid Valve: Slow closing[**with stainless-steel body**]; controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

- I. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each evaporative refrigerant condenser cell.
 3. Enclosure: NEMA 250, **[Type 3R] [Type 4] [Type 4X]**.
 4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor evaporative refrigerant condenser water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]** and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- J. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- K. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- L. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat exchanger coil throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

Other requirements may require use of other materials.

1. Pipe Material: **[Fiberglass] [PVC] [Galvanized steel] <Insert material>**.
 2. Spray Nozzle Material: **[Plastic] [Polypropylene] [PVC] <Insert material>**.
 3. Piping Supports: Corrosion-resistant hangers and supports designed to resist movement during operation and shipment.
- N. Recirculating Piping: **[PVC] <Insert pipe material>[, with connections for separately provided, remote spray pump]**.
- O. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
1. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.

2. Motor Enclosure: [**Totally enclosed**] [**Totally enclosed nonventilated (TENV)**] [**Totally enclosed fan cooled (TEFC)**] [**with epoxy or polyurethane finish**].
3. Energy Efficiency: [**Comply with ASHRAE/IESNA 90.1**] [**NEMA Premium Efficient**].
4. Service Factor: [**1.0**] [**1.15**] <Insert value>.

P. Heat-Exchanger Coils:

1. Tube and Tube Sheet Materials: [**Copper tube with stainless-steel sheet**] [**Stainless-steel tube and sheet**] [**Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication**].
2. Heat-Exchanger Arrangement: [**Serpentine tubes**] [**Serpentine tubes with removable cover plate on inlet and outlet headers**] [**Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube**]; and sloped for complete drainage of fluid by gravity.
3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
4. Field Piping Connections: Vent, supply, and return[**suitable for mating to ASME B16.5, Class 150 flange**].

Q. [**Removable**] Drift Eliminator:

1. Material: [**FRP**] [**PVC**] [**FRP or PVC**] <Insert material>; with maximum flame-spread index of [**5**] [**25**] <Insert value> according to ASTM E 84.
2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.

R. [**Removable**] Air-Intake Screens: [**Galvanized**] [**Polymer-coated, galvanized**] [**Stainless**]-steel wire mesh.

S. Centrifugal Fan: Double-width, double-inlet fan with forward-curved blades; and statically and dynamically balanced at the factory after assembly.

1. Number of Fans: Each evaporative refrigerant condenser cell shall have a single fan or multiple fans connected to a common shaft.
2. Fan Wheel and Housing Materials: Galvanized steel.
3. Fan Shaft: Steel, coated to resist corrosion.
4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
5. Fan Shaft Bearings: Self-aligning, grease-lubricated ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of [**40,000**] [**50,000**] <Insert value> hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

T. Belt Drive:

1. Service Factor: **[1.5]** <Insert value> based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
3. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
4. Belt: One-piece, multigrooved, solid-back belt.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.

U. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: **[Totally enclosed]** **[Totally enclosed air over (TEAO)]** **[Totally enclosed fan cooled (TEFC)]** **[with epoxy or polyurethane finish]**.
3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1]** **[NEMA Premium Efficient]**.
4. Service Factor: **[1.15]** <Insert value>.
5. Insulation: **[Class F]** **[Class H]** <Insert class>.
6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
7. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C).
 - c. Internal heater automatically energized when motor is de-energized.
8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

V. Discharge Hoods:

1. Hood Configuration: **[Tapered]** **[Straight]**; totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed **[insulation and]**access doors.
2. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
 - a. Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.

W. Capacity-Control Dampers: **[Galvanized-steel]** **[Stainless-steel]** <Insert material> dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.

X. Vibration Switch: For each fan drive.

1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Vibration Detection: Sensor with a field-adjustable acceleration sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Evaporative refrigerant condenser manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch **[with manual-reset button]** for **[field connection to a DDC system for HVAC and]**hardwired connection to fan motor electrical circuit.
 4. Switch shall, on sensing excessive vibration, **[signal an alarm through the DDC system for HVAC and]** shut down the fan.
- Y. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- Z. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
1. NEMA 250, **[Type 3R] [Type 4] [Type 4X]** enclosure with removable internally mounted backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
 4. Microprocessor-based controller for automatic control of fan **[and spray pump]** based on evaporative refrigerant condenser leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
 5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead-stage rotation.
 6. Collection basin, electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.
 7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
 8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
 9. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.
 10. Power and controls to open discharge hood dampers when pump is energized and close dampers when pump is de-energized.
 11. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each evaporative refrigerant condenser cell]**.
 - a. Branch power circuit to each motor and electric basin heater and to controls **[with a disconnect switch or circuit breaker]**.
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
 12. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.

13. Visual indication of status and alarm[**with momentary test push button**] for each motor.
14. Audible alarm and silence switch.
15. Visual indication of elapsed run time, graduated in hours for each motor.
16. Evaporative refrigerant condenser shall have hardware to enable DDC system for HVAC to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Position of dampers.
 - c. Evaporative refrigerant condenser leaving-fluid temperature.
 - d. Fan vibration alarm.
 - e. Collection basin **[high] [low] [high- and low]**-water-level alarms.
 - f. **<Insert conditions to be monitored>**.

AA. Personnel Access Components:

1. Doors: Large enough for personnel to access evaporative refrigerant condenser internal components from **[both]** evaporative refrigerant condenser end walls.[**Doors shall be operable from both sides of the door.**]
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of evaporative refrigerant condenser from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at evaporative refrigerant condenser access doors when evaporative refrigerant condensers are elevated and not accessible from grade.
4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard at platforms and around top of evaporative refrigerant condenser. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of evaporative refrigerant condenser to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.

BB. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Maximum Drift Loss: **[0.005] <Insert number>** percent of design water flow.
3. Heat-Exchanger Coil(s):

Retain second, third, or fourth option in first subparagraph or retain second subparagraph if required for LEED-NC, LEED-CS, and LEED for Schools Credit EA 4.

- a. Refrigerant Type: **[R-22] [R-407C] [R-410A] [HFC-134a] <Insert type>**.
- b. Refrigerant Type: R-407C, R-410A, or HFC-134a.
- c. Minimum Heat Rejection: **<Insert Btu/h (kW)>**.
- d. Condensing Temperature: **<Insert deg F (deg C)>**.
- e. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.

4. Fan Location: [**Bottom**] [**Side**].
5. Fan Motor:
 - a. Type: [**Single speed**] [**Two speed, single winding**] [**Two speed, two winding**] [**Variable speed**].
 - b. Horsepower/Cell: <Insert horsepower>.
 - c. Full-Load Ampacity: <Insert value>.
 - d. Minimum Circuit Ampacity: <Insert value>.
 - e. Maximum Overcurrent Protection Device: <Insert amperage>.
 - f. Electrical Characteristics: [**208**] [**240**] [**480**] <Insert value>-V ac, 3 phase, 60 Hz.
6. Spray Pump and Motor:
 - a. Water Flow/Cell: <Insert **gpm** (L/s)>.
 - b. Horsepower/Cell: <Insert horsepower>.
 - c. Full-Load Ampacity: <Insert value>.
 - d. Minimum Circuit Ampacity: <Insert value>.
 - e. Maximum Overcurrent Protection Device: <Insert amperage>.
 - f. Electrical Characteristics: [**120**] [**208**] [**240**] [**277**] [**480**] <Insert value>-V ac, [**single**] [**3**] phase, 60 Hz.
7. Sound Pressure Level: <Insert **dba**> at <Insert distance in **feet** (m)> [**when measured according to CTI ATC 128**].
8. Basin Heater:
 - a. Basin Water Temperature: [**40 deg F** (5 deg C)] <Insert value>.
 - b. Outdoor Ambient Temperature: [**0 deg F** (Minus 18 deg C)] [**Minus 20 deg F** (Minus 29 deg C)] <Insert value>.
 - c. Capacity/Cell: <Insert **kilowatts**>.
 - d. Full-Load Ampacity: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection Device: <Insert amperage>.
 - g. Electrical Characteristics: [**208**] [**240**] [**480**] <Insert value>-V ac, 3 phase, 60 Hz.
 - h. Capacity/Cell: <Insert **MBtu/h** (kW)>.
 - i. Entering-Fluid Temperature: <Insert **deg F** (deg C)>.
 - j. Fluid Flow Rate: <Insert **gpm** (L/s)>.
 - k. Fluid Pressure Drop: <Insert **psig** (kPa)>.
 - l. Capacity/Cell: <Insert **MBtu/h** (kW)>.
 - m. Steam Flow: <Insert **lb/h** (L/s)>.
 - n. Steam Pressure: <Insert **psig** (kPa)>.

2.2 INDUCED-DRAFT EVAPORATIVE REFRIGERANT CONDENSERS

A. Products: Subject to compliance with requirements, provide one of the following:

1. [Baltimore Aircoil Company](#); Series CXV.
2. [EVAPCO, Inc](#); Models ATC.

3. **Recold**; Series MC.
 4. **<Insert manufacturer's name; product name or designation>**.
 5. or approved equal.
- B. Fabricate evaporative refrigerant condenser mounting base with reinforcement strong enough to resist evaporative refrigerant condenser movement during a seismic event when evaporative refrigerant condenser is anchored to field support structure.
- C. Evaporative refrigerant condenser designed to resist wind load of [30 lbf/sq. ft. (1.44 kPa)] **<Insert value>**.
- D. Casing and Frame:
1. Casing[and Frame] Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Stainless steel].
 2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
 3. Fasteners: [Galvanized] [Stainless] steel.
 4. Joints and Seams: Sealed watertight.
 5. Welded Connections: Continuous and watertight.
- E. Collection Basin: Configure evaporative refrigerant condenser for installation with a field-constructed collection basin.
- F. Collection Basin:
1. Material: [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Stainless steel].
 2. Overflow and drain connections.
 3. Makeup water connection.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, [Type 4] [Type 4X] **<Insert type>**.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: [Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].
 5. Solenoid Valve: Slow closing[with stainless-steel body]; controlled and powered through level controller in response to water-level set point.

6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Electric Basin Heater:
 1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each evaporative refrigerant condenser cell.
 3. Enclosure: NEMA 250, **[Type 3R] [Type 4] [Type 4X]**.
 4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor evaporative refrigerant condenser water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]** and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
 - J. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
 - K. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
 - L. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
 - M. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
 1. Pipe Material: **[Fiberglass] [PVC] [Galvanized steel] <Insert material>**.
 2. Spray Nozzle Material: **[Plastic] [Polypropylene] [PVC] <Insert material>**.
 3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
 - N. Recirculating Piping: **[PVC] <Insert pipe material>[, with connections for separately provided, remote spray pump]**.
 - O. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.

1. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: [**Totally enclosed**] [**Totally enclosed nonventilated (TENV)**] [**Totally enclosed fan cooled (TEFC)**] [**with epoxy or polyurethane finish**].
3. Energy Efficiency: [**Comply with ASHRAE/IESNA 90.1**] [**NEMA Premium Efficient**].
4. Service Factor: [**1.0**] [**1.15**] <Insert value>.

P. Heat-Exchanger Coils:

1. Tube and Tube Sheet Materials: [**Copper tube with stainless-steel sheet**] [**Stainless-steel tube and sheet**] [**Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication**].
2. Heat-Exchanger Arrangement: [**Serpentine tubes**] [**Serpentine tubes with removable cover plate on inlet and outlet headers**] [**Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube**]; and sloped for complete drainage of fluid by gravity.
3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
4. Field Piping Connections: Vent, supply, and return[**suitable for mating to ASME B16.5, Class 150 flange**].

Q. [**Removable**] Drift Eliminator:

1. Material: [**FRP**] [**PVC**] [**FRP or PVC**] <Insert material>; with maximum flame-spread index of [**5**] [**25**] <Insert value> according to ASTM E 84.
2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.

R. Air-Intake Louvers:

1. Material: [**FRP**] [**PVC**] [**Matching casing**].
2. UV Treatment: Treat louvers with inhibitors to protect against damage caused by UV radiation.
3. Louver Blades: Arranged to uniformly direct air into evaporative refrigerant condenser, to minimize air resistance, and to prevent water from splashing out during all modes of operation including operation with fans off.

S. Axial Fan: Balanced at the factory after assembly.

1. Blade Material: [**Aluminum**] [**FRP**] [**Galvanized steel**].
2. Hub Material: [**Aluminum**] [**FRP**] [**Galvanized steel**].
3. Blade Pitch: Field adjustable.
4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.

5. Fan Shaft Bearings: Self-aligning, grease-lubricated ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of **[40,000] [50,000] <Insert value>** hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

T. Belt Drive:

1. Service Factor: **[1.5] <Insert value>** based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
3. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
4. Belt: One-piece, multigrooved, solid-back belt.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.

U. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.

Third option provides highest degree of protection and must be used when motor is not located in the airstream.

2. Motor Enclosure: **[Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].**
3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].**
4. Service Factor: **[1.15] <Insert value>**.
5. Insulation: **[Class F] [Class H] <Insert class>**.
6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
7. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C).
 - c. Internal heater automatically energized when motor is de-energized.
8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

V. Fan Discharge Stack: Material shall match casing, **[manufacturer's standard] [velocity recovery]** design.

1. Stack Extension: Fabricated to extend above fan deck **<Insert distance>** unless otherwise indicated.

2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

W. Vibration Switch: For each fan drive.

1. Enclosure: NEMA 250, [Type 4] [Type 4X] <Insert type>.
2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Evaporative refrigerant condenser manufacturer shall recommend switch set point for proper operation and protection.
3. Provide switch[with manual-reset button] for [field connection to a DDC system for HVAC and]hardwired connection to fan motor electrical circuit.
4. Switch shall, on sensing excessive vibration,[signal an alarm through the DDC system for HVAC and] shut down the fan.

Retain second paragraph if controls are provided with evaporative refrigerant condenser.

X. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."

Not all manufacturers offer factory-installed control packages; those that do offer control packages have limited features available with the package. Consult manufacturers for additional information.

Y. Control Package: Factory installed and wired, and functionally tested at factory before shipment.

Retain applicable subparagraphs, based on Project conditions, to require these features and to correspond with components retained in paragraphs above.

1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
2. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Microprocessor-based controller for automatic control of fan[and spray pump] based on evaporative refrigerant condenser leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead-stage rotation.
6. Collection basin electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each evaporative refrigerant condenser cell].

- a. Branch power circuit to each motor and electric basin heater and to controls[**with a disconnect switch or circuit breaker**].
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
10. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
 11. Visual indication of status and alarm[**with momentary test push button**] for each motor.
 12. Audible alarm and silence switch.
 13. Visual indication of elapsed run time, graduated in hours for each motor.
 14. Evaporative refrigerant condenser shall have hardware to enable DDC system for HVAC to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Evaporative refrigerant condenser leaving-fluid temperature.
 - c. Fan vibration alarm.
 - d. Collection basin [**high**] [**low**] [**high- and low**]-water-level alarms.
 - e. **<Insert conditions to be monitored>**.

Z. Personnel Access Components:

1. Doors: Large enough for personnel to access evaporative refrigerant condenser internal components from both evaporative refrigerant condenser end walls. Doors shall be operable from both sides of the door.
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of evaporative refrigerant condenser from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at evaporative refrigerant condenser access doors when evaporative refrigerant condensers are elevated and not accessible from grade.
4. Handrail: Aluminum, galvanized steel, or stainless steel, complete with kneerail and toeboard at platforms, and around top of evaporative refrigerant condenser. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of evaporative refrigerant condenser to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high-water level of the collection basin.
 - b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

AA. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Maximum Drift Loss: [**0.005**] **<Insert number>** percent of design water flow.

3. Heat-Exchanger Coil:
 - a. Refrigerant Type: [R-22] [R-407C] [R-410A] [HFC-134a] <Insert type>.
 - b. Refrigerant Type: R-407C, R-410A, or HFC-134a.
 - c. Minimum Heat Rejection: <Insert Btu/h (kW)>.
 - d. Condensing Temperature: <Insert deg F (deg C)>.
 - e. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.

4. Fan Motor:
 - a. Type: [Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed].
 - b. Horsepower/Cell: <Insert horsepower>.
 - c. Full-Load Ampacity: <Insert value>.
 - d. Minimum Circuit Ampacity: <Insert value>.
 - e. Maximum Overcurrent Protection Device: <Insert amperage>.
 - f. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.

5. Spray Pump and Motor:
 - a. Water Flow/Cell: <Insert gpm (L/s)>.
 - b. Horsepower/Cell: <Insert horsepower>.
 - c. Full-Load Ampacity: <Insert value>.
 - d. Minimum Circuit Ampacity: <Insert value>.
 - e. Maximum Overcurrent Protection Device: <Insert amperage>.
 - f. Electrical Characteristics: [120] [208] [240] [277] [480] <Insert value>-V ac, [single] [3] phase, 60 Hz.

6. Sound Pressure Level: <Insert dBA> at <Insert distance in feet (m)> [when measured according to CTI ATC 128].

7. Basin Heater:
 - a. Basin Water Temperature: [40 deg F (5 deg C)] <Insert value>.
 - b. Outdoor Ambient Temperature: [0 deg F (Minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert value>.
 - c. Capacity/Cell: <Insert kilowatts>.
 - d. Full-Load Ampacity: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection Device: <Insert amperage>.
 - g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
 - h. Capacity/Cell: <Insert MBtu/h (kW)>.
 - i. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - j. Fluid Flow Rate: <Insert gpm (L/s)>.
 - k. Fluid Pressure Drop: <Insert psig (kPa)>.
 - l. Capacity/Cell: <Insert MBtu/h (kW)>.
 - m. Steam Flow: <Insert lb/h (L/s)>.
 - n. Steam Pressure: <Insert psig (kPa)>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for concrete bases, anchor-bolt sizes and locations, piping systems, and electrical systems to verify actual locations and sizes before evaporative refrigerant condenser installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 - 1. Install evaporative refrigerant condensers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete."]** **[Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Maintain manufacturer's recommended clearances for service and maintenance.
- C. Loose Equipment: Install electrical components, devices, and accessories that are not factory mounted.

3.3 CONNECTIONS

- A. Install piping adjacent to evaporative refrigerant condensers to allow service and maintenance.
- B. Install flexible pipe connectors at final connection of evaporative refrigerant condensers mounted on vibration isolators.
- C. Run overflow, drain, and bleed lines to sanitary sewage system.
- D. Domestic Water Piping: Comply with requirements in Section 221116 "Domestic Water Piping." Connect to water-level control with shutoff valve and union or flange at each connection.
- E. Refrigerant Piping: Comply with requirements in Section 232300 "Refrigerant Piping." Connect to evaporative refrigerant condenser coil with isolation valves at each connection.
- F. Hot-Water Piping: Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Connect to supply and return

basin-heater tappings with shutoff valve, strainer, control valve, and union or flange on supply connection and union or flange and balancing valve on return connection.

- G. Steam and Condensate Piping: Comply with requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Connect steam supply to basin heater with shutoff valve, strainer, control valve, and union or flange and condensate piping with union or flange, shutoff valve, strainer, and an appropriate steam trap.
- H. Ducts: Comply with requirements in Section 233113 "Metal Ducts." Connect ducts to evaporative refrigerant condenser inlet and outlet, full size of outlet, with flexible duct connection.

3.4 STARTUP SERVICE

- A. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
- B. Obtain performance tables from manufacturer.
- C. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Clean entire unit including basins.
 - 3. Verify that accessories are properly installed.
 - 4. Check makeup water float.
 - 5. Verify clearances for airflow and for evaporative refrigerant condenser servicing.
 - 6. Check for vibration isolation and structural support.
 - 7. Lubricate bearings on fans and shafts.
 - 8. Verify fan wheel rotation for correct direction and for vibration or binding. Correct vibration and binding problems.
 - 9. Adjust belts to proper alignment and tension.
 - 10. Operate variable-speed fans through entire operating range and check for harmonic vibration imbalance. Set motor controller to skip speeds resulting in abnormal vibration.
 - 11. Check vibration switch setting. Verify operation.
 - 12. Verify water level in basin. Fill to proper startup level. Check makeup water-level control and valve.
 - 13. Start external-circuit circulating pumps.
 - 14. Verify operation of evaporative refrigerant condenser basin, makeup line, automatic freeze protect dump, and controlling device. Replace defective and malfunctioning units.
 - 15. Verify operation of basin heater and control thermostat. Replace defective and malfunctioning units.
 - 16. Verify that evaporative refrigerant condenser discharge is not recirculating into air intakes. Recommend corrective action.

17. Check HVAC water treatment system for proper operation, and measure chemical treatment levels. Verify operation of evaporative refrigerant condenser basin automatic blowdown and of controlling device.

3.5 ADJUSTING

- A. Adjust water-level control for proper operating level.
- B. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number> months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain evaporative refrigerant condensers.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236333

SECTION 236413.13 - DIRECT-FIRED ABSORPTION WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, water-cooled, direct-fired absorption chillers.
 - 2. Heat-exchanger, brush-cleaning system.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- C. IPLV: Integrated part-load value. A single-number, part-load efficiency figure of merit calculated per the method defined by ARI 560 and referenced to ARI standard rating conditions.
- D. NPLV: Nonstandard part-load value. A single-number, part-load efficiency figure of merit calculated per the method defined by ARI 560 and intended for operating conditions other than the ARI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Direct-fired absorption chillers shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **and the unit will be fully operational after the seismic event**."
- B. Condenser-Fluid Temperature Performance:

1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of [60 deg F (16 deg C)] <Insert temperature> and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
 2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of [70 deg F (21 deg C)] <Insert temperature>.
 3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
- C. Site Altitude: Chiller shall be suitable for altitude at which it is installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
- D. Performance Tolerance: Comply with the following in lieu of ARI 560:
1. Allowable Capacity Tolerance: [Zero] <Insert number> percent.
 2. Allowable IPLV/NPLV Performance Tolerance: [Zero] <Insert number> percent.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Indicate valves, strainers, and thermostatic valves required for complete system. Include rated capacities, operating characteristics, furnished specialties and accessories, and the following:
1. Performance at ARI standard conditions and at conditions indicated.
 2. Performance at ARI standard unloading conditions.
 3. Minimum evaporator flow rate.
 4. Absorbent capacity of chiller.
 5. Refrigerant capacity of chiller.
 6. Fluid capacity of evaporator and condenser.
 7. Fluid capacity of generator.
 8. Characteristics of safety relief devices.
 9. Minimum entering condenser-fluid temperature.
 10. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in [5 deg F (3 deg C)] <Insert temperature> increments.
 11. If equipped, fluid capacity of dedicated hot-water heater exchanger.
 12. Combustion-air flow.
 13. Exhaust gas airflow.
 14. Exhaust gas minimum and maximum operating temperature.
 15. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1.

2. Product Data for Prerequisite EA 3: Documentation indicating that refrigerants comply.
 3. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
- C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring Diagrams: For power, signal, and control wiring.
 3. Insulated Surface Diagrams: Indicating cold and hot surfaces requiring field-applied insulation with area tabulated for each.
 4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Structural supports.
 2. Piping roughing-in requirements.
 3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 4. Access requirements, including working clearances for mechanical controls and electrical equipment, and clearances for tube pull and service.
- B. Certificates: For certification required in "Quality Assurance" Article.

Verify availability with manufacturers and retain below if required by seismic criteria applicable to Project. See "Seismic Considerations" Article in the Evaluations. Coordinate below with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
 - D. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
 - E. Source quality-control reports.
 - F. Startup service reports.
 - G. Warranty: Sample of special warranty.
- 1.7 CLOSEOUT SUBMITTALS
- A. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.
 - B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- 1.8 MAINTENANCE MATERIALS
- A. Provide [**two (2)**] <Insert number> containers of [**lubricating oil**] [**refrigerant**].
- 1.9 QUALITY ASSURANCE
- A. ARI Rating: Rate chiller performance according to requirements in ARI 560.
 - B. ASHRAE Compliance:
 1. ASHRAE 15 for safety code for mechanical refrigeration.
 2. ASHRAE/IESNA 90.1.
 - C. ASME Compliance: Fabricate and label chiller pressure vessels to comply with applicable portions of ASME Boiler and Pressure Vessel Code.
 - D. Comply with NFPA 70.
 - E. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.
 1. **UL Compliance: [UL 726, "Oil-Fired Boiler Assemblies."] [UL 726, "Oil-Fired Boiler Assemblies"; and UL 795, "Commercial-Industrial Gas Heating Equipment."] [UL 795, "Commercial-Industrial Gas Heating Equipment."]**

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Ship chillers factory charged with nitrogen.
- B. Ship absorbent and refrigerant in chillers or in containers separate from chillers.
- C. Ship **[absorbent] [and] [refrigerant]** in containers separate from chillers.
- D. Package chiller for export shipping in totally enclosed **[bagging] [crate] [crate with bagging]**.
- E. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.
- F. Protect units from physical damage.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
 - 1. Extended warranties include, but are not limited to, the following:
 - a. Complete chiller.
 - b. **[Pumps and motors] [Purge unit] [Burner assembly] <Insert components>**.
 - c. **[Absorbent] [Absorbent and refrigerant]** only.
 - d. Parts **[only] [and labor]**.
 - e. Loss of absorbent and refrigerant for any reason.
 - 2. Warranty Period: Minimum **[two (2)] [three (3)] [four (4)] [five (5)] <Insert number>** years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Section 016000 "Product Requirements."

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Trane; a division of American Standard.
 2. YORK; a Johnson Controls company.
 3. or approved equal.
 4. **<Insert manufacturer's name>.**
 5. or approved equal.

2.2 MANUFACTURED UNIT

- A. Description: Factory-assembled and -tested, hermetic-design chiller complete with absorber, evaporator, condenser, generator, solution heat exchanger, controls, absorbent solution pump with motor, refrigerant pump with motor, purge unit with motor, burner assembly, motor controllers, rupture disk, interconnecting unit piping and wiring, indicated accessories, and mounting frame.
1. Disassemble chiller into major assemblies, as required by the installation, after factory testing and before packaging for shipment.
- B. Absorbent and Refrigerant:
1. Absorbent: Lithium bromide solution with corrosion inhibitor.
 2. Refrigerant: Deionized [**or distilled**]water.
 3. Performance Enhancer: Heat and mass transfer enhancer to improve performance.
- C. Seismic Fabrication Requirements: Fabricate mounting base and attachment to chiller, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

2.3 PUMPS

- A. Hermetically sealed, self-lubricating, and fitted with self-adjusting, spring-loaded, wear-compensating, tapered carbon bearings.
- B. Pump motor assembly shall be designed to operate for not less than 50,000 hours between inspections.
- C. Pump motors shall be cooled and bearings lubricated, either by fluid being pumped or by a filtered supply of liquid refrigerant.

- D. Pump suction and discharge shall be equipped with isolation valves.
- E. Absorbent solution and refrigerant shall have separate and dedicated pumps.
 - 1. Absorbent solution and refrigerant flow-control method shall be manufacturer's choice to comply with operating requirements indicated.
- F. Purge System: Unit mounted and factory wired, equipped with controls and a pump to automatically remove noncondensable vapors.
 - 1. Purge Pump Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: **[Open dripproof] [or] [totally enclosed]**.

2.4 HEAT-EXCHANGER SHELLS

- A. Configuration: Two shells; one shell consists of the absorber/evaporator, low-stage generator/condenser and the other shell consists of the high-stage generator. Where indicated, equip chiller with a dedicated hot-water heat exchanger.
- B. Construction: Fabricated from continuously welded carbon-steel sheet or plate, or from seamless pipe.
- C. Design Pressure and Temperature Rating: Comply with applicable requirements in ASME Boiler and Pressure Vessel Code.
- D. End Tube Sheets: Carbon-steel plates continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.
- E. Intermediate Tube Sheets: Carbon-steel plates installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid tube contact resulting in abrasion and wear.
- F. Generator/Condenser Shell Pressure Relief Device: Manufacturer's standard rupture disk complying with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code.

2.5 ABSORBER

- A. Nozzle or Dispersion Trays: Designed to evenly distribute absorbent solution over tubes; constructed of brass, stainless steel, or another material that will not corrode.
- B. Tubes:
 - 1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.

2. Material: [**Copper**] [**or**] [**copper-nickel alloy**] <Insert material>.
3. Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] <Insert dimension>.
4. External Finish: Manufacturer's standard.
5. Internal Finish: [**Enhanced**] [**or**] [**smooth**].

C. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. [**Standard**] [**Marine-type**] water box with piping connections.
 - a. Water boxes [**and marine-type water-box covers**] shall have lifting lugs or eyebolts.
 - b. [**Hinged**] [**or**] [**davited**] water boxes.
 - c. [**Hinged**] [**or**] [**davited**] marine-type water-box covers.
3. Standard water box without piping connections.
 - a. Water boxes shall have lifting lugs or eyebolts.
 - b. [**Hinged**] [**or**] [**davited**] water boxes.
4. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with [**3/4-inch (19-mm)**] [**or**] [**1-inch (25-mm)**] <Insert dimension> drain connection at low point and vent connection at high point, each with threaded plug.

D. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

E. Absorber/Condenser Crossover Piping: Factory-furnished and -installed piping connecting fluid connection of absorber discharge to condenser inlet.

2.6 EVAPORATOR

- A. Nozzle or Dispersion Trays: Designed to evenly distribute refrigerant over tubes; constructed of brass, stainless steel, or another material that will not corrode.
- B. Refrigerant Holding Pan: Steel or stainless steel.
- C. Tubes:

1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
2. Material: **[Copper]** **[or]** **[copper-nickel alloy]** **<Insert material>**.
3. Minimum Wall Thickness: **[Manufacturer's choice]** **[0.025 inch (0.6 mm)]** **[0.028 inch (0.7 mm)]** **[0.035 inch (0.9 mm)]** **<Insert dimension>**.
4. External Finish: Manufacturer's standard.
5. Internal Finish: **[Enhanced]** **[or]** **[smooth]**.

D. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. **[Standard]** **[Marine-type]** water box with piping connections.
 - a. Water boxes **[and marine-type water-box covers]** shall have lifting lugs or eyebolts.
 - b. **[Hinged]** **[or]** **[davitd]** water boxes.
 - c. **[Hinged]** **[or]** **[davitd]** marine-type water-box covers.
3. Standard water box without piping connections.
 - a. Water boxes shall have lifting lugs or eyebolts.
 - b. **[Hinged]** **[or]** **[davitd]** water boxes.
4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange]** **[Welded, ASME B16.5, raised-face flange]** **[Grooved for mechanical-joint coupling]** **[Grooved with mechanical-joint coupling and flange adapter]**.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with **[3/4-inch (19-mm)]** **[or]** **[1-inch (25-mm)]** **<Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.

2.7 CONDENSER

A. Refrigerant Holding Pan: Steel or stainless steel.

B. Tubes:

1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
2. Material: **[Copper]** **[or]** **[copper-nickel alloy]** **<Insert material>**.
3. Minimum Wall Thickness: **[Manufacturer's choice]** **[0.025 inch (0.6 mm)]** **[0.028 inch (0.7 mm)]** **[0.035 inch (0.9 mm)]** **<Insert dimension>**.
4. External Finish: Manufacturer's standard.
5. Internal Finish: **[Enhanced]** **[or]** **[smooth]**.

C. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.

2. **[Standard] [Marine-type]** water box with piping connections.
 - a. Water boxes **[and marine-type water-box covers]** shall have lifting lugs or eyebolts.
 - b. **[Hinged] [or] [davited]** water boxes.
 - c. **[Hinged] [or] [davited]** marine-type water-box covers.
 3. Standard water box without piping connections.
 - a. Water boxes shall have lifting lugs or eyebolts.
 - b. **[Hinged] [or] [davited]** water boxes.
 4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange] [Welded, ASME B16.5, raised-face flange] [Grooved for mechanical-joint coupling] [Grooved with mechanical-joint coupling and flange adapter]**.
 5. Thermistor or RTD temperature sensor factory installed in each nozzle.
 6. Fit each water box with **[3/4-inch (19-mm)] [or] [1-inch (25-mm)] <Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.
- D. Additional Corrosion Protection:
1. Electrolytic corrosion-inhibitor anode.
 2. Coat wetted surfaces with a corrosion-resistant finish.
 3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.8 FIRST-STAGE GENERATOR

A. Tubes:

1. **[Replaceable,]**straight, or U tubes expanded into tube sheets.
2. Material: **[Manufacturer's standard] [steel] <Insert material>**.
3. Minimum Wall Thickness: **[Manufacturer's choice] <Insert dimension>**.
4. External Finish: Manufacturer's standard.
5. Internal Finish: Manufacturer's choice; enhanced or smooth.

B. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard water box.
3. Water boxes shall have lifting lugs or eyebolts.
4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange] [Welded, ASME B16.5, raised-face flange] [Grooved for mechanical-joint coupling] [Grooved with mechanical-joint coupling and flange adapter]**.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.

6. Fit each water box with [3/4-inch (19-mm)] [or] [1-inch (25-mm)] <Insert dimension> drain connection at low point and vent connection at high point, each with threaded plug.

2.9 SECOND-STAGE GENERATOR

A. Tubes:

1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
2. Material: [**Copper**] [or] [**copper-nickel alloy**] <Insert material>.
3. Minimum Wall Thickness: [**Manufacturer's choice**] [0.025 inch (0.6 mm)] [0.028 inch (0.7 mm)] [0.035 inch (0.9 mm)] <Insert dimension>.
4. External Finish: Manufacturer's standard.
5. Internal Finish: Manufacturer's standard.

B. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard type.
3. Water boxes shall have lifting lugs or eyebolts.
4. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with [3/4-inch (19-mm)] [or] [1-inch (25-mm)] <Insert dimension> drain connection at low point and vent connection at high point, each with threaded plug.

2.10 DEDICATED HOT-WATER HEAT EXCHANGER

A. Tubes:

1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
2. Material: [**Copper**] [or] [**copper-nickel alloy**] <Insert material>.
3. Minimum Wall Thickness: [**Manufacturer's choice**] [0.025 inch (0.6 mm)] [0.028 inch (0.7 mm)] [0.035 inch (0.9 mm)] <Insert dimension>.
4. External Finish: Manufacturer's standard.
5. Internal Finish: Manufacturer's standard.

B. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard type.
3. Water boxes shall have lifting lugs or eyebolts.

4. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with [**3/4-inch (19-mm)**] [**or**] [**1-inch (25-mm)**] <Insert dimension> drain connection at low point and vent connection at high point, each with threaded plug.

2.11 SOLUTION HEAT EXCHANGER

- A. Description: Shell-and-tube or brazed-plate heat exchanger, an integral part of chiller, increases cycle efficiency by preheating the weak solution on its way to the generator while precooling the strong solution returning from the generator.

2.12 BURNER ASSEMBLY

- A. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser suitable for [**natural gas**] [**propane**] [**and**] [**fuel oil**]. [**Mount burner on hinged access door to permit access to combustion chamber.**]
- B. Blower: Centrifugal fan integral to burner, directly driven by motor; with adjustable damper assembly and locking quadrant to set air-fuel ratio.
 1. Motors: Comply with requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- C. Oil Supply: Control devices and modulating control sequence shall comply with requirements of [**ASME CSD-1**] [**FMG**] [**IRI**] [**UL**].
 1. Oil Pump: Two-stage, gear-type oil pump shall be capable of producing **300-psig (2070-kPa)** discharge pressure and **15-in. Hg (50.7-kPa)** vacuum.
 2. Oil Piping Specialties:
 - a. Suction-line, manual, gate valve.
 - b. Removable-mesh oil strainer.
 - c. **0- to 30-in. Hg (0- to 101.3-kPa)** vacuum; **0- to 30-psig (0- to 207-kPa)** vacuum-pressure gage.
 - d. **0- to 300-psig (0- to 2070-kPa)** oil-nozzle pressure gage.
 - e. Nozzle-line, solenoid-safety-shutoff oil valve.
- D. Oil Pilot: [**Intermittent**] [**Interrupted**]-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with [**cadmium sulfide**] [**UV scanner**] flame-safety control.

- E. Gas Train: Control devices and modulating control sequence shall comply with requirements of **[ASME CSD-1] [FMG] [IRI] [UL]**.
- F. Gas Pilot: **[Intermittent] [Interrupted]**-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
- G. Burner assembly shall be equipped to limit nitrogen oxide emissions to **[20] [30]** **<Insert value>** ppm.

2.13 ELECTRICAL

- A. Factory installed and wired, and functionally tested at factory before shipment.
- B. Single-point, field-power connection to **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[42,000] [65,000]** **<Insert value>** A.
 - 1. Branch power circuit to each motor, dedicated electrical load, and to controls **[with disconnect switch or circuit breaker]**.
 - a. NEMA KS 1, heavy-duty fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
 - 2. NEMA ICS 2, Class A, full-voltage, nonreversing motor controller, hand-off-auto switch, and overcurrent protection for each motor.
 - 3. Control-circuit transformer with primary and secondary side fuses.
- C. Terminal blocks with numbered **[and color-coded]** wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
- D. Wiring Outside of Enclosures: Factory installed in metal raceway except make terminal connections with not more than a **24-inch (610-mm)** length of **[liquidtight] [or] [flexible metallic]** conduit.

2.14 CONTROLS

- A. Chiller control panel shall be separate from burner control panel.
- B. Burner Control Panel: Factory **[or field]** mounted. Maintains safe operating conditions, burner safety limits, burner operation, and interface with chiller controls; include the following components:
 - 1. On-off switch.
 - 2. Flame safeguard.
 - 3. Contacts for remote monitoring of flame failure.

4. Contacts for proof of combustion air.
 5. Exhaust gas temperature limit switch.
 6. Control-circuit transformer.
 7. Burner motor controls.
 8. Fuel-oil pump controls, if chiller is equipped with fuel-oil pump.
 9. Visual indication of on/off status of ignition, blower, and main fuel.
 10. Alarm bell.
- C. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
- D. Enclosure: Unit mounted, NEMA 250, **[Type 1] [Type 4] [Type 4x] <Insert type>**, hinged or lockable.
- E. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. Display the following information in either imperial or metric units selectable through the interface:
1. Date and time.
 2. Operating or alarm status.
 3. Operating hours.
 4. Outdoor-air temperature if required for chilled-water reset.
 5. Temperature and pressure of operating set points.
 6. Entering and leaving temperatures of chilled and condenser water.
 7. Refrigerant temperature.
 8. Solution concentration and temperature.
 9. Indication of solution and purge-pump operation.
 10. Generator shell pressure.
 11. Number of starts.
 12. Number of purge cycles.
 13. Entering and leaving hot-water temperatures.
 14. Burner firing rate displayed in percent.
 15. **<Insert status display items>**.
- F. Control Functions:
1. Manual or automatic startup and shutdown time schedule.
 2. Automatic cycle to prevent crystallization.
 3. Entering and leaving chilled-water temperatures and control set points. Chilled-water temperature shall be reset based on **[return-water] [outdoor-air] [space] <Insert condition>** temperature.
 4. Entering and leaving hot-water temperatures and control set points. Hot-water temperature shall be reset based on **[return-water] [outdoor-air] [space] <Insert condition>** temperature.
 5. Condenser-fluid temperature.
 6. Cooling provided and heating energy used within programmable time periods, minimum monthly.
 7. Heating provided and heating energy used within programmable time periods, minimum monthly.

8. **<Insert control functions>**.
- G. Capacity Control: Automatically controls burner firing rate to maintain chilled-water temperature set point for cooling loads and heating-water temperature set point for heating loads ranging from [30] **<Insert number>** to 100 percent.
- H. Safety Shutdowns: Chiller shall automatically shut down and require manual restart. Display a message following each safety shutdown.
1. Crystallization.
 2. Low refrigerant temperature.
 3. Loss of chilled- or condenser-water flow.
 4. Low leaving chilled-water temperature[, 2 deg F (1 deg C) **below set point**] **<Insert condition>**.
 5. First-stage generator low-solution level.
 6. First-stage generator high temperature or pressure.
 7. Burner alarm or control malfunction.
 8. Power failure.
 9. Solution pump overloads.
 10. External auxiliary safety shutdown.
 11. High solution concentration.
 12. Incomplete dilution cycle.
 13. **<Insert conditions>**.
- I. Warning Conditions: Chiller shall remain operational but inhibit burner firing rate to prevent safety shutdown. Control panel shall close warning contacts and generate a message when one of the following operating conditions is detected:
1. Low refrigerant temperature.
 2. High generator temperature or pressure.
 3. High or low entering condenser-water temperature.
 4. Solution temperature sensor failure.
 5. Low chilled-water flow.
 6. Purge-pump current overload.
 7. **<Insert warning conditions>**.
- J. Cycling Shutdowns: Permit automatic restart when preprogrammed limits are reached. Display a message following each cycle shutdown.
1. Cooling Mode:
 - a. Loss of condenser-water flow.
 - b. Low leaving chilled-water temperature.
 - c. Power failure.
 - d. **<Insert conditions>**.
 2. Heating Mode:
 - a. Loss of hot-water flow.
 - b. High leaving hot-water temperature.

- c. Power failure.
 - d. **<Insert conditions>**.
- K. Trending: Capability to trend analog data up to five parameters simultaneously over an adjustable period and frequency of polling.
- L. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
- M. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
- N. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer **[and a notebook computer]**.
- O. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
- 1. Hardwired Points:
 - a. Monitoring: On-off status, **[common trouble alarm] <Insert monitoring point>**.
 - b. Control: On-off operation, **[chilled-water, discharge temperature set-point adjustment] [hot-water, discharge temperature set-point adjustment] <Insert control point>**.
 - 2. **[ASHRAE 135 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol] <Insert type of interface>** communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.
- 2.15 FINISH
- A. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
- 1. Provide at least one coat of primer with a total dry film thickness of at least **2 mils (0.05 mm)**.
 - 2. Provide at least two coats of **[alkyd-modified, vinyl enamel] [epoxy] [polyurethane]** finish with a total dry film thickness of at least **4 mils (0.10 mm)**.
 - 3. Paint surfaces that are to be insulated before applying the insulation.
 - 4. Paint installed insulation to match adjacent uninsulated surfaces.
 - 5. Color of finish coat to be **[manufacturer's standard] [custom color selected by DEN Project Manager] <Insert color description>**.

2.16 ACCESSORIES

- A. Sight Glasses: Equip unit with sight glasses for visual inspection of absorbent solution and refrigerant levels. Provide at least one sight glass in absorber and evaporator sections.
- B. Flow Switches:
1. Chiller manufacturer shall furnish a switch for each [**condenser**] [**evaporator and condenser**] and shall verify field-mounting location before installation.
 2. Paddle Flow Switches:
 - a. Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
 - b. Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
 - c. Pressure rating equal to pressure rating of heat exchanger.
 - d. Construct body and wetted parts of Type 316 stainless steel.
 - e. House switch in an NEMA 250, [**Type 4**] <Insert type> enclosure constructed of die-cast aluminum.
 - f. Vane length to suit installation.
 3. Pressure Differential Switches:
 - a. Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
 - b. Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set point shift due to variation in working pressure.
 - c. Set Point: Screw type, field adjustable.
 - d. Electrical Connections: Internally mounted, screw-type terminal blocks.
 - e. Switch Enclosure: NEMA 250, [**Type 4**] <Insert type>.
 - f. Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
- C. Vibration Isolation:
1. Chiller manufacturer shall furnish neoprene-pad vibration isolation for each chiller.
 - a. Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
 - b. Fabricate pads from 40- to 50-durometer neoprene.
 - c. Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.

2.17 CAPACITIES AND CHARACTERISTICS

- A. Capacity: <Insert tons (kW)>.
- B. Full-Load Efficiency (COP): <Insert number>.
- C. Part-Load Efficiency [(IPLV)] [(NPLV)]: <Insert number>.
- D. Evaporator:
1. Pressure Rating: [150 psig (1035 kPa)] [300 psig (2070 kPa)] <Insert psig (kPa)>.
 2. Number of Passes: [Two] [Three] [Four].
 3. Fluid Type: [Water] <Insert fluid type>.
 4. Design Fluid Flow Rate: <Insert gpm (L/s)>.
 5. Minimum Fluid Flow Rate: <Insert gpm (L/s)>.
 6. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 7. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 8. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 9. Fluid Velocity: <Insert fps (m/s)>.
 10. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)]
[0.00025 sq. ft. x h x deg F/Btu (0.000045 sq. m x deg C/W)] [0.0005 sq. ft. x h x
deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.
- E. Absorber/Condenser:
1. Pressure Rating: [150 psig (1035 kPa)] [300 psig (2070 kPa)] <Insert psig (kPa)>.
 2. Number of Passes: [One] [Two] [Three].
 3. Fluid Type: [Water] <Insert fluid type>.
 4. Design Fluid Flow Rate: <Insert gpm (L/s)>.
 5. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 6. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 7. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 8. Fluid Velocity: <Insert fps (m/s)>.
 9. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000045 sq. m x deg C/W)]
[0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg
F/Btu (0.00022 sq. m x deg C/W)] <Insert value>.
- F. Dedicated Hot-Water Heat Exchanger:
1. Capacity: <Insert MBtu/h (kW)>.
 2. Pressure Rating: [150 psig (1035 kPa)] [300 psig (2070 kPa)] <Insert psig (kPa)>.
 3. Number of Passes: [One] [Two] [Three] [Four].
 4. Fluid Type: [Water] <Insert fluid type>.
 5. Design Fluid Flow Rate: <Insert gpm (L/s)>.
 6. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 7. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 8. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 9. Fluid Velocity: <Insert fps (m/s)>.

10. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)]
[0.00025 sq. ft. x h x deg F/Btu (0.000045 sq. m x deg C/W)] [0.0005 sq. ft. x h x
deg F/Btu (0.00011 sq. m x deg C/W)] **<Insert value>**.

G. Burner Blower:

1. Motor Horsepower: **<Insert value>**.
2. RPM: **<Insert value>**.

H. Pump Horsepower:

1. Purge: **<Insert value>**.
2. Refrigerant: **<Insert value>**.
3. Solution: **<Insert value>**.

I. Chiller Control Electrical Requirements:

1. Power Input: **<Insert kilowatts>**.
2. Minimum Circuit Ampacity: **<Insert value>**.
3. Maximum Overcurrent Protection Device: **<Insert amperage>**.
4. Characteristics: [120] **<Insert value>**-V ac, single phase, 60 Hz.

J. Chiller Electrical Requirements:

1. Power Input: **<Insert kilowatts>**.
2. Minimum Circuit Ampacity: **<Insert value>**.
3. Maximum Overcurrent Protection Device: **<Insert amperage>**.
4. Characteristics: [208] [240] [480] **<Insert value>**-V ac, three phase, 60 Hz.

K. Natural-Gas Heating Value: **<Insert Btu/cu. ft. (kJ/L)>**.

L. Gas Input: **<Insert cfh (mL/s)>**.

M. Fuel-Oil Heating Value: **<Insert Btu/gal. (MJ/L)>**.

N. Oil Input: **<Insert gph (mL/s)>**.

O. Noise Rating: [80] [85] **<Insert dBA>** sound power level when measured according to ARI 575. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.18 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

A. Furnish for field installation a brush-cleaning system on each chiller [condenser] **<Insert heat exchanger>** for tube cleaning and improved heat transfer.

B. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.

- C. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
- D. Components:
1. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed **0.025 inch** (0.6 mm).
 2. Basket: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
 3. Four-Way Valve:
 - a. Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
 - b. Configure valve with parallel flow connections to minimize field installation piping.
 - c. Construct valve to comply with ASME Boiler and Pressure Vessel Code , at a system working pressure equal to condenser.
 - d. Pipe connections shall be flanged.
 - e. Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
 - f. Hydrostatically test valve to 1.5 times the design working pressure.
 - g. Design the valve to cause no more than **0.5-psig** (3-kPa) pressure drop at design flow conditions.
 - h. Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.
 - i. Valve Actuator: Mount electric actuator to operate valve.
 - j. Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.
 - k. Position Switches: Factory mount microswitches on valve to indicate the complete turn of valve in both normal and reverse flow.
 4. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:
 - a. NEMA 250, **[Type 1]** **[Type 4]** **[Type 4x]** **[Type 12]** enclosure.
 - b. Timer to automatically initiate the cleaning cycle over a 24-hour period.
 - c. Manual override of preset cleaning cycle.
 - d. Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow or incomplete valve turn.
 - e. For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
 - f. Flow-switch bypass.

- g. Unloading signal to chiller.

2.19 SOURCE QUALITY CONTROL

- A. Perform functional **[run]** tests of chillers before shipping.
- B. Factory test and inspect absorber, generator, evaporator, and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test tube-side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Vacuum and pressure test shells for leaks.
- C. Rate sound power level according to ARI 575.
- D. Burner Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion requirements indicated.
- E. Factory performance test chillers, before shipping, according to ARI 560.
1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Reduction in capacity from design to minimum load in steps of **[10] [25] [33]** **<Insert number>** with condenser fluid at design conditions.
 - c. Reduction in capacity from design to minimum load in steps of **[10] [25] [33]** **<Insert number>** with varying entering condenser-fluid temperature from design to minimum conditions in **[5 deg F (3 deg C)] <Insert temperature>** increments.
 - d. At **[one] [two] [three] [four] [five] [10]** **<Insert number>** point(s) of varying part-load performance to be selected by Owner at time of test.
- F. Factory sound test chillers, before shipping, according to ARI 575.
1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Chiller operating at calculated worst-case sound condition.
 - c. At **[one] [two] [three] [four] [five]** **<Insert number>** point(s) of varying part-load performance to be selected by Owner at time of test.
- G. Allow **[Owner]** **<Insert entity>** access to place where chillers are being tested. Notify DEN Project Manager **[14]** **<Insert number>** days in advance of testing.
- H. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine chillers before installation. Reject chillers that are damaged.
- B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.
 - 1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install chillers on support structure indicated.
- C. Equipment Mounting:
 - 1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Maintain manufacturer's recommended clearances for service and maintenance.
- E. Charge chiller with absorbent and refrigerant if not factory charged.
- F. Install separate devices furnished by manufacturer and not factory installed.
- G. Insulate hot and cold chiller surfaces that are recommended by chiller manufacturer to be insulated. Comply with requirements in Section 230716 "HVAC Equipment Insulation."
- H. Install electrical devices furnished with chiller but not specified to be factory mounted.
- I. Install control wiring to field-mounted electrical devices.
- J. Provide connections to chilled water piping.

1. On inlet, provide:
 - a. Thermometer well for temperature controller.
 - b. Thermometer.
 - c. Strainer.
 - d. Flow switch.
 - e. Flexible pipe connector.
 - f. Pressure gage.
 - g. Shut-off valve.
2. On outlet, provide:
 - a. Thermometer.
 - b. Flexible pipe connector.
 - c. Pressure gage.
 - d. **[Shut-off] [Balancing]** valve.

3.3 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

- A. Install brush-cleaning system control panel adjacent to chiller control panel.
- B. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
- C. Provide field electric power, as required, to each system control panel and electric-actuated valve.
- D. Provide pneumatic piping with pressure regulator and an isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
- E. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
- F. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

3.4 CONNECTIONS

- A. Comply with requirements for hydronic piping in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements for gas piping in Section 231123 "Facility Natural-Gas Piping" or Section 231126 "Facility Liquefied-Petroleum Gas Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Connect gas piping full size to gas-train inlet with shutoff valve and union.

- D. Install gas-fired boilers according to NFPA 54.
- E. Comply with requirements for fuel-oil piping in Section 231113 "Facility Fuel-Oil Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- F. Connect oil piping full size to burner inlet with shutoff valve and union.
- G. Install oil-fired boilers according to NFPA 31.
- H. Install piping adjacent to chiller to allow service and maintenance.
- I. Hot-Water Heat-Exchanger Connections: Connect to heat-exchanger inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with shutoff valve and pressure gage. Connect to heat-exchanger outlet with shutoff valve, check valve, balancing valve,[**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**or**] [**mechanical coupling**].
- J. Evaporator-Fluid Connections: Connect to evaporator inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with shutoff valve and pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve,[**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**or**] [**mechanical coupling**].
- K. Absorber/Condenser-Fluid Connections: Connect to inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with shutoff valve and pressure gage. Connect to outlet with shutoff valve, balancing valve,[**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage,[**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**or**] [**mechanical coupling**].
 - 1. If not factory furnished or installed, provide pipe connecting fluid connection of absorber discharge and condenser inlet.
- L. Refrigerant Pressure Relief Device Connections: Extend [**vent piping**] [**separate vent piping for each chiller**] to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.
- M. Extend [**purge vent piping**] [**separate purge vent piping for each chiller**] to the outdoors. Comply with ASHRAE 15.
- N. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.
- O. Comply with requirements for chimney system in Section 235133 "Insulated Sectional Chimneys" and Section 235116 "Fabricated Breechings and Accessories." Drawings indicate general arrangement of pipe, fittings, and specialties. Connect chimney system to chiller burner outlet and extend to the outdoors.

- P. Connect fuel-fired burner assembly and blower and associated damper for combustion air.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service. Supply service of factory trained representative for a period of **<Insert number>** days to supervise testing, dehydration and charging of machine, start-up, and instruction on operation and maintenance.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Operate chiller for run-in period.
 3. Verify that absorbent and refrigerant charge is sufficient and chiller has been leak tested.
 4. Verify that pumps are installed and functional.
 5. Verify that thermometers and gages are installed.
 6. Operate chiller for run-in period.
 7. Verify that refrigerant pressure relief device is vented to the outdoors.
 8. Verify proper motor rotation.
 9. Verify proper fuel supply. Adjust air-fuel ratio and combustion.
 10. Verify proper combustion-air source.
 11. Verify proper exhaust emissions.
 12. Verify static deflection of vibration isolators including deflection during chiller startup and shutdown.
 13. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
 14. Verify and record performance of chiller protection devices.
 15. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
 16. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
- C. Prepare test and inspection startup reports.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain chillers. [**Video record the training sessions.**]
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236413.13

SECTION 236413.16 - INDIRECT-FIRED ABSORPTION WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, water-cooled, [~~single-~~] [~~and~~] [~~double-~~]effect absorption chillers.
 - 2. Heat-exchanger, brush-cleaning system.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- B. DDC: Direct digital control.
- C. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 560 and referenced to ARI standard rating conditions.
- D. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 560 and intended for operating conditions other than the ARI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Indirect-fired absorption chillers shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
- B. Condenser-Fluid Temperature Performance:

1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of [60 deg F (16 deg C)] [55 deg F (13 deg C)] [40 deg F (4.4 deg C)] <Insert temperature> and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
 2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of [65 deg F (18 deg C)] [60 deg F (16 deg C)] [55 deg F (13 deg C)].
 3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
- C. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
- D. Performance Tolerance: Comply with the following in lieu of ARI 560:
1. Allowable Capacity Tolerance: [Zero] <Insert number> percent.
 2. Allowable IPLV/NPLV Performance Tolerance: [Zero] <Insert number> percent.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Indicate valves, strainers, and thermostatic valves required for complete system. Include rated capacities, operating characteristics, furnished specialties and accessories.
1. Performance at ARI standard conditions and at conditions indicated.
 2. Performance at ARI standard unloading conditions.
 3. Minimum evaporator flow rate.
 4. Absorbent capacity of chiller.
 5. Refrigerant capacity of chiller.
 6. Fluid capacity of evaporator and condenser.
 7. Fluid capacity of generator.
 8. Characteristics of safety relief devices.
 9. Minimum entering condenser-fluid temperature.
 10. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in [5 deg F (3 deg C)] <Insert temperature> increments.
 11. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with ASHRAE 90.1.
 2. Product Data for Prerequisite EA 3: Documentation indicating that refrigerants comply.

3. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
- C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring Diagrams: For power, signal, and control wiring.
 3. Insulated Surface Diagrams: Indicating cold and hot surfaces requiring insulation with area tabulated for each.
 4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Structural supports.
 2. Piping roughing-in requirements.
 3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
- B. Certificates: For certification required in "Quality Assurance" Article.
- C. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
- E. Source quality-control reports.

- F. Startup service reports.
- G. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIALS

- A. Provide [**two (2)**] <Insert number> containers of [**lubricating oil**] [**refrigerant**].

1.9 QUALITY ASSURANCE

- A. ARI Rating: Rate chiller performance according to requirements in ARI 560.
- B. ASHRAE Compliance:
 - 1. ASHRAE 15 for safety code for mechanical refrigeration.
 - 2. ASHRAE/IESNA 90.1.
- C. ASME Compliance: Fabricate and label chiller pressure vessels to comply with applicable portions of ASME Boiler and Pressure Vessel Code.
- D. Comply with NFPA 70.
- E. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Ship chillers factory charged with nitrogen.
- B. Ship absorbent and refrigerant in chillers or in containers separate from chillers.
- C. Ship [**absorbent**] [**and**] [**refrigerant**] in containers separate from chillers.
- D. Package chiller for export shipping in totally enclosed [**bagging**] [**crate**] [**crate with bagging**].
- E. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.

- F. Protect units from physical damage.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

1. Extended warranties include, but are not limited to, the following:

- a. Complete chiller.
- b. **[Pumps and motors] [Purge unit] <Insert components>.**
- c. **[Absorbent] [Absorbent and refrigerant] only.**
- d. **Parts [only] [and labor].**
- e. Loss of absorbent and refrigerant for any reason.

- B. Warranty Period: Minimum **[two (2)] [three (3)] [four (4)] [five (5)] <Insert number>** years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. Carrier Corporation; a United Technologies company.
2. Trane; a division of American Standard.
3. YORK; a Johnson Controls company.
4. **<Insert manufacturer's name>.**
5. or approved equal.

2.2 MANUFACTURED UNIT

- A. Description: Factory-assembled and -tested, hermetic-design chiller complete with absorber, evaporator, condenser, generator, solution heat exchanger, controls, absorbent solution pump with motor, refrigerant pump with motor, purge unit with motor, motor controllers, rupture disk, interconnecting unit piping and wiring, indicated accessories, and mounting frame.
1. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
- B. Absorbent and Refrigerant:
1. Absorbent: Lithium bromide solution with corrosion inhibitor.
 2. Refrigerant: Deionized **[or distilled]**water.
 3. Performance Enhancer: Heat and mass transfer enhancer to improve performance.
- C. Seismic Fabrication Requirements: Fabricate mounting base and attachment to chiller, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

2.3 PUMPS

- A. Hermetically sealed, self-lubricating, and fitted with self-adjusting, spring-loaded, wear-compensating tapered carbon bearings.
- B. Pump motor assembly shall be designed to operate for not less than **[25,000] [50,000]** hours between inspections.
- C. Pump motors cooled, and bearings lubricated, either by fluid being pumped or by a filtered supply of liquid refrigerant.
- D. Pump suction and discharge equipped with isolation valves.
- E. Separate and dedicated pumps for absorbent solution and refrigerant.
1. Absorbent solution and refrigerant flow-control method shall be manufacturer's choice to comply with operating requirements indicated.
- F. Purge System: Unit mounted and factory wired, equipped with controls and a pump to automatically remove noncondensable vapors.
1. Purge Pump Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Enclosure: **[Open dripproof] [Totally enclosed] [Open dripproof or totally enclosed]**.

2.4 HEAT-EXCHANGER Shells

- A. Configuration for Single-Effect Chillers: Two shells; one shell consists of the absorber/evaporator and the other shell consists of the condenser/generator.
- B. Configuration for Double-Effect Chillers: Two shells; one shell consists of the absorber/evaporator, low-stage generator/condenser and the other shell consists of the high-stage generator.
- C. Construction: Fabricated from continuously welded carbon-steel sheet or plate, or from seamless pipe.
- D. Design Pressure and Temperature Rating: Comply with applicable requirements in ASME Boiler and Pressure Vessel Code.
- E. End Tube Sheets: Carbon-steel plates continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
- F. Intermediate Tube Sheets: Carbon-steel plates installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
- G. Generator/Condenser Shell Pressure Relief Device: Manufacturers standard rupture disk complying with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

2.5 ABSORBER

- A. Nozzle or Dispersion Trays: Designed to evenly distribute absorbent solution over tubes. Constructed of brass, stainless steel, or another material that will not corrode.
- B. Tubes:
 - 1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
 - 2. Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <Insert material>.
 - 3. Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] <Insert dimension>.
 - 4. External Finish: Manufacturer's standard.
 - 5. Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].
- C. Water Boxes:
 - 1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 - 2. [**Standard**] [**Marine**] type for water box with piping connections.

- a. Water boxes [**and marine water-box covers**] shall have lifting lugs or eyebolts.
 - b. [**Hinged**] [**or**] [**davited**] water boxes.
 - c. [**Hinged**] [**or**] [**davited**] marine water-box covers.
3. Standard type for water box without piping connections.
- a. Water boxes shall have lifting lugs or eyebolts.
 - b. [**Hinged**] [**or**] [**davited**] water boxes.
 - c. [**Hinged**] [**or**] [**davited**] marine water-box covers.
4. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with [**3/4-inch (19-mm)**] [**1-inch (25-mm)**] [**3/4- or 1-inch (19- or 25-mm)**] **<Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.

D. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

E. Absorber/Condenser Crossover Piping: Factory [**furnished**] [**installed**] piping connecting fluid connection of absorber discharge to condenser inlet.

2.6 EVAPORATOR

- A. Nozzle or Dispersion Trays: Designed to evenly distribute refrigerant over tubes. Constructed of brass, stainless steel, or another material that will not corrode.
- B. Refrigerant Holding Pan: [**Steel**] [**Stainless steel**] [**Steel or stainless steel**].
- C. Tubes:
1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
 2. Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] **<Insert material>**.
 3. Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] **<Insert dimension>**.
 4. External Finish: Manufacturer's standard.
 5. Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].
- D. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. **[Standard] [Marine]** type for water box with piping connections.
 - a. Water boxes **[and marine water-box covers]** shall have lifting lugs or eyebolts.
 - b. **[Hinged] [or] [davited]** water boxes.
 - c. **[Hinged] [or] [davited]** marine water-box covers.
3. Standard type for water box without piping connections.
 - a. Water boxes shall have lifting lugs or eyebolts.
 - b. **[Hinged] [or] [davited]** water boxes.
 - c. **[Hinged] [or] [davited]** marine water-box covers.
4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange] [Welded, ASME B16.5, raised-face flange] [Grooved for mechanical-joint coupling] [Grooved with mechanical-joint coupling and flange adapter]**.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with **[3/4-inch (19-mm)] [1-inch (25-mm)] [3/4- or 1-inch (19- or 25-mm)]** **<Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.

2.7 CONDENSER

- A. Refrigerant Holding Pan: **[Steel] [Stainless steel] [Steel or stainless steel]**.
- B. Tubes:
 1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
 2. Material: **[Copper] [Copper-nickel alloy] [Stainless steel] [Titanium] [Copper, copper-nickel alloy, stainless steel, or titanium]** **<Insert material>**.
 3. Minimum Wall Thickness: **[Manufacturer's choice] [0.025 inch (0.6 mm)] [0.028 inch (0.7 mm)] [0.035 inch (0.9 mm)]** **<Insert dimension>**.
 4. External Finish: Manufacturer's standard.
 5. Internal Finish: **[Enhanced] [Smooth] [Enhanced or smooth]**.
- C. Water Boxes:
 1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 2. **[Standard] [Marine]** type for water box with piping connections.
 - a. Water boxes **[and marine water-box covers]** shall have lifting lugs or eyebolts.
 - b. **[Hinged] [or] [davited]** water boxes.
 - c. **[Hinged] [or] [davited]** marine water-box covers.
 3. Standard type for water box without piping connections.

- a. Water boxes shall have lifting lugs or eyebolts.
 - b. **[Hinged]** **[or]** **[davitd]** water boxes.
 - c. **[Hinged]** **[or]** **[davitd]** marine water-box covers.
4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange]** **[Welded, ASME B16.5, raised-face flange]** **[Grooved for mechanical-joint coupling]** **[Grooved with mechanical-joint coupling and flange adapter]**.
 5. Thermistor or RTD temperature sensor factory installed in each nozzle.
 6. Fit each water box with **[3/4-inch (19-mm)]** **[1-inch (25-mm)]** **[3/4- or 1-inch (19- or 25-mm)]** **<Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.

D. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.8 GENERATOR FOR SINGLE-EFFECT CHILLERS

A. Tubes:

1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
2. Material: **[06/11 copper-nickel alloy]** **[Stainless steel]** **[Titanium]** **[06/11 copper-nickel alloy, stainless steel, or titanium]** **<Insert material>**.
3. Minimum Wall Thickness: **[Manufacturer's choice]** **[0.035 inch (0.9 mm)]** **<Insert dimension>**.
4. External Finish: Manufacturer's standard.
5. Internal Finish: **[Smooth]** **[Enhanced or smooth]**.

B. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard type water box.
3. Water boxes shall have lifting lugs or eyebolts.
4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange]** **[Welded, ASME B16.5, raised-face flange]** **[Grooved for mechanical-joint coupling]** **[Grooved with mechanical-joint coupling and flange adapter]**.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with **[3/4-inch (19-mm)]** **[1-inch (25-mm)]** **[3/4- or 1-inch (19- or 25-mm)]** **<Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.

C. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.9 FIRST-STAGE GENERATOR FOR DOUBLE-EFFECT CHILLERS

A. Tubes:

1. Replaceable, straight, or U tubes expanded into tube sheets.
2. Material: **[Manufacturer's standard] [06/11 copper-nickel alloy] [Type 409 stainless steel] [Titanium] [06/11 copper-nickel alloy, Type 409 stainless steel] <Insert material>**.
3. Minimum Wall Thickness: **[Manufacturer's choice] [0.028 inch (0.7 mm)] [0.035 inch (0.9 mm)] <Insert dimension>**.
4. External Finish: Manufacturer's standard.
5. Internal Finish: **[Smooth] [Enhanced or smooth]**.

B. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard type water box.
3. Water boxes shall have lifting lugs or eyebolts.
4. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange] [Welded, ASME B16.5, raised-face flange] [Grooved for mechanical-joint coupling] [Grooved with mechanical-joint coupling and flange adapter]**.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with **[3/4-inch (19-mm)] [1-inch (25-mm)] [3/4- or 1-inch (19- or 25-mm)] <Insert dimension>** drain connection at low point and vent connection at high point, each with threaded plug.

C. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.10 SECOND-STAGE GENERATOR FOR DOUBLE-EFFECT CHILLERS

A. Tubes:

1. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.

2. Material: [**Copper**] [**Copper-nickel alloy**] [**Copper or copper-nickel alloy**] [**Stainless steel**] [**Titanium**] <Insert material>.
3. Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] <Insert dimension>.
4. External Finish: Manufacturer's standard.
5. Internal Finish: [**Smooth**] [**Enhanced or smooth**].

B. Water Boxes:

1. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard type water box.
3. Water boxes shall have lifting lugs or eyebolts.
4. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
5. Thermistor or RTD temperature sensor factory installed in each nozzle.
6. Fit each water box with [**3/4-inch (19-mm)**] [**1-inch (25-mm)**] [**3/4- or 1-inch (19- or 25-mm)**] <Insert dimension> drain connection at low point and vent connection at high point, each with threaded plug.

C. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.11 SOLUTION HEAT EXCHANGER

- A. Description: Shell-and-tube or brazed-plate heat exchanger; integral part of chiller to increase cycle efficiency by preheating the weak solution on its way to the generator while precooling the strong solution returning from the generator.

2.12 STEAM CONDENSATE DRAIN COOLER

- A. Description: Shell-and-tube heat exchanger constructed of carbon-steel shell and copper-nickel-alloy or stainless-steel tubes.

2.13 FACTORY-APPLIED INSULATION

- A. Factory-Applied Insulation on Cold Surfaces:

1. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C 534, Type I for tube and Type II for sheet materials.
 - a. Thickness: [**3/4 inch (19 mm)**] [**1-1/2 inches (38 mm)**] <Insert dimension>.

2. Adhesive: As recommended by insulation manufacturer.
3. Factory apply insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets; evaporator water boxes including nozzles; refrigerant pump; cold surfaces of motor; and cold piping.
 - a. Apply adhesive to 100 percent of insulation contact surface.
 - b. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
 - c. Seal seams and joints to provide a vapor barrier.
 - d. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

B. Factory-Applied Insulation on Hot Surfaces:

1. Mineral-fiber board, pipe or tank insulation complying with one of following:
 - a. ASTM C 547, Type I or Type II, Grade A.
 - b. ASTM C 612, Type IB.
 - c. ASTM C 1393, Type II or Type IIIA, Category 2.
 - d. Thickness: [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension>.
2. Adhesive: As recommended by insulation manufacturer.
3. Factory apply materials over all hot surfaces to provide smooth, straight, and even surfaces; free of voids.
 - a. Apply adhesive to insulation contact surface as recommended by insulation manufacturer.
 - b. Install insulation anchor pins and washers if required by insulation manufacturer to secure insulation to surfaces to be insulated.
 - c. Completely encapsulate insulation with metal jacket, leaving no exposed insulation. Provide removable jacket on components requiring access for service and inspection.
 - d. Paint exposed surfaces of metal jacket to match other painted parts unless jacket material is aluminum or stainless steel.

2.14 ELECTRICAL

- A. Factory installed and wired, and functionally tested at factory before shipment.
- B. Single-point, field-power connection to [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**]. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <Insert value> A.
 1. Branch power circuit to each motor, dedicated electrical load, and controls[**with disconnect switch or circuit breaker**].

- a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
2. NEMA ICS 2, Class A, full-voltage, nonreversing motor controller, hand-off-auto switch, and overcurrent protection for each motor.
 3. Control-circuit transformer with primary and secondary side fuses.
- C. Terminal blocks with numbered [**and color-coded**] wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
- D. Wiring Outside of Enclosures: Factory installed in metal raceway except make terminal connections with not more than a **24-inch** (610-mm) length of [**liquidtight**] [**or**] [**flexible metallic**] conduit.

2.15 CONTROLS

- A. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
- B. Enclosure: Unit mounted, NEMA 250, [**Type 1**] [**Type 4**] [**Type 4x**] **<Insert type>**, hinged or lockable.
- C. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:
1. Date and time.
 2. Operating or alarm status.
 3. Operating hours.
 4. Outdoor-air temperature if required for chilled-water reset.
 5. Temperature and pressure of operating set points.
 6. Entering and leaving temperatures of chilled and condenser water.
 7. Refrigerant temperature.
 8. Solution concentration and temperature.
 9. Indication of solution and purge-pump operation.
 10. Generator shell pressure.
 11. Number of starts.
 12. Number of purge cycles.
 13. Hot-water valve actuator potentiometer position (percentage).
 14. Entering and leaving hot-water temperatures.
 15. Steam demand limit.
 16. Inlet steam pressure and temperature.
 17. Steam valve actuator potentiometer position (percentage).
 18. First-stage generator pressure and temperature.
 19. **<Insert status display items>**.

D. Control Functions:

1. Manual or automatic startup and shutdown time schedule.
2. Automatic cycle to prevent crystallization.
3. Entering and leaving chilled-water temperatures and control set points.
Chilled-water temperature shall be reset based on [return-water] [outdoor-air] [space] temperature.
4. Condenser-fluid temperature.
5. Cooling provided and heating energy used within programmable time periods, minimum monthly.
6. <Insert control functions>.

E. Capacity Control: Automatically controls input flow rate of heat source to maintain chilled-water temperature set point for cooling loads ranging from 10 to 100 percent.

F. Control Valve Package: [Factory-furnished, for field installation,] [Factory-installed] control valve package suitable for energy source indicated.

1. Body: Cast-iron, carbon-steel, or stainless-steel body with flanged connections.
2. Type: [Manufacturer's choice] [V-notch ball] [Butterfly] [Globe style with cage-guide plug] <Insert type> constructed of stainless steel.
3. Rating: Pressure and temperature rating to match heat exchanger.
4. Shutoff: Capable of bubble-tight shutoff against maximum system pressure.
5. Size: Determined by chiller manufacturer.
6. Modulation: [Two] [Three]-way.
7. Turndown: As required to achieve stable control through the indicated operating range.
8. Actuator: Electric powered from chiller control panel and installed on valve.

G. Safety Shutdowns:

1. Crystallization.
2. Low refrigerant temperature.
3. Loss of chilled- or condenser-water flow.
4. Low leaving chilled-water temperature[, 2 deg F (1 deg C) below set point].
5. First-stage generator low-solution level.
6. First-stage generator high temperature or pressure.
7. Power failure.
8. Solution pump overloads.
9. External auxiliary safety shutdown.
10. High solution concentration.
11. Incomplete dilution cycle.
12. High entering-water temperature.
13. High inlet steam pressure and temperature.
14. <Insert conditions>.

H. Warning Conditions: Control panel shall close warning contacts and generate a message when one of the following operating conditions is detected:

1. Low refrigerant temperature.

2. High generator temperature or pressure.
 3. High entering generator-water temperature (single-stage generator only).
 4. High or low entering condenser-water temperature.
 5. Solution temperature sensor failure.
 6. Low chilled-water flow.
 7. **<Insert warning conditions>**.
- I. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
- J. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
- K. Control Authority:
1. At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
- L. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer **and a notebook computer**.
- M. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display chiller status and alarms.
1. Hardwired Points:
 - a. Monitoring: On-off status, **[common trouble alarm] <Insert monitoring point>**.
 - b. Control: On-off operation, **[chilled-water, discharge temperature set-point adjustment] [generator heat source capacity limiting] <Insert control point>**.
 2. **[ASHRAE 135 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol] <Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the DDC system for HVAC.
- 2.16 FINISH
- A. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
1. Provide at least one coat of primer with a total dry film thickness of at least **2 mils (0.05 mm)**.
 2. Provide at least two coats of **[alkyd-modified, vinyl enamel] [epoxy] [polyurethane]** finish with a total dry film thickness of at least **4 mils (0.10 mm)**.

3. Paint surfaces that are to be insulated before applying the insulation.
4. Paint installed insulation to match adjacent uninsulated surfaces.
5. Color of finish coat to be **[manufacturer's standard] [custom color selected by DEN Project Manager] <Insert color description>**.

- B. Provide Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.

2.17 ACCESSORIES

- A. Sight Glasses: Equip unit with sight glasses for visual inspection of absorbent solution and refrigerant levels. Provide at least one sight glass in absorber and evaporator sections.

- B. Flow Switches:

1. Chiller manufacturer shall furnish a switch for each **[condenser] [evaporator and condenser]** and verify field-mounting location before installation.

2. Paddle Flow Switches:

- a. Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.
- b. Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
- c. Pressure rating equal to pressure rating of heat exchanger.
- d. Construct body and wetted parts of Type 316 stainless steel.
- e. House switch in a NEMA 250, **[Type 4] <Insert type>** enclosure constructed of die-cast aluminum.
- f. Vane length to suit installation.

3. Pressure Differential Switches:

- a. Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
- b. Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
- c. Set Point: Screw type, field adjustable.
- d. Electrical Connections: Internally mounted screw-type terminal blocks.
- e. Switch Enclosure: NEMA 250, **[Type 4] <Insert type>**.
- f. Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

- C. Vibration Isolation:

1. Chiller manufacturer shall furnish neoprene-pad vibration isolation for each chiller.

- a. Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
- b. Fabricate pads from 40- to 50-durometer neoprene.
- c. Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.

D. Lithium Bromide Filter:

1. Factory install a filter, isolation valves, and associated piping.
2. Filter shall consist of a stainless-steel body, with removable and cleanable 150-micron, stainless-steel element.
3. Isolation valves shall provide isolation for filter servicing without disturbing operation of chiller.

2.18 CAPACITIES AND CHARACTERISTICS

A. Capacity: <Insert tons (kW)>.

B. Full-Load Efficiency (COP): <Insert number>.

C. Part-Load Efficiency [(IPLV)] [(NPLV)]: <Insert number>.

D. Evaporator:

1. Pressure Rating: [150 psig (1035 kPa)] [300 psig (2070 kPa)] <Insert psig (kPa)>.
2. Number of Passes: [One] [Two] [Three] <Insert number>.
3. Fluid Type: [Water] <Insert fluid type>.
4. Design Fluid Flow Rate: <Insert gpm (L/s)>.
5. Minimum Fluid Flow Rate: <Insert gpm (L/s)>.
6. Entering-Fluid Temperature: <Insert deg F (deg C)>.
7. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
8. Fluid Pressure Drop: <Insert feet of head (kPa)>.
9. Fluid Velocity: <Insert fps (m/s)>.
10. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000045 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.

E. Absorber/Condenser:

1. Pressure Rating: [150 psig (1035 kPa)] [300 psig (2070 kPa)] <Insert psig (kPa)>.
2. Number of Passes: [One] [Two] [Three].
3. Fluid Type: [Water] <Insert fluid type>.
4. Design Fluid Flow Rate: <Insert gpm (L/s)>.
5. Entering-Fluid Temperature: <Insert deg F (deg C)>.
6. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
7. Fluid Pressure Drop: <Insert feet of head (kPa)>.
8. Fluid Velocity: <Insert fps (m/s)>.

9. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000045 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg F/Btu (0.00022 sq. m x deg C/W)] <Insert value>.

F. Hot-Water Generator:

1. Capacity: <Insert MBtu/h (kW)>.
2. Pressure Rating: [150 psig (1035 kPa)] [300 psig (2070 kPa)] <Insert psig (kPa)>.
3. Number of Passes: [One] [Two] [Three].
4. Fluid Type: [Water] <Insert fluid type>.
5. Design Fluid Flow Rate: <Insert gpm (L/s)>.
6. Entering-Fluid Temperature: <Insert deg F (deg C)>.
7. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
8. Fluid Pressure Drop: <Insert feet of head (kPa)>.
9. Fluid Velocity: <Insert fps (m/s)>.
10. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000045 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.

G. Steam Generator:

1. Capacity: <Insert MBtu/h (kW)>.
2. Flow Rate: <Insert lb/h (L/s)>.
3. Pressure: <Insert psig (kPa)>.
4. Pressure Rating: [15 psig (104 kPa)] [150 psig (1035 kPa)] <Insert psig (kPa)>.

H. Pump Horsepower:

1. Purge: <Insert value>.
2. Refrigerant: <Insert value>.
3. Solution: <Insert value>.

I. Chiller Control Electrical Requirements:

1. Power Input: <Insert kilowatts>.
2. Minimum Circuit Ampacity: <Insert value>.
3. Maximum Overcurrent Protection Device: <Insert amperage>.
4. Characteristics: [120] <Insert value>-V ac, single phase, 60 Hz.

J. Chiller Electrical Requirements:

1. Power Input: <Insert kilowatts>.
2. Minimum Circuit Ampacity: <Insert value>.
3. Maximum Overcurrent Protection Device: <Insert amperage>.
4. Characteristics: [208] [240] [480] <Insert value>-V ac, three phase, 60 Hz.

- K. Noise Rating: [80] [85] <Insert dBA> sound power level when measured according to ARI 575. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.19 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

- A. Furnish for field installation a brush-cleaning system on each chiller [**condenser**] <**Insert heat exchanger**> for tube cleaning and improved heat transfer.
- B. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
- C. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
- D. Components:
1. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed **0.025 inch** (0.6 mm).
 2. Basket: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
 3. Four-Way Valve:
 - a. Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
 - b. Configure valve with parallel flow connections to minimize field installation piping.
 - c. Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.
 - d. Pipe connections shall be flanged.
 - e. Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
 - f. Hydrostatically test to 1.5 times the design working pressure.
 - g. Design the valve to cause no more than **0.5-psig** (3-kPa) pressure drop at design flow conditions.
 - h. Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.
 - i. Valve Actuator: Mount electric actuator to operate valve.
 - j. Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.
 - k. Position Switches: Factory mount microswitches on the valve to indicate the complete turn of valve in both normal and reverse flow.
 4. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:
 - a. NEMA 250, [**Type 1**] [**Type 4**] [**Type 4x**] [**Type 12**] enclosure.

- b. Timer to automatically initiate the cleaning cycle over a 24-hour period.
- c. Manual override of preset cleaning cycle.
- d. Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow turn or incomplete valve turn.
- e. For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
- f. Flow-switch bypass.
- g. Unloading signal to chiller.

2.20 SOURCE QUALITY CONTROL

- A. Perform functional **[run]** tests of chillers before shipping.
- B. Factory test and inspect absorber, generator, evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test tube-side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Vacuum and pressure test shells for leaks.
- C. Rate sound power level according to ARI 575.
- D. Factory performance test chillers, before shipping, according to ARI 560.
 1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Reduction in capacity from design to minimum load in steps of **[10] [25] [33]** **<Insert number>** with condenser fluid at design conditions.
 - c. Reduction in capacity from design to minimum load in steps of **[10] [25] [33]** **<Insert number>** with varying entering condenser-fluid temperature from design to minimum conditions in **[5 deg F (3 deg C)] <Insert temperature>** increments.
 - d. At **[one] [two] [three] [four] [five] [10]** **<Insert number>** point(s) of varying part-load performance to be selected by Owner at time of test.
- E. Factory sound test chillers, before shipping, according to ARI 575.
 1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Chiller operating at calculated worst-case sound condition.
 - c. At **[one] [two] [three] [four] [five]** **<Insert number>** point(s) of varying part-load performance to be selected by Owner at time of test.
- F. Allow **[Owner]** **<Insert entity>** access to place where chillers are being tested. Notify DEN Project Manager**[14]** **<Insert number>** days in advance of testing.
- G. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one (1) week of test date.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine chillers before installation. Reject chillers that are damaged.
- B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.
 - 1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install chillers on support structure indicated.
- C. Equipment Mounting:
 - 1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Maintain manufacturer's recommended clearances for service and maintenance.
- E. Charge chiller with absorbent and refrigerant if not factory charged.
- F. Install separate devices furnished by manufacturer and not factory installed.
- G. Insulate hot and cold chiller surfaces that are recommended by chiller manufacturer to be insulated, and are not factory insulated. Comply with requirements in Section 230716 "HVAC Equipment Insulation."
- H. Provide connections to chilled water piping.
 - 1. On inlet, provide:
 - a. Thermometer well for temperature controller.
 - b. Thermometer.

- c. Strainer.
 - d. Flow switch.
 - e. Flexible pipe connector.
 - f. Pressure gage.
 - g. Shut-off valve.
2. On outlet, provide:
- a. Thermometer.
 - b. Flexible pipe connector.
 - c. Pressure gage.
 - d. **[Shut-off] [Balancing]** valve.

3.3 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

- A. Install brush-cleaning system control panel adjacent to chiller control panel.
- B. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
- C. Provide field electric power, as required, to each system control panel and electric actuated valve.
- D. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
- E. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
- F. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

3.4 CONNECTIONS

- A. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties" for hydronic piping. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties" for steam and condensate piping. Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Install piping adjacent to chiller to allow service and maintenance.
- D. Generator Steam Piping Connections:

1. Connect steam piping with trapped drip leg, gate valve, strainer, control valve, and pressure gage. Install pressure reducing valve and safety relief valve upstream from steam-control valve to protect control valve from excessive steam pressure. Make connections to chiller with a **[flange] [or] [union]**.
 2. Connect steam condensate piping with vacuum breaker, trapped drip leg, gate valve, strainer, float and thermostatic trap(s), **[condensate cooler,] [condensate receiver,] [condensate receiver and pump,]** and check valve. Make connections to chiller with a **[flange] [or] [union]**.
- E. Generator Hot-Water Connections: Connect to generator inlet with shutoff valve, **[strainer,] [flexible connector,]** control valve, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to generator outlet with shutoff valve, check valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with shutoff valve and pressure gage, **[flow meter,]** and drain connection with valve. Make connections to chiller with a **[flange] [or] [mechanical coupling]**.
- F. Evaporator-Fluid Connections: Connect to evaporator inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with shutoff valve and pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with shutoff valve and pressure gage, **[flow meter,]** and drain connection with valve. Make connections to chiller with a **[flange] [or] [mechanical coupling]**.
- G. Absorber/Condenser-Fluid Connections: Connect to inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with shutoff valve and pressure gage. Connect to outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with shutoff valve and pressure gage, **[flow meter,]** and drain connection with valve. Make connections to chiller with a **[flange] [or] [mechanical coupling]**.
1. If not factory furnished or installed, provide pipe connecting fluid connection of absorber discharge and condenser inlet.
- H. Refrigerant Pressure Relief Device Connections: Extend **[vent piping] [separate vent piping for each chiller]** to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.
- I. Extend **[purge vent piping] [separate purge vent piping for each chiller]** to the outdoors. Comply with ASHRAE 15.
- J. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.
- ### 3.5 STARTUP SERVICE
- A. Engage a factory-authorized service representative to assist Contractor and perform startup service. Supply service of factory trained representative for a period of **<Insert**

number> days to supervise testing, dehydration and charging of machine, start-up, and instruction on operation and maintenance.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Operate chiller for run-in period.
3. Verify that absorbent and refrigerant charge is sufficient and chiller has been leak tested.
4. Verify that pumps are installed and functional.
5. Verify that thermometers and gages are installed.
6. Operate chiller for run-in period.
7. Verify that refrigerant pressure relief device is vented outside.
8. Verify proper motor rotation.
9. Verify static deflection of vibration isolators including deflection during chiller startup and shutdown.
10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
11. Verify and record performance of chiller protection devices.
12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

C. Prepare test and inspection startup reports.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain chillers. [**Video record the training sessions.**]

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

A. No separate payment will be made for work under this Section. The cost of the work

described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236413.16

SECTION 236416 - CENTRIFUGAL WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, water-cooled, electric-motor-driven centrifugal chillers.
 - 2. Packaged, portable refrigerant recovery units.
 - 3. Heat-exchanger, brush-cleaning system.
- B. Related Section:
 - 1. Section 283500 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- B. DDC: Direct digital control.
- C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
- D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and referenced to ARI standard rating conditions.
- E. kW/Ton (kW/kW): The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons (kW) at any given set of rating conditions.
- F. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and intended for operating conditions other than the ARI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Centrifugal chillers shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
- B. Condenser-Fluid Temperature Performance:
1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of **[60 deg F (16 deg C)] [55 deg F (13 deg C)] [40 deg F (4 deg C)] <Insert temperature>** and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
 2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of **[65 deg F (18 deg C)] [60 deg F (16 deg C)] [55 deg F (13 deg C)]**.
 3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
- C. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
- D. Performance Tolerance: Comply with the following in lieu of ARI 506/110:
1. Allowable Capacity Tolerance: **[Zero] <Insert number>** percent.
 2. Allowable IPLV/NPLV Performance Tolerance: **[Zero] <Insert number>** percent.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
1. Performance at ARI standard conditions and at conditions indicated.
 2. Performance at ARI standard unloading conditions.
 3. Minimum evaporator flow rate.
 4. Refrigerant capacity of chiller.
 5. Oil capacity of chiller.
 6. Fluid capacity of evaporator, condenser[, **and heat-reclaim condenser**].
 7. Characteristics of safety relief valves.
 8. Minimum entering condenser-fluid temperature.
 9. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in **[5 deg F (3 deg C)] <Insert temperature>** increments.

10. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
- C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring Diagrams: For power, signal, and control wiring.
 3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
- D. INFORMATIONAL SUBMITTALS
- E. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Structural supports.
 2. Piping roughing-in requirements.
 3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
- F. Certificates: For certification required in "Quality Assurance" Article.
- G. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- H. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
- I. Source quality-control reports.

- J. Startup service reports.
- K. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIALS

- A. Provide [**two (2)**] <Insert number> containers of [**lubricating oil**] [**refrigerant**].

1.8 QUALITY ASSURANCE

- A. ARI Certification: Certify chiller according to ARI 550 certification program.
- B. ARI Rating: Rate chiller performance according to requirements in ARI 506/110.
- C. ASHRAE Compliance:
 - 1. ASHRAE 15 for safety code for mechanical refrigeration.
 - 2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.
- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
- E. ASME Compliance: Fabricate and label chillers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1[, **as applicable to chiller design**]. For chillers charged with R-134a refrigerant, include an ASME U-stamp and nameplate certifying compliance.
- F. Comply with NFPA 70.
- G. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.
- H. Green Seal Compliance: Signed by [**manufacturer**] [**Green Seal**] certifying compliance with GS-31.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Ship chillers from the factory fully charged with refrigerant.

- B. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.
- C. Ship each oil-lubricated chiller with a full charge of oil.
 - 1. Ship oil **[factory installed in chiller] [in containers separate from chiller]**.
- D. Package chiller for export shipping in totally enclosed **[bagging] [crate] [crate with bagging]**.
- E. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.
- F. Protect units from physical damage.

1.10 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

1.11 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
 - 1. Extended warranties include, but are not limited to, the following:
 - a. Complete chiller including refrigerant and oil charge.
 - b. Complete compressor and drive assembly including refrigerant and oil charge.
 - c. Refrigerant **[and oil]** charge.
 - d. Parts **[only] [and labor]**.
 - e. Loss of refrigerant charge for any reason.
 - 2. Warranty Period: Minimum **[two (2)] [three (3)] [four (4)] [five (5)]** <Insert **number**> years from date of Substantial Completion.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation](#).
 2. [McQuay International](#).
 3. [Trane](#).
 4. [York International Corporation](#).
 5. **<Insert manufacturer's name>**.
 6. or approved equal.

2.2 MANUFACTURED UNIT

- A. Description: Factory-assembled and -tested chiller complete with compressor, compressor motor, compressor motor controller, [**lubrication system**] evaporator, condenser, [**heat-reclaim condenser as indicated**,] controls, interconnecting unit piping and wiring, and indicated accessories.
1. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
 2. For chillers with dual compressors, provide each compressor with a dedicated motor and motor controller, and provide for continued operation when either compressor-drive assembly fails or is being serviced.
- B. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.

2.3 COMPRESSOR-DRIVE ASSEMBLY

- A. Description: Single-stage or multistage, variable-displacement, centrifugal-type compressor driven by an electric motor.
1. Where indicated, provide oil-free compressor technology using a permanent magnet synchronous motor, magnetic bearings, integral variable frequency controller, and digital electronic controls.
- B. Compressor:
1. Casing: Cast iron, precision ground.
 2. Impeller: High-strength cast aluminum or cast-aluminum alloy on carbon- or alloy-steel shaft.
- C. Drive: [**Direct-drive, hermetic**] [**Gear-drive, hermetic**] [**Gear-drive, open**] [**Direct- or gear-drive, hermetic**] [**Direct- or gear-drive, open or hermetic**] design using an electric motor as the driver.

1. Gear Drives: For chillers with gear drives, provide single- or double-helical gear design continuously coated with oil while chiller is operating. Gears shall comply with American Gear Manufacturer Association standards.
 2. Drive Coupling: For chillers with open drives, provide flexible disc with all-metal construction and no wearing parts to ensure long life without the need for lubrication.
 3. Seals: Seal drive assembly to prevent refrigerant leakage.
- D. Compressor Motor:
1. Continuous-duty, squirrel-cage, induction-type, two-pole motor with energy efficiency required to suit chiller energy efficiency indicated.
 2. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
 3. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.
 4. For chillers with open drives, provide motor with **[open-dripproof]** **[weather-protected, Type I]** **[weather-protected, Type II]** **[totally enclosed]** enclosure.
 5. Provide motor with thermistor or RTD in **[single motor winding]** **[each of three-phase motor windings]** to monitor temperature and report information to chiller control panel.
 6. Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.
 7. Provide open-drive motor with internal electric heater, internally powered from chiller power supply.
- E. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
1. Overspeed Test: 25 percent above design operating speed.
- F. Service: Easily accessible for inspection and service.
1. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
 2. Provide lifting lugs or eyebolts attached to casing.
- G. Economizers: For multistage chillers, provide interstage economizers.
- H. Capacity Control: Modulating, variable-inlet, guide-vane assembly combined with hot-gas bypass, if necessary, to achieve performance indicated.
1. Maintain stable operation that is free of surge, cavitation, and vibration throughout range of operation. Configure to achieve most energy-efficient operation possible.
 2. Operating Range: From 100 to **[15]** **[10]** **[5]** **[zero]** **<Insert number>** percent of design capacity.

3. Condenser-Fluid Unloading Requirements over Operating Range:
[Constant-design entering condenser-fluid temperature] [Drop-in entering condenser-fluid temperature of 2.5 deg F (1.4 deg C) for each 10 percent in capacity reduction] <Insert conditions>.
 4. Chillers with variable frequency controllers shall modulate compressor speed with variable-inlet, guide-vane control to achieve optimum energy efficiency.
- I. Oil Lubrication System: Consisting of pump, filtration, **[heater,]**cooler, factory-wired power connection, and controls.
1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, coastdown, and standby conditions including power failure.
 2. **[Manufacturer's standard method] [Thermostatically controlled oil heater properly sized]** to remove refrigerant from oil.
 3. **[Oil filter] [Dual oil filters, one redundant,]** shall be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.
 4. **[Refrigerant] [Water] [Refrigerant- or water]-**cooled oil cooler.
 5. Factory-installed and pressure-tested piping with isolation valves and accessories.
 6. Oil compatible with refrigerant and chiller components.
 7. Positive visual indication of oil level.

2.4 REFRIGERATION

- A. Refrigerant:
1. Type: **[R-123; ASHRAE 34, Class B1] [or] [R-134a; ASHRAE 34, Class A1]**.
 2. Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
- B. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
- C. Pressure Relief Device:
1. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 2. For Chillers Using R-123: **[Rupture disc constructed of frangible carbon] [Spring-loaded, pressure relief valve; single- or multiple-reseating type]**.
 3. For Chillers Using R-134a: ASME-rated, spring-loaded, pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.
- D. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.

- E. Refrigerant Isolation for Chillers Using R-134a: Factory install [**positive shutoff, manual**] isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell. [**In addition, provide isolation valve on suction side of compressor from evaporator to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell.**]
- F. Purge System:
1. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic purge system for collection and return of refrigerant and lubricating oil and for removal of noncondensables including, but not limited to, water, water vapor, and noncondensable gases.
 2. System shall be a thermal purge design, refrigerant or air cooled, equipped with a carbon filter that includes an automatic regeneration cycle.
 3. Factory wire to chiller's main power supply and system complete with controls, piping, and refrigerant valves to isolate the purge system from the chiller.
 4. Construct components of noncorrodible materials.
 5. Controls shall interface with chiller control panel to indicate modes of operation, set points, data reports, diagnostics, and alarms.
 6. Efficiency of not more than **0.02 lb of refrigerant per pound of air** (9 g of refrigerant per gram of air) when rated according to ARI 580.
 7. Operation independent of chiller per ASHRAE 147.
- G. Positive-Pressure System:
1. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic positive-pressure system.
 2. During nonoperational periods, positive-pressure system shall automatically maintain a positive pressure for atmosphere in the refrigerant pressure vessel of not less than **0.5 psig (3 kPa)** adjustable up to a pressure that remains within the vessel design pressure limits.
 3. System shall be factory wired and include controller, electric heat, pressure transmitter, or switch.

2.5 EVAPORATOR

- A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
- B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
- C. Designed to prevent liquid refrigerant carryover from entering compressor.
- D. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.
- E. Tubes:

1. Individually replaceable from either end and without damage to tube sheets and other tubes.
 2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 3. Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <Insert material>.
 4. Nominal OD: [**Manufacturer's choice**] [**3/4 inch (19 mm)**] [**1 inch (25 mm)**] [**3/4 or 1 inch (19 or 25 mm)**].
 5. Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] <Insert value>.
 6. External Finish: Manufacturer's standard.
 7. Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].
- F. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
- G. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
- H. Water Box:
1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 2. [**Standard**] [**Marine**] type for water box with piping connections. Standard type for water box without piping connections.
 3. Provide water boxes [**and marine water-box covers**] with lifting lugs or eyebolts.
 4. [**Hinged**] [**Davited**] [**Hinged or davited**] water boxes.
 5. [**Hinged**] [**Davited**] [**Hinged or davited**] marine water-box covers.
 6. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
 7. Thermistor or RTD temperature sensor factory installed in each nozzle.
 8. Fit each water box with [**3/4-inch (19-mm)**] [**1-inch (25-mm)**] [**3/4- or 1-inch (19- or 25-mm)**] <Insert size> drain connection at low point and vent connection at high point, each with threaded plug.
- I. Additional Corrosion Protection:
1. Electrolytic corrosion-inhibitor anode.
 2. Coat wetted surfaces with a corrosion-resistant finish.
 3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.
- ## 2.6 CONDENSER
- A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.

- B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
- C. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
- D. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.
- E. Tubes:
1. Individually replaceable from either end and without damage to tube sheets and other tubes.
 2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 3. Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <Insert material>.
 4. Nominal OD: [**Manufacturer's choice**] [**3/4 inch (19 mm)**] [**1 inch (25 mm)**] [**3/4 or 1 inch (19 or 25 mm)**].
 5. Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] <Insert value>.
 6. External Finish: Manufacturer's standard.
 7. Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].
- F. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
- G. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
- H. Water Box:
1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 2. [**Standard**] [**Marine**] type for water box with piping connections. Standard type for water box without piping connections.
 3. Provide water boxes [**and marine water-box covers**] with lifting lugs or eyebolts.
 4. [**Hinged**] [**Davited**] [**Hinged or davited**] water boxes.
 5. [**Hinged**] [**Davited**] [**Hinged or davited**] marine water-box covers.
 6. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
 7. Thermistor or RTD temperature sensor factory installed in each nozzle.
 8. Fit each water box with [**3/4-inch (19-mm)**] [**1-inch (25-mm)**] [**3/4- or 1-inch (19- or 25-mm)**] <Insert size> drain connection at low point and vent connection at high point, each with threaded plug.
- I. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.7 HEAT-RECLAIM CONDENSER

- A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator and condenser.
- B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
- C. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
- D. Tubes:
1. Individually replaceable from either end and without damage to tube sheets and other tubes.
 2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 3. Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <Insert material>.
 4. Nominal OD: [**Manufacturer's choice**] [**3/4 inch (19 mm)**] [**1 inch (25 mm)**] [**3/4 or 1 inch (19 or 25 mm)**].
 5. Minimum Wall Thickness: **Manufacturer's choice** [**0.025 inch (0.6 mm)**] [**0.028 inch (0.7 mm)**] [**0.035 inch (0.9 mm)**] <Insert value>.
 6. External Finish: Manufacturer's standard.
 7. Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].
- E. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
- F. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
- G. Water Box:
1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 2. [**Standard**] [**Marine**] type for water box with piping connections. Standard type for water box without piping connections.
 3. Provide water boxes [**and marine water-box covers**] with lifting lugs or eyebolts.
 4. [**Hinged**] [**Davited**] [**Hinged or davited**] water boxes.
 5. [**Hinged**] [**Davited**] [**Hinged or davited**] marine water-box covers.

6. Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].
7. Thermistor or RTD temperature sensor factory installed in each nozzle.
8. Fit each water box with [**3/4-inch (19-mm)**] [**1-inch (25-mm)**] [**3/4- or 1-inch (19- or 25-mm)**] <Insert size> drain connection at low point and vent connection at high point, each with threaded plug.

H. Additional Corrosion Protection:

1. Electrolytic corrosion-inhibitor anode.
2. Coat wetted surfaces with a corrosion-resistant finish.
3. Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

2.8 INSULATION

A. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

1. Thickness: [**3/4 inch (19 mm)**] [**1-1/2 inches (38 mm)**] <Insert thickness>.

B. Adhesive: As recommended by insulation manufacturer.

C. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.

1. Apply adhesive to 100 percent of insulation contact surface.
2. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
3. Seal seams and joints to provide a vapor barrier.
4. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

2.9 ELECTRICAL

A. Factory installed and wired, and functionally tested at factory before shipment.

B. Single-point, field-power connection to [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**]. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <Insert value> A.

1. Branch power circuit to each motor, electric heater, dedicated electrical load, and controls[**with disconnect switch or circuit breaker**].
 - a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
 2. NEMA ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller for each variable-speed motor furnished.
 3. Control-circuit transformer with primary and secondary side fuses.
- C. Terminal blocks with numbered [**and color-coded**]wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
- D. Factory-installed wiring outside of enclosures shall be in metal raceway except make terminal connections with not more than a **24-inch** (610-mm) length of [**liquidtight**] [**flexible metallic**] [**liquidtight or flexible metallic**] conduit.
- E. Factory install and wire capacitor bank for the purpose of power factor correction to [**0.95**] <Insert value> at all operating conditions.
1. If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.
 2. Capacitors shall be non-PCB dielectric fluid, metallized electrode design, low loss with low-temperature rise. The kVAR ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.
 3. Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within one minute after de-energizing.
 4. Provide a ground terminal and a terminal block or individual connectors for phase connection.
- 2.10 MOTOR CONTROLLER
- A. Enclosure: [**Factory installed, unit mounted**] [**Factory furnished, field mounted**], [**NEMA 250**] [**NEMA ICS 6**], [**Type 1**] [**Type 4**] [**Type 4X**] [**Type 12**] <Insert type>, with hinged full-front access door[**with lock and key or padlock and key**].
- B. Control Circuit: Obtained from [**integral control power transformer**] <Insert source of control power> with a control power [**transformer**] [**source**] of enough capacity to operate connected control devices.
- C. Overload Relay: Shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.

- D. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.
- E. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.
- F. Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition; include isolation switch and current-limiting fuses.
- G. Solid-State, Reduced-Voltage Controller: NEMA ICS 2.
 - 1. Surge suppressor in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
 - 2. Visual indication of motor and control status, including the following conditions:
 - a. Controller on.
 - b. Overload trip.
 - c. Loss of phase.
 - d. Starter fault.
- H. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
 - 1. Externally Operated[, **Door-Interlocked**] Disconnect: [**Fused disconnect switch**] [**Nonfused disconnect switch**] [**Circuit breaker**]. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <Insert value> A.
 - 2. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
 - 3. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
 - 4. Control Relays: Time-delay relays.
 - 5. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
 - 6. Number-of-Starts Counter: Numerical readout on face of enclosure.
 - 7. Meters: Panel type, [**2-1/2 inches** (64 mm)] [**4-1/4 inches** (108 mm)] with [**90**] [**120**] [**270**]-degree scale and [**1**] [**2**] percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:
 - a. Ammeter: Output current for each phase, with current sensors rated to suit application.
 - b. Voltmeter: Output voltage for each phase.
 - c. Frequency Meter: Output frequency.
 - d. Real-time clock with current time and date.
 - e. Total run time.
 - f. <Insert features>.
 - 8. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:

- a. Selectable, digital display of the following:
 - 1) Phase Currents, Each Phase: Plus or minus 1 percent.
 - 2) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - 3) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - 4) Three-Phase Real Power: Plus or minus 2 percent.
 - 5) Three-Phase Reactive Power: Plus or minus 2 percent.
 - 6) Power Factor: Plus or minus 2 percent.
 - 7) Frequency: Plus or minus 0.5 percent.
 - 8) Integrated Demand with Demand Interval Selectable from Five to 60 Minutes: Plus or minus 2 percent.
 - 9) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
 - b. Mounting: Display and control unit flush or semirecessed in instrument compartment door.
9. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.
 10. Power Protection: Chiller shall shut down within six cycles of power interruption.

2.11 VARIABLE FREQUENCY CONTROLLER

- A. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
- B. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
- C. Enclosure: Unit mounted, NEMA 250, **[Type 1] [Type 4] [Type 4x] [Type 12]**, with hinged full-front access door with lock and key.
- D. Integral Disconnecting Means: **[Door-interlocked]**, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[42,000] [65,000] <Insert value>** A.
- E. Technology: Pulse width modulated (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.
- F. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.
 1. Rectifier section shall be a full-wave diode bridge that changes fixed-voltage, fixed-frequency, ac line power to a fixed dc voltage. Silicon controller rectifiers, current source inverters, and paralleling of devices are unacceptable. Rectifier shall be insensitive to phase rotation of the ac line.

2. Regulator shall provide full digital control of frequency and voltage.
 3. Inverter section shall change fixed dc voltage to variable-frequency, variable ac voltage, for application to a squirrel-cage motor. Inverter shall produce a sine-coded, pulse width modulated (PWM) output wave form and shall conduct no radio-frequency interference back to the input power supply.
- G. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.
- H. Operating Requirements:
1. Input AC Voltage Tolerance: **[460-V ac, plus 10 percent or 506 V maximum] <Insert voltage and tolerance>**.
 2. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
 3. Capable of driving full load, without derating, under the following conditions:
 - a. Ambient Temperature: 0 to 50 deg C.
 - b. Relative Humidity: Up to **[90] [95]** percent (noncondensing).
 - c. Altitude: **[3300 feet (1005 m)] [6600 feet (2010 m)]**.
 4. Minimum Efficiency: 96 percent at 60 Hz, full load.
 5. Minimum Displacement Primary-Side Power Factor: 95 percent without harmonic filter, 98 percent with harmonic filter.
 6. Overload Capability: 1.05 times the full-load current for 7 seconds.
 7. Starting Torque: As required by compressor-drive assembly.
 8. Speed Regulation: Plus or minus 1 percent.
 9. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
 10. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
 11. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.
- I. Internal Adjustability Capabilities:
1. Minimum Output Frequency: 6 Hz.
 2. Maximum Output Frequency: 60 Hz.
 3. Acceleration: 2 seconds to a minimum of 60 seconds.
 4. Deceleration: 2 seconds to a minimum of 60 seconds.
 5. Current Limit: 30 percent to a minimum of 100 percent of maximum rating.
- J. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:
1. Overtemperature.
 2. Short circuit at controller output.
 3. Ground fault at controller output. Variable frequency controller shall be able to start a grounded motor.
 4. Open circuit at controller output.

5. Input undervoltage.
 6. Input overvoltage.
 7. Loss of input phase.
 8. Reverse phase.
 9. AC line switching transients.
 10. Instantaneous overload, line to line or line to ground.
 11. Sustained overload exceeding 100 percent of controller rated current.
 12. Starting a rotating motor.
- K. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
- L. Automatic Reset and Restart: Capable of [**three**] <Insert number> restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.
- M. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:
1. Power on.
 2. Run.
 3. Overvoltage.
 4. Line fault.
 5. Overcurrent.
 6. External fault.
 7. Motor speed (percent).
 8. Fault or alarm status (code).
 9. DC-link voltage.
 10. Motor output voltage.
 11. Input kilovolt amperes.
 12. Total power factor.
 13. Input kilowatts.
 14. Input kilowatt-hours.
 15. Three-phase input voltage.
 16. Three-phase output voltage.
 17. Three-phase input current.
 18. Three-phase output current.
 19. Three-phase input voltage total harmonic distortion.
 20. Three-phase input current total harmonic distortion.
 21. Output frequency (Hertz).
 22. Elapsed operating time (hours).
 23. Diagnostic and service parameters.
- N. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.
- O. Control Signal Interface:

1. Electric Input Signal Interface: A minimum of two analog inputs (0 to 10 V or 0/4-20 mA) and six programmable digital inputs.
 - P. Active Harmonic Distortion Filter: Factory mounted and wired to limit total voltage and current distortion to [5] <Insert number> percent.
 - Q. Input Line Conditioning: <Insert requirements>.
 - R. Cooling: [Air] [Refrigerant] [Water] [Air, refrigerant, or water] cooled.
 - S. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
 1. Control Relays: Auxiliary and adjustable time-delay relays.
 - T. Chiller Capacity Control Interface: Equip chiller with adaptive control logic to automatically adjust the compressor motor speed and the compressor pre-rotation inlet vane position independently to achieve maximum part-load efficiency in response to sensor inputs that are integral to the chiller controls.
- 2.12 CONTROLS
- A. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
 - B. Enclosure: Unit mounted, NEMA 250, [Type 1] [Type 4] [Type 4x] [Type 12] <Insert type>, hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.
 - C. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:
 1. Date and time.
 2. Operating or alarm status.
 3. Fault history with not less than last 10 faults displayed.
 4. Set points of controllable parameters.
 5. Trend data.
 6. Operating hours.
 7. Number of chiller starts.
 8. Outdoor-air temperature or space temperature if required for chilled-water reset.
 9. Entering- and leaving-fluid temperatures of evaporator and condenser.
 10. Difference in fluid temperatures of evaporator and condenser.
 11. Fluid flow of evaporator and condenser.
 12. Fluid pressure drop of evaporator and condenser.
 13. Refrigerant pressures in evaporator and condenser.
 14. Refrigerant saturation temperature in evaporator and condenser shell.
 15. Compressor refrigerant suction and discharge temperature.

16. Compressor bearing temperature.
17. Motor bearing temperature.
18. Motor winding temperature.
19. Oil temperature.
20. Oil discharge pressure.
21. Phase current.
22. Percent of motor rated load amperage.
23. Phase voltage.
24. Demand power (kilowatts).
25. Energy use (kilowatt-hours).
26. Power factor.
27. For chillers equipped with variable frequency controllers and harmonic filters, include the following:
 - a. Output voltage and frequency.
 - b. Voltage total harmonic distortion for each phase.
 - c. Supply current total demand distortion for each phase.
 - d. Inlet vane position.
 - e. Controller internal ambient temperature.
 - f. Heatsink temperature.
28. Purge suction temperature if purge system is provided.
29. Purge elapsed time if purge system is provided.
30. **<Insert status display items>**.

D. Control Functions:

1. Manual or automatic startup and shutdown time schedule.
2. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on [**return-water**] [**outdoor-air**] [**space**] temperature.
3. Current limit and demand limit.
4. Condenser-fluid temperature.
5. External chiller emergency stop.
6. Variable evaporator flow.
7. Thermal storage.
8. Heat reclaim.
9. **<Insert control functions>**.

E. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:

1. Low evaporator [**pressure**] [**temperature**] [**pressure or temperature**]; high condenser pressure.
2. Low evaporator fluid temperature.
3. Low oil differential pressure.
4. High or low oil pressure.
5. High oil temperature.
6. High compressor-discharge temperature.
7. Loss of condenser-fluid flow.

8. Loss of evaporator fluid flow.
 9. Motor overcurrent.
 10. Motor overvoltage.
 11. Motor undervoltage.
 12. Motor phase reversal.
 13. Motor phase failure.
 14. Sensor- or detection-circuit fault.
 15. Processor communication loss.
 16. Motor controller fault.
 17. Extended compressor surge.
 18. Excessive air-leakage detection for chillers using R-123 refrigerant.
 19. **<Insert manually reset safety controls>**.
- F. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
- G. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
- H. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
- I. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer **and a notebook computer**.
- J. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display chiller status and alarms.
1. Hardwired Points:
 - a. Monitoring: On-off status, **[common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt-hours)] [power factor] <Insert monitoring point>**.
 - b. Control: On-off operation, **[chilled-water, discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>**.
 2. **[ASHRAE 135 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol] <Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the DDC system for HVAC.

2.13 FINISH

- A. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
1. Provide at least one coat of primer with a total dry film thickness of at least **2 mils** (0.05 mm).
 2. Provide at least two coats of [**alkyd-modified, vinyl enamel**] [**epoxy**] [**polyurethane**] finish with a total dry film thickness of at least **4 mils** (0.10 mm).
 3. Paint surfaces that are to be insulated before applying the insulation.
 4. Paint installed insulation to match adjacent uninsulated surfaces.
 5. Color of finish coat to be [**manufacturer's standard**] [**custom color selected by Architect**] <Insert color description>.
- B. Provide Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.

2.14 ACCESSORIES

- A. Flow Switches:
1. Chiller manufacturer shall furnish a switch for each [**condenser**] [**evaporator and condenser**] and verify field-mounting location before installation.
 2. Paddle Flow Switches:
 - a. Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.
 - b. Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
 - c. Pressure rating equal to pressure rating of heat exchanger.
 - d. Construct body and wetted parts of Type 316 stainless steel.
 - e. House switch in a NEMA 250, [**Type 4**] <Insert type> enclosure constructed of die-cast aluminum.
 - f. Vane length to suit installation.
 3. Pressure Differential Switches:
 - a. Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
 - b. Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
 - c. Set Point: Screw type, field adjustable.
 - d. Electrical Connections: Internally mounted screw-type terminal blocks.
 - e. Switch Enclosure: NEMA 250, [**Type 4**] <Insert type>.
 - f. Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

B. Vibration Isolation:

1. Chiller manufacturer shall furnish vibration isolation for each chiller.
2. Neoprene Pad:
 - a. Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
 - b. Fabricate pads from 40- to 50-durometer neoprene.
 - c. Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.
3. Spring Isolator:
 - a. Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions. Isolators shall be designed so that the Kx/Ky ratio shall be 1.0 or more for stability.
 - b. Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.
 - c. Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate. An elastomeric pad with a minimum thickness of 0.25 inch (6 mm) shall be bonded to the baseplate.
 - d. Spring assembly shall be removable and shall fit within a welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.
 - e. Isolators shall be selected for a nominal [1-inch (25-mm)] [2-inch (50-mm)] <Insert dimension> deflection.

C. Sound Barrier:

1. Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.
2. Provide for repeated installation and removal without use of tape or calk.
3. Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.
4. Covers shall be double sewn and lock stitched with edges folded and sewn so no raw cut edges are exposed.
5. Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.
6. Continuously lap all exposed seams at least 2 inches (50 mm) for better sound containment.
7. Permanently label each section of cover to indicate its location, description, size, and number sequence.

8. Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.

D. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

2.15 CAPACITIES AND CHARACTERISTICS

A. Capacity: <Insert tons (kW)>.

B. Full-Load Efficiency:

1. COP: <Insert value>.
2. EER: <Insert value>.
3. Power Input/Cooling Output: <Insert kW/ton (kW/kW)>.
4. Comply with GS-31.
5. Comply with FEMP.

C. Part-Load Efficiency:

1. IPLV: <Insert value>.
2. NPLV: <Insert value>.
3. Comply with GS-31.
4. Comply with FEMP.

D. Evaporator:

1. Pressure Rating: <Insert psig (kPa)>.
2. Number of Passes: [One] [Two] [Three].
3. Fluid Type: [Water] <Insert fluid type>.
4. Design Fluid Flow Rate: <Insert gpm (L/s)>.
5. Minimum Fluid Flow Rate: <Insert gpm (L/s)>.
6. Entering-Fluid Temperature: <Insert deg F (deg C)>.
7. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
8. Fluid Pressure Drop: <Insert feet of head (kPa)>.
9. Fluid Velocity: <Insert fps (m/s)>.
10. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.

E. Condenser:

1. Pressure Rating: <Insert psig (kPa)>.
2. Number of Passes: [One] [Two] [Three].
3. Fluid Type: [Water] <Insert fluid type>.
4. Design Fluid Flow Rate: <Insert gpm (L/s)>.

5. Entering-Fluid Temperature: <Insert deg F (deg C)>.
6. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
7. Fluid Pressure Drop: <Insert feet of head (kPa)>.
8. Fluid Velocity: <Insert fps (m/s)>.
9. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg F/Btu (0.00022 sq. m x deg C/W)] <Insert value>.

F. Heat-Reclaim Condenser:

1. Pressure Rating: <Insert psig (kPa)>.
2. Number of Passes: [One] [Two] [Three].
3. Fluid Type: [Water] <Insert fluid type>.
4. Design Fluid Flow Rate: <Insert gpm (L/s)>.
5. Entering-Fluid Temperature: <Insert deg F (deg C)>.
6. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
7. Fluid Pressure Drop: <Insert feet of head (kPa)>.
8. Fluid Velocity: <Insert fps (m/s)>.
9. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.

G. Compressor:

1. Number of Compressors: [One] [Two].
2. [First]Compressor Rated Load Amperes: <Insert value>.
3. [First]Compressor Locked-Rotor Amperes: <Insert value>.
4. Second Compressor Rated Load Amperes: <Insert value>.
5. Second Compressor Locked-Rotor Amperes: <Insert value>.

H. Chiller Control Electrical Requirements:

1. Power Connections: [Integral] [Field].
2. Power Input: <Insert kilowatts>.
3. Minimum Circuit Ampacity: <Insert value>.
4. Maximum Overcurrent Protection Device: <Insert amperage>.
5. Volts: [120] <Insert value>-V ac.
6. Phase: [Single] [Three].
7. Hertz: 60.

I. Chiller Electrical Requirements:

1. Power Input: <Insert kilowatts>.
2. Power Factor: [0.90] [0.95] <Insert value>.
3. Minimum Circuit Ampacity: <Insert value>.
4. Maximum Overcurrent Protection Device: <Insert amperage>.
5. Volts: [208] [240] [480] [600] [2300] [4160] <Insert value>-V ac.
6. Phase: Three.
7. Hertz: 60.

- J. Noise Rating: **[85] <Insert dBA>** sound power level when measured according to ARI 575. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.16 PACKAGED REFRIGERANT RECOVERY UNITS

- A. Packaged portable unit consisting of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest chiller furnished.

2.17 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

- A. Furnish for field installation a brush-cleaning system on each chiller **[condenser] <Insert heat exchanger>** for tube cleaning and improved heat transfer.
- B. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
- C. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
- D. Components:
1. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed **0.025 inch (0.6 mm)**.
 2. Basket: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
 3. Four-Way Valve:
 - a. Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
 - b. Configure valve with parallel flow connections to minimize field installation piping.
 - c. Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.
 - d. Pipe connections shall be flanged.
 - e. Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
 - f. Hydrostatically test to 1.5 times the design working pressure.

1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Chiller operating at calculated worst-case sound condition.
 - c. At [**one**] [**two**] [**three**] [**four**] [**five**] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.
 2. Allow [**Owner**] <Insert entity> access to place where chillers are being tested. Notify DEN Project Manager [**14**] <Insert number> days in advance of testing.
 3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- D. For chillers using R-134a refrigerant, factory test and inspect evaporator [**and condenser**] [, **condenser, and heat-reclaim condenser**] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- E. For chillers using R-123 refrigerant, factory test and inspect evaporator [**and condenser**] [, **condenser and heat-reclaim condenser**] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test fluid side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Pressure proof test refrigerant side of heat exchangers to a minimum of 45 psig (310 kPa). Vacuum and pressure test for leaks.
- F. For chillers located indoors, rate sound power level according to ARI 575.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine chillers before installation. Reject chillers that are damaged.
- B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.
 1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install chillers on support structure indicated.
- C. Equipment Mounting:

1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Maintain manufacturer's recommended clearances for service and maintenance.
- E. Charge chiller with refrigerant and fill with oil if not factory installed.
- F. Install separate devices furnished by manufacturer and not factory installed.
- G. Provide connections to chilled water piping.
1. On inlet, provide:
 - a. Thermometer well for temperature controller.
 - b. Thermometer.
 - c. Strainer.
 - d. Flow switch.
 - e. Flexible pipe connector.
 - f. Pressure gage.
 - g. Shut-off valve.
 2. On outlet, provide:
 - a. Thermometer.
 - b. Flexible pipe connector.
 - c. Pressure gage.
 - d. [**Shut-off**] [**Balancing**] valve.

3.3 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

- A. Install brush-cleaning system control panel adjacent to chiller control panel.
- B. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
- C. Provide field electric power, as required, to each system control panel and electric actuated valve.
- D. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.

- E. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
- F. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

3.4 CONNECTIONS

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping," Section 232116 Hydronic Piping Specialties," and Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to chiller to allow service and maintenance.
- C. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage, [**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**mechanical coupling**] [**flange or mechanical coupling**].
- D. Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage, [**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**mechanical coupling**] [**flange or mechanical coupling**].
- E. Heat-Reclaim Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage, [**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**mechanical coupling**] [**flange or mechanical coupling**].
- F. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend [**vent piping**] [**separate vent piping for each chiller**] to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.
- G. For chillers equipped with a purge system, extend [**purge vent piping**] [**separate purge vent piping for each chiller**] to the outdoors. Comply with ASHRAE 15 and ASHRAE 147.
- H. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service. Supply service of factory trained representative for a period of **<Insert number>** days to supervise testing, dehydration and charging of machine, start-up, and instruction on operation and maintenance.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
 3. Verify that pumps are installed and functional.
 4. Verify that thermometers and gages are installed.
 5. Operate chiller for run-in period.
 6. Check bearing lubrication and oil levels.
 7. Verify that refrigerant pressure relief device is vented outside.
 8. Verify proper motor rotation.
 9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
 10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator[**and condenser**] [, **condenser, and heat-reclaim condenser**].
 11. Verify and record performance of chiller protection devices.
 12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
- C. Prepare test and inspection startup reports.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain chillers.[**Video record the training sessions.**]
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236416

SECTION 236419 - RECIPROCATING WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, water-cooled, electric-motor-driven, reciprocating water chillers.
 - 2. Packaged, air-cooled, electric-motor-driven, reciprocating water chillers.
 - 3. Packaged refrigerant recovery units.
- B. Related Sections:
 - 1. Section 283500 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- B. DDC: Direct digital control.
- C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
- D. IPLV: Integrated part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and referenced to ARI standard rating conditions.
- E. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
- F. NPLV: Nonstandard part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and intended for operating conditions other than the ARI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Reciprocating water chillers shall withstand the effects of earthquake motions determined according to [SEI/ASCE 7] <Insert requirement>.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.5 ACTION SUBMITTALS

- A. Product Data: Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories. Indicate valves, strainers, and thermostatic valves required for complete system.
1. Performance at ARI standard conditions and at conditions indicated.
 2. Performance at ARI standard unloading conditions.
 3. Minimum evaporator flow rate.
 4. Refrigerant capacity of water chiller.
 5. Oil capacity of water chiller.
 6. Fluid capacity of evaporator.
 7. Fluid capacity of condenser.
 8. Characteristics of safety relief valves.
 9. Minimum entering condenser-water temperature.
 10. Performance at varying capacity with constant-design entering condenser-water temperature. Repeat performance at varying capacity for different entering condenser-water temperatures from design to minimum in [5 deg F (3 deg C)] <Insert deg F (deg C)> increments.
 11. Minimum entering condenser-air temperature.
 12. Performance at varying capacity with constant-design entering condenser-air temperature. Repeat performance at varying capacity for different entering condenser-air temperatures from design to minimum in [10 deg F (6 deg C)] <Insert deg F (deg C)> increments.
 13. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Complete set of manufacturer's prints of water chiller assemblies, control panels, sections and elevations, and unit isolation. Include the following:
1. Assembled unit dimensions.
 2. Weight and load distributions.
 3. Required clearances for maintenance and operation.
 4. Sizes and locations of piping and wiring connections.
 5. Wiring Diagrams: For power, signal, and control wiring.
 6. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be

installed, including adjacent equipment not specified by this Section.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Structural supports.
 - 2. Piping roughing-in requirements.
 - 3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 - 4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
- B. Certificates: For certification required in "Quality Assurance" Article.
- C. Seismic Qualification Certificates: For water chillers, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
- E. Source quality-control test reports.
- F. Startup service reports.
- G. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each water chiller to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIALS

- A. Provide [**two (2)**] <Insert number> containers of [**lubricating oil**] [**refrigerant**].

1.9 QUALITY ASSURANCE

- A. ARI Certification: Certify chiller according to ARI 590 certification program.
- B. ARI Rating: Rate water chiller performance according to requirements in ARI 506/110, "Water Chilling Packages Using the Vapor Compression Cycle."
- C. ASHRAE Compliance: ASHRAE 15 for safety code for mechanical refrigeration.
- D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- E. ASME Compliance: Fabricate and stamp water chiller heat exchangers to comply with ASME Boiler and Pressure Vessel Code.
- F. Comply with NFPA 70.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Ship water chillers from the factory fully charged with refrigerant and filled with oil.
- B. Package water chiller for export shipping.
- C. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.
- D. Protect units from physical damage.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water chillers that fail in materials or workmanship within specified warranty period.
 - 1. Compressor Warranty Period: Minimum [**five (5)**] <Insert number> years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PACKAGED WATER-COOLED WATER CHILLERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation](#).
 2. [McQuay International](#).
 3. **<Insert manufacturer's name>**.
 4. or approved equal.
- B. Description: Factory-assembled and run-tested water chiller complete with compressor(s), compressor motors and motor controllers, evaporator, condenser where indicated, electrical power, controls, and indicated accessories.
- C. Fabricate water chiller mounting base with reinforcement strong enough to resist water chiller movement during a seismic event when water chiller is anchored to field support structure.
- D. Compressors:
1. Description: Positive-displacement direct drive with semihermetically sealed and accessible bolted casings.
 2. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
 3. Operating Speed: 1750 rpm for 60-Hz applications.
 4. Capacity Control: Combinations of cylinder unloading and on-off compressor cycling[**of multiple compressors**][, **plus hot-gas bypass**]. Compressor shall be capable of operating at part-load conditions without increased vibration over normal vibration at full-load operation and shall be capable of continuous operation at its lowest step of unloading.
 5. Oil Lubrication System: Automatically reversible, positive-displacement pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
 6. Vibration Isolation: Mount individual compressors on either neoprene or spring isolators.
 7. Sound-reduction package shall consist of acoustic enclosures around the compressors that are designed to reduce sound level without affecting performance.
- E. Compressor Motors:

1. Hermetically sealed and cooled by refrigerant suction gas.
2. High-torque, four-pole induction type with inherent thermal-overload protection on each phase.

F. Compressor Motor Controllers:

1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
2. Part-Wind Start: NEMA ICS 2, Class A, reduced voltage, nonreversing.

G. Refrigeration:

1. Refrigerant: R-22. Classified as Safety Group A1 according to ASHRAE 34.
2. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
3. Refrigerant Circuit: Each circuit shall include [a thermal] [an electronic] expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
4. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

H. Evaporator:

1. Brazed-plate or shell-and-tube design, as indicated.
2. Shell and Tube:
 - a. Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
 - b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - c. Shell Material: Carbon steel.
 - d. Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
 - e. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
 - f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
3. Brazed Plate:
 - a. Direct-expansion, single-pass, brazed-plate design.
 - b. Type 316 stainless-steel construction.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.

- d. Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.

I. Condenser:

1. Shell and tube, brazed plate, or without integral condenser; as indicated.
2. Shell and Tube:
 - a. Description: Shell-and-tube design with refrigerant flowing through the shell and fluid flowing through the tubes within the shell.
 - b. Provides positive subcooling of liquid refrigerant.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - d. Shell Material: Carbon steel.
 - e. Water Boxes: Removable, of carbon-steel construction, located at each end of the tube bundle with fluid nozzles terminated with mechanical-coupling end connections for connection to field piping.
 - f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
 - g. Provide each condenser with a pressure relief device, purge cock, and liquid-line shutoff valve.
3. Brazed Plate:
 - a. Single-pass, brazed-plate design provides positive subcooling of liquid refrigerant.
 - b. Type 316 stainless-steel construction.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - d. Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
 - e. Provide each condenser with a liquid-line shutoff valve.
4. Provide water chiller without an integral condenser and design chiller for field connection to remote condenser. Coordinate requirements with Section 236313 "Air-Cooled Refrigerant Condensers."

J. Electrical Power:

1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
2. House in a unit-mounted, NEMA 250, **[Type 1] <Insert type>** enclosure with hinged access door with lock and key or padlock and key.
3. Wiring shall be numbered and color-coded to match wiring diagram.
4. Install factory wiring outside of an enclosure in a raceway.
5. Field power interface shall be to **[wire lugs] [NEMA KS 1, heavy-duty, nonfused disconnect switch]**.
6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:

- a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA KS 1, heavy-duty, nonfusible switch.
 - c. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
7. Provide each motor with overcurrent protection.
 8. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
 9. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
 10. Controls Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
 11. Control Relays: Auxiliary and adjustable time-delay relays.
 12. Indicate the following for water chiller electrical power supply:
 - a. Current, phase to phase, for all three phases.
 - b. Voltage, phase to phase and phase to neutral for all three phases.
 - c. Three-phase real power (kilowatts).
 - d. Three-phase reactive power (kilovolt amperes reactive).
 - e. Power factor.
 - f. Running log of total power versus time (kilowatt hours).
 - g. Fault log, with time and date of each.
 - h. **<Insert features>**.

K. Controls:

1. Stand-alone, microprocessor based.
2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
3. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Operating hours.
 - d. Outside-air temperature if required for chilled-water reset.
 - e. Temperature and pressure of operating set points.
 - f. Entering and leaving temperatures of chilled water.
 - g. Entering and leaving temperatures of condenser water.
 - h. Refrigerant pressures in evaporator and condenser.
 - i. Saturation temperature in evaporator and condenser.
 - j. No cooling load condition.
 - k. Elapsed time meter (compressor run status).
 - l. Pump status.
 - m. Antirecycling timer status.
 - n. Percent of maximum motor amperage.
 - o. Current-limit set point.

- p. Number of compressor starts.
 - q. **<Insert items>**.
4. Control Functions:
- a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on **[return-water] [outside-air] [space]** temperature.
 - c. Current limit and demand limit.
 - d. Condenser-water temperature.
 - e. External water chiller emergency stop.
 - f. Antirecycling timer.
 - g. Automatic lead-lag switching.
 - h. **<Insert functions>**.
5. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
- a. Low evaporator pressure or high condenser pressure.
 - b. Low chilled-water temperature.
 - c. Refrigerant high pressure.
 - d. High or low oil pressure.
 - e. High oil temperature.
 - f. Loss of chilled-water flow.
 - g. Loss of condenser-water flow.
 - h. Control device failure.
 - i. **<Insert items>**.
6. Interface with DDC System for HVAC: Factory-installed hardware and software to enable DDC system for HVAC to monitor, control, and display water chiller status and alarms.
- a. Hardwired Points:
 - 1) Monitoring: On/off status, **[common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt hours)] <Insert monitoring point>**.
 - 2) Control: On/off operation, **[chilled-water discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>**.
 - b. **[ASHRAE 135 (BACnet)] [LonTalk] [Industry-accepted open-protocol] <Insert type of interface>** communication interface with DDC system for HVAC shall enable DDC system for HVAC operator to control and monitor the water chiller from a remote operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through DDC system for HVAC.

L. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
2. Thickness: [3/4 inch (19 mm)] <Insert thickness>.
3. Factory-applied insulation over cold surfaces of water chiller components.
 - a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Apply protective coating to exposed surfaces of insulation.

M. Accessories:

1. Factory-furnished, chilled-[**and condenser-**]water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves.
3. Factory-furnished spring isolators for field installation.

N. Capacities and Characteristics:

1. Capacity: <Insert tons (kW)>.
2. Full-Load Efficiency:
 - a. COP: <Insert number>.
 - b. EER: <Insert number>.
 - c. Power Input/Cooling Output, kW/ton (kW/kW): <Insert value>.
3. Part-Load Efficiency:
 - a. IPLV: <Insert number>.
 - b. NPLV: <Insert number>.
4. Evaporator Type: [**Brazed plate**] [**Shell and tube**].
5. Evaporator Pressure Rating: <Insert psig (kPa)>.
6. Evaporator Fluid Type: [**Water**] <Insert fluid type>.
7. Design Evaporator Fluid Flow Rate: <Insert gpm (L/s)>.
8. Minimum Evaporator Fluid Flow Rate: <Insert gpm (L/s)>.
9. Evaporator Entering-Fluid Temperature: <Insert deg F (deg C)>.
10. Evaporator Leaving-Fluid Temperature: <Insert deg F (deg C)>.
11. Evaporator Fluid Pressure Drop: <Insert feet of head (kPa)>.
12. Evaporator Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert factor>.
13. Condenser Type: [**Brazed plate**] [**Shell and tube**] [**Chiller without integral condenser**].
14. Condenser Pressure Rating: <Insert psig (kPa)>.
15. Condenser Fluid Type: [**Water**] <Insert fluid type>.
16. Condenser Fluid Flow Rate: <Insert gpm (L/s)>.
17. Condenser Entering-Fluid Temperature: <Insert deg F (deg C)>.
18. Condenser Leaving-Fluid Temperature: <Insert deg F (deg C)>.
19. Condenser Fluid Pressure Drop: <Insert feet of head (kPa)>.

20. Condenser Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg F/Btu (0.00022 sq. m x deg C/W)] <Insert factor>.
21. Number of Refrigeration Circuits: [One] [Two].
22. Compressor Rated Load Amperes: <Insert value>.
23. Compressor Locked-Rotor Amperes: <Insert value>.
24. Controls Power Connection: [Fed through integral transformer] [Separate field power connection].
 - a. Controls Power Input: <Insert kilowatts>.
 - b. Controls Minimum Circuit Ampacity: <Insert value>.
 - c. Controls Maximum Overcurrent Protection Device: <Insert amperage>.
 - d. Controls Electrical Characteristics: [120] <Insert value>-V ac, [single] [three] phase, 60 Hz.
25. Chiller Power Input: <Insert kilowatts>.
26. Chiller Minimum Circuit Ampacity: <Insert value>.
27. Chiller Maximum Overcurrent Protection Device: <Insert amperage>.
28. Chiller Electrical Characteristics: [208] [240] [480] [600] <Insert value>-V ac, three phase, 60 Hz.
29. Noise Rating: <Insert dBA> at <Insert distance in feet (m)> when measured according to ARI 575.

2.2 PACKAGED AIR-COOLED WATER CHILLERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. Carrier Corporation.
 2. <Insert manufacturer's name>.
 3. or approved equal.
- B. Description: Factory-assembled and run-tested water chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
- C. Fabricate base, frame, and attachment to water chiller components strong enough to resist movement during a seismic event when water chiller base is anchored to field support structure.
- D. Cabinet:
 1. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit. Base shall be designed to limit deflection to L/200 and shall be a minimum of 4 inches ((100 mm))high.
 2. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly

- supported from base.
 - 3. Casing: Galvanized steel.
 - 4. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a [500] <Insert hours>-hour salt-spray test according to ASTM B 117.
 - 5. Sound-reduction package consisting of the following:
 - a. Acoustic enclosure around compressors.
 - b. Reduced-speed fans with acoustic treatment.
 - c. Designed to reduce sound level without affecting performance.
 - 6. Security Package: Provide security grilles with fasteners for additional protection of compressors, evaporator, and condenser coils. Grilles shall be coated for corrosion resistance and shall be removable for service access.
- E. Compressors:
- 1. Description: Positive-displacement direct drive with semihermetically sealed and accessible bolted casings.
 - 2. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
 - 3. Operating Speed: 1750 rpm for 60-Hz applications.
 - 4. Capacity Control: Combinations of cylinder unloading and on-off compressor cycling of multiple compressors[, **plus hot-gas bypass**]. Compressor shall be capable of operating at part-load conditions without increased vibration over normal vibration at full-load operation and shall be capable of continuous operation at its lowest step of unloading.
 - 5. Oil Lubrication System: Automatically reversible, positive-displacement pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
 - 6. Vibration Isolation: Mount individual compressors on spring isolators with an isolation efficiency of 95 percent.
- F. Compressor Motors:
- 1. Hermetically sealed and cooled by refrigerant suction gas.
 - 2. High-torque, four-pole induction type with inherent thermal-overload protection on each phase.
- G. Compressor Motor Controllers:
- 1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
 - 2. Part-Wind Start: NEMA ICS 2, Class A, reduced voltage, nonreversing.
- H. Refrigeration:
- 1. Refrigerant: R-22. Classified as Safety Group A1 according to ASHRAE 34.
 - 2. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

3. Refrigerant Circuit: Each circuit shall include **[a thermal] [an electronic]** expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
4. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

I. Evaporator:

1. Description: Direct-expansion shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
2. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
3. Shell Material: Carbon steel.
4. Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
5. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
6. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
7. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to **minus 20 deg F (minus 29 deg C)**.
8. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.

J. Air-Cooled Condenser:

1. Plate-fin coil with integral subcooling circuit, leak tested at **150 psig (1034 kPa)**.
 - a. Construct coils of copper tubes mechanically bonded to **[aluminum] [aluminum with precoated epoxy-phenolic] [copper]** fins.
 - b. Coat coils with a baked epoxy corrosion-resistant coating after fabrication.
 - c. Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.
2. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
3. Fan Motors: Totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings, and having built-in overcurrent- and thermal-overload protection.
4. Fan Guards: Steel safety guards with corrosion-resistant coating.

K. Electrical Power:

1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.

2. House in a unit-mounted, NEMA 250, **[Type 3R] [Type 4] <Insert type>** enclosure with hinged access door with lock and key or padlock and key.
 3. Wiring shall be numbered and color-coded to match wiring diagram.
 4. Install factory wiring outside of an enclosure in a raceway.
 5. Field power interface shall be to **[wire lugs] [NEMA KS 1, heavy-duty, nonfused disconnect switch]**.
 6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
 - a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA KS 1, heavy-duty, nonfusible switch.
 - c. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
 7. Provide each motor with overcurrent protection.
 8. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
 9. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
 10. Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
 - a. Power unit-mounted controls where indicated.
 - b. Power unit-mounted, ground-fault interrupt (GFI) duplex receptacle.
 11. Control Relays: Auxiliary and adjustable time-delay relays.
 12. Indicate the following for water chiller electrical power supply:
 - a. Current, phase to phase, for all three phases.
 - b. Voltage, phase to phase and phase to neutral for all three phases.
 - c. Three-phase real power (kilowatts).
 - d. Three-phase reactive power (kilovolt amperes reactive).
 - e. Power factor.
 - f. Running log of total power versus time (kilowatt hours).
 - g. Fault log, with time and date of each.
 - h. **<Insert features>**.
- L. Controls:
1. Stand-alone, microprocessor based.
 2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
 3. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Operating hours.

- d. Outside-air temperature if required for chilled-water reset.
 - e. Temperature and pressure of operating set points.
 - f. Entering and leaving temperatures of chilled water.
 - g. Refrigerant pressures in evaporator and condenser.
 - h. Saturation temperature in evaporator and condenser.
 - i. No cooling load condition.
 - j. Elapsed time meter (compressor run status).
 - k. Pump status.
 - l. Antirecycling timer status.
 - m. Percent of maximum motor amperage.
 - n. Current-limit set point.
 - o. Number of compressor starts.
 - p. **<Insert items>**.
4. Control Functions:
- a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperature, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on **[return-water] [outside-air] [space]** temperature.
 - c. Current limit and demand limit.
 - d. External water chiller emergency stop.
 - e. Antirecycling timer.
 - f. Automatic lead-lag switching.
 - g. **<Insert functions>**.
5. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
- a. Low evaporator pressure or high condenser pressure.
 - b. Low chilled-water temperature.
 - c. Refrigerant high pressure.
 - d. High or low oil pressure.
 - e. High oil temperature.
 - f. Loss of chilled-water flow.
 - g. Control device failure.
 - h. **<Insert items>**.
6. Interface with DDC System for HVAC: Factory-installed hardware and software to enable DDC system for HVAC to monitor, control, and display water chiller status and alarms.
- a. Hardwired Points:
 - 1) Monitoring: On/off status, **[common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt hours)] <Insert monitoring point>**.
 - 2) Control: On/off operation, **[chilled-water discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>**.

- b. **[ASHRAE 135 (BACnet)] [LonTalk] [Industry-accepted open-protocol]** <Insert type of interface> communication interface with DDC system for HVAC shall enable DDC system for HVAC operator to control and monitor the water chiller from a remote operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through DDC system for HVAC.

M. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
2. Thickness: **[3/4 inch (19 mm)] <Insert thickness>**.
3. Factory-applied insulation over cold surfaces of water chiller components.
 - a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Apply protective coating to exposed surfaces of insulation.

N. Accessories:

1. Factory-furnished, chilled-**[and condenser-]**water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves.
3. Factory-furnished spring isolators for field installation.

O. Capacities and Characteristics:

1. Capacity: **<Insert tons (kW)>**.
2. Full-Load Efficiency:
 - a. COP: **<Insert number>**.
 - b. EER: **<Insert number>**.
 - c. Power Input/Cooling Output, **kW/ton (kW/kW): <Insert value>**.
3. Part-Load Efficiency:
 - a. IPLV: **<Insert number>**.
 - b. NPLV: **<Insert number>**.
4. Low Ambient Operation: Chiller designed for operation to **minus 20 deg F** (minus 29 deg C).
5. High Ambient Operation: Chiller designed for operation to **125 deg F** (52 deg C).
6. Evaporator Configuration: **[Integral to chiller] [Shipped loose for remote field installation]**.
7. Evaporator Pressure Rating: **[300 psig (2068 kPa)] <Insert value>**.
8. Evaporator Fluid Type: **[Water] <Insert fluid type>**.
9. Design Evaporator Fluid Flow Rate: **<Insert gpm (L/s)>**.
10. Minimum Evaporator Fluid Flow Rate: **<Insert gpm (L/s)>**.
11. Evaporator Entering-Fluid Temperature: **<Insert deg F (deg C)>**.

12. Evaporator Leaving-Fluid Temperature: <Insert deg F (deg C)>.
13. Evaporator Fluid Pressure Drop: <Insert feet of head (kPa)>.
14. Evaporator Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.
15. Condenser Entering-Air Temperature: <Insert deg F (deg C)>.
16. Site Altitude: <Insert feet (m)>.
17. Condenser Fan External Static Pressure: [0.4-inch wg (100 Pa)] [1.0-inch wg (250 Pa)].
18. Number of Refrigeration Circuits: Two.
19. Compressor Rated Load Amperes: <Insert value>.
20. Compressor Locked-Rotor Amperes: <Insert value>.
21. Controls Power Connection: [Fed through integral transformer] [Separate field power connection].
 - a. Controls Power Input: <Insert kilowatts>.
 - b. Controls Minimum Circuit Ampacity: <Insert value>.
 - c. Controls Maximum Overcurrent Protection Device: <Insert amperage>.
 - d. Controls Electrical Characteristics: [120] <Insert value>-V ac, single phase, 60 Hz.
22. Chiller Power Input: <Insert kilowatts>.
23. Chiller Minimum Circuit Ampacity: <Insert value>.
24. Chiller Maximum Overcurrent Protection Device: <Insert amperage>.
25. Chiller Electrical Characteristics: [208] [240] [480] [600] <Insert value>-V ac, three phase, 60 Hz.
26. Noise Rating: <Insert dBA> at <Insert distance in feet (m)> when measured according to ARI 370.

2.3 PACKAGED REFRIGERANT RECOVERY UNITS

- A. Packaged portable unit shall consist of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest water chiller.

2.4 SOURCE QUALITY CONTROL

- A. Perform functional test of water chillers before shipping.
- B. Factory performance test water chillers, before shipping, according to ARI 506/110, "Water Chilling Packages Using the Vapor Compression Cycle."
 1. Allow [Owner] <Insert entity> access to place where water chillers are being tested. Notify DEN Project Manager [14] <Insert number> days in advance of testing.

- C. Factory test and inspect evaporator [**and water-cooled condenser**] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.
- D. For water chillers located indoors, rate sound power level according to ARI 575 procedure.
- E. For water chillers located outdoors, rate sound power level according to ARI 370 procedure.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before water chiller installation, examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting water chiller performance, maintenance, and operations.
 - 1. Water chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 WATER CHILLER INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install water chillers on support structure indicated.
- C. Equipment Mounting:
 - 1. Install water chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Maintain manufacturer's recommended clearances for service and maintenance.
- E. Charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.
- F. Install separate devices furnished by manufacturer and not factory installed.

- G. Provide connections to chilled water piping.
1. On inlet, provide:
 - a. Thermometer well for temperature controller.
 - b. Thermometer.
 - c. Strainer.
 - d. Flow switch.
 - e. Flexible pipe connector.
 - f. Pressure gage.
 - g. Shut-off valve.
 2. On outlet, provide:
 - a. Thermometer.
 - b. Flexible pipe connector.
 - c. Pressure gage.
 - d. **[Shut-off] [Balancing]** valve.

3.3 CONNECTIONS

- A. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements in Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Install piping adjacent to chiller to allow service and maintenance.
- D. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with pressure gage, **[flow meter,]** and drain connection with valve. Make connections to water chiller with a **[union] [flange] [mechanical coupling] [union, flange, or mechanical coupling]**.
- E. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with pressure gage, **[flow meter,]** and drain connection with valve. Make connections to water chiller with a **[union] [flange] [mechanical coupling] [union, flange, or mechanical coupling]**.
- F. Refrigerant Pressure Relief Valve Connections: For water chillers installed indoors, extend vent piping to the outside without valves or restrictions. **[Comply with ASHRAE 15.]**
- G. Connect each drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection if required.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service. Supply service of factory trained representative for a period of **<Insert number>** days to supervise testing, dehydration and charging of machine, start-up, and instruction on operation and maintenance.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
- C. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - 1. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
 - 2. Verify that pumps are installed and functional.
 - 3. Verify that thermometers and gages are installed.
 - 4. Operate water chiller for run-in period.
 - 5. Check bearing lubrication and oil levels.
 - 6. Verify that refrigerant pressure relief for chillers installed indoors is vented outside.
 - 7. Verify proper motor rotation.
 - 8. Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.
 - 9. Verify and record performance of chilled-[**and condenser-**]water flow and low-temperature interlocks.
 - 10. Verify and record performance of water chiller protection devices.
 - 11. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
- D. Prepare a written startup report that records results of tests and inspections.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain water chillers.[**Video record the training sessions.**]
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236419

SECTION 236423 - SCROLL WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, water-cooled, electric-motor-driven, scroll water chillers.
 - 2. Packaged, air-cooled, electric-motor-driven, scroll water chillers.
 - 3. Packaged refrigerant recovery units.
- B. Related Sections:
 - 1. Section 283500 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- B. DDC: Direct digital control.
- C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
- D. IPLV: Integrated part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and referenced to ARI standard rating conditions.
- E. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
- F. NPLV: Nonstandard part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and intended for operating conditions other than the ARI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Scroll water chillers shall withstand the effects of earthquake motions determined according to **[SEI/ASCE 7] <Insert requirement>**.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Indicate valves, strainers, and thermostatic valves required for complete system. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
1. Performance at ARI standard conditions and at conditions indicated.
 2. Performance at ARI standard unloading conditions.
 3. Minimum evaporator flow rate.
 4. Refrigerant capacity of water chiller.
 5. Oil capacity of water chiller.
 6. Fluid capacity of evaporator.
 7. Fluid capacity of condenser.
 8. Characteristics of safety relief valves.
 9. Minimum entering condenser-water temperature.
 10. Performance at varying capacity with constant design condenser-water temperature. Repeat performance at varying capacity for different condenser-water temperatures from design to minimum in [5 deg F (3 deg C)] **<Insert deg F (deg C)>** increments.
 11. Minimum entering condenser-air temperature
 12. Performance at varying capacity with constant design entering condenser-air temperature. Repeat performance at varying capacity for different entering condenser-air temperatures from design to minimum in [10 deg F (6 deg C)] **<Insert deg F (deg C)>** increments.
 13. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
- C. Shop Drawings: Complete set of manufacturer's prints of water chiller assemblies, control panels, sections and elevations, and unit isolation. Include the following:
1. Assembled unit dimensions.
 2. Weight and load distribution.
 3. Required clearances for maintenance and operation.
 4. Size and location of piping and wiring connections.
 5. Wiring Diagrams: For power, signal, and control wiring.

6. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Structural supports.
 2. Piping roughing-in requirements.
 3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
- B. Certificates: For certification required in "Quality Assurance" Article.
- C. Seismic Qualification Certificates: For water chillers, accessories, and components from manufacturers.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
- E. Source quality-control test reports.
- F. Startup service reports.
- G. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each water chiller to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300

"Submittal Procedures".

1.8 MAINTENANCE MATERIALS

- A. Provide [**two (2)**] <Insert number> containers of [**lubricating oil**] [**refrigerant**].

1.9 QUALITY ASSURANCE

- A. ARI Certification: Certify chiller according to ARI 590 certification program.
- B. ARI Rating: Rate water chiller performance according to requirements in ARI 506/110, "Water Chilling Packages Using the Vapor Compression Cycle."
- C. ASHRAE Compliance: ASHRAE 15 for safety code for mechanical refrigeration.
- D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- E. ASME Compliance: Fabricate and stamp water chiller heat exchangers to comply with ASME Boiler and Pressure Vessel Code.
- F. Comply with NFPA 70.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Ship water chillers from the factory fully charged with refrigerant and filled with oil.
- B. Package water chiller for export shipping.
- C. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.
- D. Protect units from physical damage.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water chillers that fail in materials or workmanship within specified period.
1. Compressor Warranty Period: Minimum **[five (5)] <Insert number>** years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PACKAGED WATER-COOLED WATER CHILLERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [McQuay International](#).
 2. [Trane](#).
 3. **<Insert manufacturer's name>**.
 4. or approved equal.
- B. Description: Factory-assembled and run-tested water chiller complete with compressor(s), compressor motors and motor controllers, evaporator, condenser where indicated, electrical power, controls, and indicated accessories.
- C. Fabricate water chiller mounting base with reinforcement strong enough to resist water chiller movement during a seismic event when water chiller is anchored to field support structure.
- D. Compressors:
1. Description: Positive-displacement direct drive with hermetically sealed casing.
 2. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
 3. Operating Speed: Nominal 3600 rpm for 60-Hz applications.
 4. Capacity Control: On-off compressor cycling[, **plus hot-gas bypass**].
 5. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
 6. Vibration Isolation: Mount individual compressors on vibration isolators.
 7. Sound-reduction package shall consist of acoustic enclosures around the compressors that are designed to reduce sound level without affecting performance.

E. Compressor Motors:

1. Hermetically sealed and cooled by refrigerant suction gas.
2. High-torque, two-pole induction type with inherent thermal-overload protection on each phase.

F. Compressor Motor Controllers:

1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.

G. Refrigeration:

1. Refrigerant: R-22. Classified as Safety Group A1 according to ASHRAE 34.
2. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
3. Refrigerant Circuit: Each circuit shall include a thermal-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
4. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

H. Evaporator:

1. Brazed-plate or shell-and-tube design, as indicated.
2. Shell and Tube:
 - a. Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
 - b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - c. Shell Material: Carbon steel.
 - d. Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
 - e. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
 - f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
3. Brazed Plate:
 - a. Direct-expansion, single-pass, brazed-plate design.
 - b. Type 316 stainless-steel construction.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.

- d. Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.

I. Condenser:

1. Shell and tube or without integral condenser; as indicated.
2. Shell and Tube:
 - a. Description: Shell-and-tube design with refrigerant flowing through the shell and fluid flowing through the tubes within the shell.
 - b. Provides positive subcooling of liquid refrigerant.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - d. Shell Material: Carbon steel.
 - e. Water Boxes: Removable, of carbon-steel construction, located at each end of the tube bundle with fluid nozzles terminated with mechanical-coupling end connections for connection to field piping.
 - f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
 - g. Provide each condenser with a pressure relief device, purge cock, and liquid-line shutoff valve.
3. Provide water chiller without an integral condenser and design chiller for field connection to remote condenser. Coordinate requirements with Section 236313 "Air-Cooled Refrigerant Condensers."

J. Electrical Power:

1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
2. House in a unit-mounted, NEMA 250, [Type 1] <Insert type> enclosure with hinged access door with lock and key or padlock and key.
3. Wiring shall be numbered and color-coded to match wiring diagram.
4. Install factory wiring outside of an enclosure in a raceway.
5. Field power interface shall be to [wire lugs] [NEMA KS 1, heavy-duty, nonfused disconnect switch].
6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
 - a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA KS 1, heavy-duty, nonfusible switch.
 - c. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
7. Provide each motor with overcurrent protection.
8. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.

9. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
10. Controls Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
11. Control Relays: Auxiliary and adjustable time-delay relays.
12. Indicate the following for water chiller electrical power supply:
 - a. Current, phase to phase, for all three phases.
 - b. Voltage, phase to phase and phase to neutral for all three phases.
 - c. Three-phase real power (kilowatts).
 - d. Three-phase reactive power (kilovolt amperes reactive).
 - e. Power factor.
 - f. Running log of total power versus time (kilowatt hours).
 - g. Fault log, with time and date of each.
 - h. **<Insert features>**.

K. Controls:

1. Stand-alone, microprocessor based.
2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
3. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Operating hours.
 - d. Outside-air temperature if required for chilled-water reset.
 - e. Temperature and pressure of operating set points.
 - f. Entering and leaving temperatures of chilled water.
 - g. Entering and leaving temperatures of condenser water.
 - h. Refrigerant pressures in evaporator and condenser.
 - i. Saturation temperature in evaporator and condenser.
 - j. No cooling load condition.
 - k. Elapsed time meter (compressor run status).
 - l. Pump status.
 - m. Antirecycling timer status.
 - n. Percent of maximum motor amperage.
 - o. Current-limit set point.
 - p. Number of compressor starts.
 - q. **<Insert items>**.
4. Control Functions:
 - a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on **[return-water] [outside-air] [space]** temperature.
 - c. Current limit and demand limit.

- d. Condenser-water temperature.
 - e. External water chiller emergency stop.
 - f. Antirecycling timer.
 - g. Automatic lead-lag switching.
 - h. **<Insert functions>**.
5. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
- a. Low evaporator pressure or high condenser pressure.
 - b. Low chilled-water temperature.
 - c. Refrigerant high pressure.
 - d. High or low oil pressure.
 - e. High oil temperature.
 - f. Loss of chilled-water flow.
 - g. Loss of condenser-water flow.
 - h. Control device failure.
 - i. **<Insert items>**.
6. Interface with DDC System for HVAC: Factory-installed hardware and software to enable DDC system for HVAC to monitor, control, and display water chiller status and alarms.
- a. Hardwired Points:
 - 1) Monitoring: On/off status, [**common trouble alarm**] [**electrical power demand (kilowatts)**] [**electrical power consumption (kilowatt hours)**] **<Insert monitoring point>**.
 - 2) Control: On/off operation, [**chilled-water discharge temperature set-point adjustment**] [**electrical power demand limit**] **<Insert control point>**.
 - b. [**ASHRAE 135 (BACnet)**] [**LonTalk**] [**Modbus**] [**Industry-accepted open-protocol**] **<Insert type of interface>** communication interface with DDC system for HVAC shall enable DDC system for HVAC operator to remotely control and monitor the water chiller from an operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through DDC system for HVAC.
- L. Insulation:
1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
 2. Thickness: [**3/4 inch (19 mm)**] **<Insert thickness>**.
 3. Factory-applied insulation over cold surfaces of water chiller components.
 - a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
 4. Apply protective coating to exposed surfaces of insulation.

M. Accessories:

1. Factory-furnished, chilled-[**and condenser-**]water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigeration circuit.
3. Factory-furnished [**neoprene**] [**spring**] [**neoprene or spring**] isolators for field installation.

N. Capacities and Characteristics:

1. Capacity: <Insert tons (kW)>.
2. Full-Load Efficiency:
 - a. COP: <Insert number>.
 - b. EER: <Insert number>.
 - c. Power Input/Cooling Output, kW/Ton (kW/kW): <Insert value>.
3. Part-Load Efficiency:
 - a. IPLV: <Insert number>.
 - b. NPLV: <Insert number>.
4. Evaporator Type: [**Brazed plate**] [**Shell and tube**] [**Brazed plate or shell and tube**].
5. Evaporator Pressure Rating: <Insert psig (kPa)>.
6. Evaporator Fluid Type: [**Water**] <Insert fluid type>.
7. Design Evaporator Fluid Flow Rate: <Insert gpm (L/s)>.
8. Minimum Evaporator Fluid Flow Rate: <Insert gpm (L/s)>.
9. Evaporator Entering-Fluid Temperature: <Insert deg F (deg C)>.
10. Evaporator Leaving-Fluid Temperature: <Insert deg F (deg C)>.
11. Evaporator Fluid Pressure Drop: <Insert feet of head (kPa)>.
12. Evaporator Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.
13. Condenser Type: [**Shell and tube**] [**Chiller without integral condenser**].
14. Condenser Pressure Rating: <Insert psig (kPa)>.
15. Condenser Fluid Type: [**Water**] <Insert fluid type>.
16. Condenser Fluid Flow Rate: <Insert gpm (L/s)>.
17. Condenser Entering-Fluid Temperature: <Insert deg F (deg C)>.
18. Condenser Leaving-Fluid Temperature: <Insert deg F (deg C)>.
19. Condenser Fluid Pressure Drop: <Insert feet of head (kPa)>.
20. Condenser Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg F/Btu (0.00022 sq. m x deg C/W)] <Insert factor>.
21. Number of Refrigeration Circuits: [**One**] [**Two**].
22. Compressor Rated Load Amperes: <Insert value>.
23. Compressor Locked-Rotor Amperes: <Insert value>.
24. Controls Power Connection: Fed through integral transformer.
25. Chiller Power Input: <Insert kilowatts>.

26. Chiller Minimum Circuit Ampacity: **<Insert value>**.
27. Chiller Maximum Overcurrent Protection Device: **<Insert amperage>**.
28. Chiller Electrical Characteristics: **[208] [240] [480] [600] <Insert value>**-V ac, three phase, 60 Hz.
29. Noise Rating: **<Insert dBA>** at **<Insert distance in feet (m)>** when measured according to ARI 575.

2.2 PACKAGED AIR-COOLED WATER CHILLERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Carrier Corporation](#).
 2. [McQuay International](#).
 3. [Trane](#).
 4. [York International Corporation](#).
 5. **<Insert manufacturer's name>**.
 6. or approved equal.
- B. Description: Factory-assembled and run-tested water chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
- C. Fabricate base, frame, and attachment to water chiller components strong enough to resist movement during a seismic event when water chiller base is anchored to field support structure.
- D. Cabinet:
 1. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
 2. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported from base.
 3. Casing: Galvanized steel.
 4. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a **[500] <Insert hours>**-hour salt-spray test according to ASTM B 117.
 5. Sound-reduction package consisting of the following:
 - a. Acoustic enclosure around compressors.
 - b. Reduced-speed fans with acoustic treatment.
 - c. Designed to reduce sound level without affecting performance.
 6. Security Package: Provide security grilles with fasteners for additional protection of compressors, evaporator, and condenser coils. Grilles shall be coated for corrosion resistance and shall be removable for service access.

E. Compressors:

1. Description: Positive-displacement direct drive with hermetically sealed casing.
2. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
3. Operating Speed: Nominal 3600 rpm for 60-Hz applications.
4. Capacity Control: On-off compressor cycling[, **plus hot-gas bypass**].
5. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
6. Vibration Isolation: Mount individual compressors on vibration isolators.

F. Compressor Motors:

1. Hermetically sealed and cooled by refrigerant suction gas.
2. High-torque, two-pole induction type with inherent thermal-overload protection on each phase.

G. Compressor Motor Controllers:

1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.

H. Refrigeration:

1. Refrigerant: **[R-22] [R-407c] [or] [R-410a]**. Classified as Safety Group A1 according to ASHRAE 34.
2. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
3. Refrigerant Circuit: Each circuit shall include a thermal-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
4. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

I. Evaporator:

1. Brazed-plate or shell-and-tube design, as indicated.
2. Shell and Tube:
 - a. Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
 - b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - c. Shell Material: Carbon steel.
 - d. Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.

- e. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
 - f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
3. Brazed Plate:
- a. Direct-expansion, single-pass, brazed-plate design.
 - b. Type 316 stainless-steel construction.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
 - d. Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
4. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to **minus 20 deg F** (minus 29 deg C).
5. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.
- J. Air-Cooled Condenser:
1. Plate-fin coil with integral subcooling on each circuit, rated at **450 psig** (3103 kPa).
 - a. Construct coils of copper tubes mechanically bonded to **[aluminum]** **[aluminum with precoated epoxy-phenolic]** **[copper]** fins.
 - b. Coat coils with a baked epoxy corrosion-resistant coating after fabrication.
 - c. Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.
 2. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
 3. Fan Motors: Totally enclosed nonventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings, and having built-in overcurrent- and thermal-overload protection.
 4. Fan Guards: Steel safety guards with corrosion-resistant coating.
- K. Electrical Power:
1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
 2. House in a unit-mounted, NEMA 250, **[Type 3R]** **<Insert type>** enclosure with hinged access door with lock and key or padlock and key.
 3. Wiring shall be numbered and color-coded to match wiring diagram.
 4. Install factory wiring outside of an enclosure in a raceway.
 5. Field power interface shall be to **[wire lugs]** **[NEMA KS 1, heavy-duty, nonfused disconnect switch]**.
 6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:

- a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA KS 1, heavy-duty, nonfusible switch.
 - c. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
7. Provide each motor with overcurrent protection.
 8. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
 9. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
 10. Provide power factor correction capacitors to correct power factor to **[0.90] [0.95]** **<Insert value>** at full load.
 11. Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
 - a. Power unit-mounted controls where indicated.
 - b. Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.
 12. Control Relays: Auxiliary and adjustable time-delay relays.
 13. Indicate the following for water chiller electrical power supply:
 - a. Current, phase to phase, for all three phases.
 - b. Voltage, phase to phase and phase to neutral for all three phases.
 - c. Three-phase real power (kilowatts).
 - d. Three-phase reactive power (kilovolt amperes reactive).
 - e. Power factor.
 - f. Running log of total power versus time (kilowatt hours).
 - g. Fault log, with time and date of each.
 - h. **<Insert features>**.
- L. Controls:
1. Stand-alone, microprocessor based.
 2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
 3. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Operating hours.
 - d. Outside-air temperature if required for chilled-water reset.
 - e. Temperature and pressure of operating set points.
 - f. Entering and leaving temperatures of chilled water.
 - g. Refrigerant pressures in evaporator and condenser.
 - h. Saturation temperature in evaporator and condenser.
 - i. No cooling load condition.
 - j. Elapsed time meter (compressor run status).

- k. Pump status.
 - l. Antirecycling timer status.
 - m. Percent of maximum motor amperage.
 - n. Current-limit set point.
 - o. Number of compressor starts.
 - p. **<Insert items>**.
4. Control Functions:
- a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on **[return-water] [outside-air] [space]** temperature.
 - c. Current limit and demand limit.
 - d. External water chiller emergency stop.
 - e. Antirecycling timer.
 - f. Automatic lead-lag switching.
 - g. **<Insert functions>**.
5. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
- a. Low evaporator pressure or high condenser pressure.
 - b. Low chilled-water temperature.
 - c. Refrigerant high pressure.
 - d. High or low oil pressure.
 - e. High oil temperature.
 - f. Loss of chilled-water flow.
 - g. Control device failure.
 - h. **<Insert items>**.
6. Interface with DDC System for HVAC: Factory-installed hardware and software to enable DDC system for HVAC to monitor, control, and display water chiller status and alarms.
- a. Hardwired Points:
 - 1) Monitoring: On/off status, **[common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt hours)] <Insert monitoring point>**.
 - 2) Control: On/off operation, **[chilled-water discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>**.
 - b. **[ASHRAE 135 (BACnet)] [LonTalk] [Industry-accepted open-protocol] <Insert type of interface>** communication interface with DDC system for HVAC shall enable DDC system for HVAC operator to remotely control and monitor the water chiller from an operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through DDC system for HVAC.

M. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
2. Thickness: [3/4 inch (19 mm)] [1-1/2 inches (38 mm)] <Insert thickness>.
3. Factory-applied insulation over cold surfaces of water chiller components.
 - a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Apply protective coating to exposed surfaces of insulation.

N. Accessories:

1. Factory-furnished, chilled-[**and condenser-**]water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigeration circuit.
3. Factory-furnished [**neoprene**] [**spring**] [**neoprene or spring**] isolators for field installation.

O. Capacities and Characteristics:

1. Capacity: <Insert tons (kW)>.
2. Full-Load Efficiency:
 - a. COP: <Insert number>.
 - b. EER: <Insert number>.
 - c. Power Input/Cooling Output, kW/Ton (kW/kW): <Insert value>.
3. Part-Load Efficiency:
 - a. IPLV: <Insert number>.
 - b. NPLV: <Insert number>.
4. Low Ambient Operation: Chiller designed for operation to [0 deg F (minus 18 deg C)] <Insert value>.
5. High Ambient Operation: Chiller designed for operation to [115 deg F (46 deg C)] <Insert value>.
6. Evaporator Configuration: [**Integral to chiller**] [**Shipped loose for remote field installation**].
7. Evaporator Pressure Rating: [150 psig (1034 kPa)] [300 psig (2068 kPa)] <Insert value>.
8. Evaporator Fluid Type: [**Water**] <Insert fluid type>.
9. Design Evaporator Fluid Flow Rate: <Insert gpm (L/s)>.
10. Minimum Evaporator Fluid Flow Rate: <Insert gpm (L/s)>.
11. Evaporator Entering-Fluid Temperature: <Insert deg F (deg C)>.
12. Evaporator Leaving-Fluid Temperature: <Insert deg F (deg C)>.
13. Evaporator Fluid Pressure Drop: <Insert feet of head (kPa)>.

14. Evaporator Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.
15. Condenser Entering-Air Temperature: <Insert deg F (deg C)>.
16. Site Altitude: <Insert feet (m)>.
17. Number of Refrigeration Circuits: [One] [Two].
18. Compressor Rated Load Amperes: <Insert value>.
19. Compressor Locked-Rotor Amperes: <Insert value>.
20. Controls Power Connection: [Fed through integral transformer] [Separate field power connection].
 - a. Controls Power Input: <Insert kilowatts>.
 - b. Controls Minimum Circuit Ampacity: <Insert value>.
 - c. Controls Maximum Overcurrent Protection Device: <Insert amperage>.
 - d. Controls Electrical Characteristics: [120] <Insert value>-V ac, single phase, 60 Hz.
21. Chiller Power Input: <Insert kilowatts>.
22. Chiller Minimum Circuit Ampacity: <Insert value>.
23. Chiller Maximum Overcurrent Protection Device: <Insert amperage>.
24. Chiller Electrical Characteristics: [208] [240] [480] [600] <Insert value>-V ac, three phase, 60 Hz.
25. Noise Rating: <Insert dBA> at <Insert distance in feet (m)> when measured according to ARI 370.

2.3 PACKAGED REFRIGERANT RECOVERY UNITS

- A. Packaged portable unit shall consist of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest water chiller.

2.4 SOURCE QUALITY CONTROL

- A. Perform functional test of water chillers before shipping.
- B. Factory performance test water chillers, before shipping, according to ARI 506/110, "Water Chilling Packages Using the Vapor Compression Cycle."
 1. Allow [Owner] <Insert entity> access to place where water chillers are being tested. Notify DEN Project Manager [14] <Insert number> days in advance of testing.
- C. Factory test and inspect evaporator [and water-cooled condenser] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.

- D. For water chillers located indoors, rate sound power level according to ARI 575 procedure.
- E. For water chillers located outdoors, rate sound power level according to ARI 370 procedure.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before water chiller installation, examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting water chiller performance, maintenance, and operations.
 - 1. Water chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 WATER CHILLER INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install water chillers on support structure indicated.
- C. Equipment Mounting:
 - 1. Install water chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Maintain manufacturer's recommended clearances for service and maintenance.
- E. Charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.
- F. Install separate devices furnished by manufacturer and not factory installed.
- G. Provide connections to chilled water piping.
 - 1. On inlet, provide:

- a. Thermometer well for temperature controller.
- b. Thermometer.
- c. Strainer.
- d. Flow switch.
- e. Flexible pipe connector.
- f. Pressure gage.
- g. Shut-off valve.

2. On outlet, provide:

- a. Thermometer.
- b. Flexible pipe connector.
- c. Pressure gage.
- d. **[Shut-off] [Balancing]** valve.

3.3 CONNECTIONS

- A. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements in Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Install piping adjacent to chiller to allow service and maintenance.
- D. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with pressure gage, [**flow meter,**] and drain connection with valve. Make connections to water chiller with a [**union**] [**flange**] [**mechanical coupling**] [**union, flange, or mechanical coupling**].
- E. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with pressure gage, [**flow meter,**] and drain connection with valve. Make connections to water chiller with a [**union**] [**flange**] [**mechanical coupling**] [**union, flange, or mechanical coupling**].
- F. Refrigerant Pressure Relief Valve Connections: For water chillers installed indoors, extend vent piping to the outside without valves or restrictions. [**Comply with ASHRAE 15.**]
- G. Connect each drain connection with a union and drain pipe and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection if required.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service. Supply service of factory trained representative for a period of **<Insert number>** days to supervise testing, dehydration and charging of machine, start-up, and instruction on operation and maintenance.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
- C. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - 1. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
 - 2. Verify that pumps are installed and functional.
 - 3. Verify that thermometers and gages are installed.
 - 4. Operate water chiller for run-in period.
 - 5. Check bearing lubrication and oil levels.
 - 6. Verify that refrigerant pressure relief device for chillers installed indoors is vented outside.
 - 7. Verify proper motor rotation.
 - 8. Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.
 - 9. Verify and record performance of chilled-[**and condenser-**]water flow and low-temperature interlocks.
 - 10. Verify and record performance of water chiller protection devices.
 - 11. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
- D. Prepare a written startup report that records results of tests and inspections.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain water chillers.[**Video record the training sessions.**]
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236423

SECTION 236426 - ROTARY-SCREW WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, water-cooled, single-compressor chillers.
 - 2. Packaged, water-cooled, multiple-compressor chillers.
 - 3. Packaged, air-cooled chillers.
 - 4. Packaged, portable refrigerant recovery units.
 - 5. Heat-exchanger, brush-cleaning system.
- B. Related Section:
 - 1. Section 283500 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- B. DDC: Direct digital control.
- C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
- D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and referenced to ARI standard rating conditions.
- E. **kW/Ton (kW/kW)**: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in **tons (kW)** at any given set of rating conditions.

- F. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 506/110 and intended for operating conditions other than ARI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Chillers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
- B. Condenser-Fluid Temperature Performance:
1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of [60 deg F (16 deg C)] [55 deg F (13 deg C)] [40 deg F (4 deg C)] <Insert temperature> and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
 2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of [65 deg F (18 deg C)] [60 deg F (16 deg C)] [55 deg F (13 deg C)].
 3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
- C. Site Altitude: Chiller shall be suitable for altitude in which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
- D. Performance Tolerance: Comply with the following in lieu of ARI 506/110:
1. Allowable Capacity Tolerance: [Zero] <Insert number> percent.
 2. Allowable IPLV/NPLV Performance Tolerance: [Zero] <Insert number> percent.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Indicate valves, strainers, and thermostatic valves required for complete system. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
1. Performance at ARI standard conditions and at conditions indicated.
 2. Performance at ARI standard unloading conditions.
 3. Minimum evaporator flow rate.
 4. Refrigerant capacity of chiller.
 5. Oil capacity of chiller.
 6. Fluid capacity of evaporator.
 7. Characteristics of safety relief valves.

8. Fluid capacity of condenser[**and heat-reclaim condenser**].
9. Minimum entering condenser-fluid temperature.
10. Performance at varying capacities with constant-design entering condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in [5 deg F (3 deg C)] **<Insert temperature>** increments.
11. Minimum entering condenser-air temperature.
12. Maximum entering condenser-air temperature.
13. Performance at varying capacities with constant-design entering condenser-air temperature. Repeat performance at varying capacities for different entering condenser-air temperatures from design to minimum in [10 deg F (6 deg C)] **<Insert temperature>** increments.
14. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.
3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

B. Certificates: For certification required in "Quality Assurance" Article.

- C. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
- E. Source quality-control reports.
- F. Startup service reports.
- G. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIALS

- A. Provide [**two (2)**] <Insert number> containers of [**lubricating oil**] [**refrigerant**].

1.9 QUALITY ASSURANCE

- A. ARI Certification: Certify chiller according to [**ARI 550**] [**and**] [**ARI 590**] certification program(s).
- B. ARI Rating: Rate chiller performance according to requirements in ARI 506/110.
- C. ASHRAE Compliance:
 - 1. ASHRAE 15 for safety code for mechanical refrigeration.
 - 2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.
- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

- E. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.
- F. Comply with NFPA 70.
- G. Comply with requirements of UL and UL Canada and include label by a qualified testing agency showing compliance.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Ship chillers from the factory fully charged with refrigerant.
- B. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.
- C. Ship each oil-lubricated chiller with a full charge of oil.
 - 1. Ship oil [**factory installed in chiller**] [**in containers separate from chiller**].
- D. Package chiller for export shipping in totally enclosed [**crate**] [**and**] [**bagging**].
- E. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.
- F. Protect units from physical damage.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
 - 1. Extended warranties include, but are not limited to, the following:
 - a. Complete chiller including refrigerant and oil charge.

- b. Complete compressor and drive assembly including refrigerant and oil charge.
 - c. Refrigerant [**and oil**] charge.
 - d. Parts [**only**] [**and labor**].
 - e. Loss of refrigerant charge for any reason.
2. Warranty Period: Minimum [**two (2)**] [**three (3)**] [**four (4)**] [**five (5)**] <Insert number> years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PACKAGED, WATER-COOLED, SINGLE-COMPRESSOR CHILLERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation](#).
 2. [Dunham-Bush](#).
 3. [Trane](#).
 4. [York International Corporation](#).
 5. <Insert manufacturer's name>.
 6. or approved equal.
- B. Description: Factory-assembled and [**run**]-tested chiller with compressor, compressor motor, compressor motor controller, lubrication system, evaporator, condenser, [**heat-reclaim condenser as indicated**], controls, interconnecting unit piping and wiring, and indicated accessories.
1. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
- C. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.
- D. Compressor:
1. Description: [**Hermetic**] [**or**] [**open**], positive displacement, and oil lubricated.
 2. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
 3. Rotors: Manufacturer's standard one-, two-, or three-rotor design.
 4. Drive Coupling: For chillers with open drives, provide flexible disc with all-metal construction and no wearing parts to ensure long life without the need for lubrication.
 5. Seals: Seal drive assembly to prevent refrigerant leakage.
- E. Compressor Motor:
1. Continuous-duty, squirrel-cage, induction-type motor with energy efficiency required to suit chiller energy efficiency indicated.

2. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
 3. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.
 4. For chillers with open drives, provide motor with **[open-dripproof]** **[weather-protected, Type I]** **[weather-protected, Type II]** **[totally enclosed]** enclosure.
 5. Provide motor with thermistor or RTD in **[single motor winding]** **[each of three-phase motor windings]** to monitor temperature and report information to chiller control panel.
 6. Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.
 7. Provide open-drive motor with internal electric heater, internally powered from chiller power supply.
- F. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
1. Overspeed Test: 25 percent above design operating speed.
- G. Service: Easily accessible for inspection and service.
1. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
 2. Provide lifting lugs or eyebolts attached to casing.
- H. Capacity Control: Modulating slide-valve assembly or port unloaders combined with **[a variable frequency controller, if applicable, and]**hot-gas bypass, if necessary, to achieve performance indicated.
1. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
 2. Operating Range: From 100 to **[20]** **[15]** **[10]** **[5]** **[zero]** **<Insert number>** percent of design capacity.
 3. Condenser-Fluid Unloading Requirements over Operating Range: **[Constant-design entering condenser-fluid temperature]** **[Drop-in entering condenser-fluid temperature of 2.5 deg F (1.4 deg C) drop for each 10 percent in capacity reduction]** **<Insert conditions>**.
- I. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
 2. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
 3. **[Oil filter]** **[Dual oil filters, one redundant,]** shall be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.

4. **[Refrigerant] [Water] [Refrigerant- or water]**-cooled oil cooler.
5. Factory-installed and pressure-tested piping with isolation valves and accessories.
6. Oil compatible with refrigerant and chiller components.
7. Positive visual indication of oil level.

J. Refrigerant Circuit:

1. Refrigerant: Type as indicated on Drawings.
2. Refrigerant Type: **[R-22] [R-134a] [or] [any HFC] <Insert type>**. Classified as Safety Group A1 according to ASHRAE 34.
3. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
4. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
5. Pressure Relief Device:
 - a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.
6. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.
7. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell. **[In addition, provide isolation valve on suction side of compressor from evaporator to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell.]**

K. Evaporator:

1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent liquid refrigerant carryover from entering compressor.
4. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.
5. Tubes:
 - a. Individually replaceable from either end and without damage to tube sheets and other tubes.

- b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 - c. Material: **[Copper]** **[Copper-nickel alloy]** **[Copper or copper-nickel alloy]** **<Insert material>**.
 - d. Nominal OD: **[Manufacturer's choice]** **[3/4 inch (19 mm)]** **[1 inch (25 mm)]** **[3/4 or 1 inch (19 or 25 mm)]**.
 - e. Minimum Wall Thickness: **[Manufacturer's choice]** **[0.025 inch (0.6 mm)]** **[0.028 inch (0.7 mm)]** **[0.035 inch (0.9 mm)]** **<Insert dimension>**.
 - f. External Finish: Manufacturer's standard.
 - g. Internal Finish: **[Enhanced]** **[Smooth]** **[Enhanced or smooth]**.
 6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
 7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
 8. Water Box:
 - a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 - b. **[Standard]** **[Marine]** type for water box with piping connections. Standard type for water box without piping connections.
 - c. Provide water boxes **[and marine water-box covers]** with lifting lugs or eyebolts.
 - d. **[Hinged]** **[or]** **[dovetailed]** water boxes.
 - e. **[Hinged]** **[or]** **[dovetailed]** marine water-box covers.
 - f. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange]** **[Welded, ASME B16.5, raised-face flange]** **[Grooved for mechanical-joint coupling]** **[Grooved with mechanical-joint coupling and flange adapter]**.
 - g. Thermistor or RTD temperature sensor factory installed in each nozzle.
 - h. Fit each water box with **[3/4-inch (19-mm)]** **[1-inch (25-mm)]** **[3/4- or 1-inch (19- or 25-mm)]** **<Insert size>** drain connection at low point and vent connection at high point, each with threaded plug.
 9. Additional Corrosion Protection:
 - a. Electrolytic corrosion-inhibitor anode.
 - b. Coat wetted surfaces with a corrosion-resistant finish.
- L. Condenser:
 1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.
 2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
 3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.

4. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.
5. Tubes:
 - a. Individually replaceable from either end and without damage to tube sheets and other tubes.
 - b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 - c. Material: **[Copper]** **[Copper-nickel alloy]** **[Copper or copper-nickel alloy]** **<Insert material>**.
 - d. Nominal OD: **[Manufacturer's choice]** **[3/4 inch (19 mm)]** **[1 inch (25 mm)]** **[3/4 or 1 inch (19 or 25 mm)]**.
 - e. Minimum Wall Thickness: **[Manufacturer's choice]** **[0.025 inch (0.6 mm)]** **[0.028 inch (0.7 mm)]** **[0.035 inch (0.9 mm)]** **<Insert dimension>**.
 - f. External Finish: Manufacturer's standard.
 - g. Internal Finish: **[Enhanced]** **[Smooth]** **[Enhanced or smooth]**.
6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
8. Water Box:
 - a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 - b. **[Standard]** **[Marine]** type for water box with piping connections. Standard type for water box without piping connections.
 - c. Provide water boxes **[and marine water-box covers]** with lifting lugs or eyebolts.
 - d. **[Hinged]** **[or]** **[davited]** water boxes.
 - e. **[Hinged]** **[or]** **[davited]** marine water-box covers.
 - f. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange]** **[Welded, ASME B16.5, raised-face flange]** **[Grooved for mechanical-joint coupling]** **[Grooved with mechanical-joint coupling and flange adapter]**.
 - g. Thermistor or RTD temperature sensor factory installed in each nozzle.
 - h. Fit each water box with **[3/4-inch (19-mm)]** **[1-inch (25-mm)]** **[3/4- or 1-inch (19- or 25-mm)]** **<Insert size>** drain connection at low point and vent connection at high point, each with threaded plug.
9. Additional Corrosion Protection:
 - a. Electrolytic corrosion-inhibitor anode.
 - b. Coat wetted surfaces with a corrosion-resistant finish.

M. Heat-Reclaim Condenser:

1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator and condenser.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
4. Tubes:
 - a. Individually replaceable from either end and without damage to tube sheets and other tubes.
 - b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 - c. Material: **[Copper]** **[Copper-nickel alloy]** **[Copper or copper-nickel alloy]** **<Insert material>**.
 - d. Nominal OD: **[Manufacturer's choice]** **[3/4 inch (19 mm)]** **[1 inch (25 mm)]** **[3/4 or 1 inch (19 or 25 mm)]**.
 - e. Minimum Wall Thickness: **[Manufacturer's choice]** **[0.025 inch (0.6 mm)]** **[0.028 inch (0.7 mm)]** **[0.035 inch (0.9 mm)]** **<Insert dimension>**.
 - f. External Finish: Manufacturer's standard.
 - g. Internal Finish: **[Enhanced]** **[Smooth]** **[Enhanced or smooth]**.
5. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
6. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
7. Water Box:
 - a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 - b. **[Standard]** **[Marine]** type for water box with piping connections. Standard type for water box without piping connections.
 - c. Provide water boxes **[and marine water-box covers]** with lifting lugs or eyebolts.
 - d. **[Hinged]** **[or]** **[dovetailed]** water boxes.
 - e. **[Hinged]** **[or]** **[dovetailed]** marine water-box covers.
 - f. Nozzle Pipe Connections: **[Welded, ASME B16.5, flat-face flange]** **[Welded, ASME B16.5, raised-face flange]** **[Grooved for mechanical-joint coupling]** **[Grooved with mechanical-joint coupling and flange adapter]**.
 - g. Thermistor or RTD temperature sensor factory installed in each nozzle.
 - h. Fit each water box with **[3/4-inch (19-mm)]** **[1-inch (25-mm)]** **[3/4- or 1-inch (19- or 25-mm)]** **<Insert size>** drain connection at low point and vent connection at high point, each with threaded plug.
8. Additional Corrosion Protection:
 - a. Electrolytic corrosion-inhibitor anode.
 - b. Coat wetted surfaces with a corrosion-resistant finish.

N. Electrical Power:

1. Factory installed and wired, and functionally tested at factory before shipment.
2. Single-point, field-power connection to **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[42,000] [65,000] <Insert value>** A.
 - a. Provide branch power circuit to each motor, electric heater, dedicated electrical load, and controls **[with disconnect switch or circuit breaker]**.
 - b. NEMA- and ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller for each variable-speed motor furnished.
 - c. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered **[and color-coded]** wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Factory-installed wiring outside of enclosures shall be in metal raceway except make connections to each motor and heater with not more than a **24-inch (610-mm)** length of liquidtight conduit.
5. Factory install and wire capacitor bank for the purpose of power factor correction to **[0.95] <Insert value>** at all operating conditions.
 - a. If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.
 - b. Capacitors shall be non-PCB dielectric fluid, metallized electrode design, low loss with low-temperature rise. The kVAr ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.
 - c. Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within 1 minute after de-energizing.
 - d. Provide a ground terminal and a terminal block or individual connectors for phase connection.

O. Motor Controller:

1. Enclosure: **[Factory installed, unit mounted] [Factory furnished, field mounted], [NEMA 250] [NEMA ICS 6], [Type 1] [Type 4] [Type 4X] [Type 12] <Insert type>**, with hinged full-front access door **[with lock and key or padlock and key]**.
2. Control Circuit: Obtained from **[integral control power transformer] <Insert source of control power>** with a control power **[transformer] [source]** of enough capacity to operate connected control devices.
3. Overload Relay: Shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.
4. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.

5. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.
6. Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition; include isolation switch and current-limiting fuses.
7. Solid-State, Reduced-Voltage Controller: NEMA ICS 2.
 - a. Surge suppressor in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
 - b. Visual indication of motor and control status, including the following conditions:
 - 1) Controller on.
 - 2) Overload trip.
 - 3) Loss of phase.
 - 4) Starter fault.
8. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
 - a. Externally Operated[, **Door-Interlocked**] Disconnect: [**Fused disconnect switch**] [**Nonfused disconnect switch**] [**Circuit breaker**]. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <Insert value> A.
 - b. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
 - c. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
 - d. Control Relays: Time-delay relays.
 - e. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
 - f. Number-of-Starts Counter: Numerical readout on face of enclosure.
 - g. Meters: Panel type, [**2-1/2 inches (64 mm)**] [**4-1/4 inches (108 mm)**] with [**90**] [**120**] [**270**]-degree scale and [**1**] [**2**] percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:
 - 1) Ammeter: Output current for each phase, with current sensors rated to suit application.
 - 2) Voltmeter: Output voltage for each phase.
 - 3) Frequency Meter: Output frequency.
 - 4) Real-time clock with current time and date.
 - 5) Total run time.
 - 6) <Insert features>.
 - h. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
 - 1) Selectable, digital display of the following:
 - a) Phase Currents, Each Phase: Plus or minus 1 percent.

- b) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - c) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - d) Three-Phase Real Power: Plus or minus 2 percent.
 - e) Three-Phase Reactive Power: Plus or minus 2 percent.
 - f) Power Factor: Plus or minus 2 percent.
 - g) Frequency: Plus or minus 0.5 percent.
 - h) Integrated Demand with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.
 - i) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
- 2) Mounting: Display and control unit flush or semirecessed in instrument compartment door.
- i. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.
 - j. Power Protection: Chiller shall shut down within six cycles of power interruption.

P. Variable Frequency Controller:

1. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
2. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
3. Enclosure: Unit mounted, NEMA 250, **[Type 1] <Insert type>**, with hinged full-front access door with lock and key.
4. Integral Disconnecting Means: **[Door-interlocked,]**NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[42,000] [65,000] [100,000] <Insert value> A**.
5. Technology: Pulse width modulated (PWM) output suitable for constant or variable torque loads.
6. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.
7. Operating Requirements:
 - a. Input AC Voltage Tolerance: **[460-V ac, plus 10 percent or 506 V maximum] <Insert voltage and tolerance>**.
 - b. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
 - c. Capable of driving full load, without derating, under the following conditions:
 - 1) Ambient Temperature: 0 to 40 deg C.
 - 2) Relative Humidity: Up to **[90] [95]** percent (noncondensing).
 - 3) Altitude: **[3300 feet (1005 m)] [6600 feet (2010 m)]**.

- d. Minimum Efficiency: 96 percent at 60 Hz, full load.
 - e. Minimum Displacement Primary-Side Power Factor: 98 percent.
 - f. Overload Capability: 1.05 times the full-load current for 7 seconds.
 - g. Starting Torque: As required by compressor-drive assembly.
 - h. Speed Regulation: Plus or minus 1 percent.
 - i. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
 - j. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
 - k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.
8. Internal Adjustability Capabilities:
- a. Minimum Output Frequency: 6 Hz.
 - b. Maximum Output Frequency: 60 Hz.
 - c. Acceleration: 2 seconds to 60 seconds.
 - d. Deceleration: Zero seconds to 60 seconds.
 - e. Current Limit: 30 to a minimum of 100 percent of maximum rating.
9. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:
- a. Overtemperature.
 - b. Short circuit at controller output.
 - c. Ground fault at controller output. Variable frequency controller shall be able to start a grounded motor.
 - d. Open circuit at controller output.
 - e. Input undervoltage.
 - f. Input overvoltage.
 - g. Loss of input-phase.
 - h. Reverse phase.
 - i. AC line switching transients.
 - j. Instantaneous overload, line to line or line to ground.
 - k. Sustained overload exceeding 100 percent of controller rated current.
 - l. Starting a rotating motor.
10. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
11. Automatic Reset and Restart: Capable of **[three]** <Insert number> restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss, and overvoltage and undervoltage trips.
12. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:
- a. Power on.

- b. Run.
 - c. Overvoltage.
 - d. Line fault.
 - e. Overcurrent.
 - f. External fault.
 - g. Motor speed (percent).
 - h. Fault or alarm status (code).
 - i. Motor output voltage.
 - j. Input kilovolt amperes.
 - k. Total power factor.
 - l. Input kilowatts.
 - m. Input kilowatt-hours.
 - n. Three-phase input voltage.
 - o. Three-phase output voltage.
 - p. Three-phase input current.
 - q. Three-phase output current.
 - r. Output frequency (Hertz).
 - s. Elapsed operating time (hours).
 - t. Diagnostic and service parameters.
13. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.
14. Harmonic Distortion Filter: Factory mounted and wired to limit total voltage and current distortion to [5] <Insert number> percent.

Q. Controls:

- 1. Standalone and microprocessor based with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
- 2. Enclosure: Unit mounted, NEMA 250, [Type 1] [Type 4] [Type 4x] [Type 12] <Insert type>, hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.
- 3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Fault history with not less than last 10 faults displayed.
 - d. Set points of controllable parameters.
 - e. Trend data.
 - f. Operating hours.
 - g. Number of chiller starts.
 - h. Outdoor-air temperature or space temperature if required for chilled-water reset.
 - i. Temperature and pressure of operating set points.
 - j. Entering- and leaving-fluid temperatures of evaporator and condenser.
 - k. Difference in fluid temperatures of evaporator and condenser.
 - l. Fluid flow of evaporator and condenser.

- m. Fluid pressure drop of evaporator and condenser.
 - n. Refrigerant pressures in evaporator and condenser.
 - o. Refrigerant saturation temperature in evaporator and condenser.
 - p. Pump status.
 - q. Antirecycling timer status.
 - r. Percent of maximum motor amperage.
 - s. Current-limit set point.
 - t. Compressor bearing temperature.
 - u. Motor bearing temperature.
 - v. Motor winding temperature.
 - w. Oil temperature.
 - x. Oil discharge pressure.
 - y. Phase current.
 - z. Percent of motor rated load amperes.
 - aa. Phase voltage.
 - bb. Demand power (kilowatts).
 - cc. Energy use (kilowatt-hours).
 - dd. Power factor.
 - ee. **<Insert items>**.
4. Control Functions:
- a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on **[return-water] [outdoor-air] [space]** temperature.
 - c. Current limit and demand limit.
 - d. Condenser-fluid temperature.
 - e. External chiller emergency stop.
 - f. Antirecycling timer.
 - g. Variable evaporator flow.
 - h. Thermal storage.
 - i. Heat reclaim.
 - j. **<Insert control functions>**.
5. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
- a. Low evaporator pressure or temperature; high condenser pressure.
 - b. Low evaporator fluid temperature.
 - c. Low oil differential pressure.
 - d. High or low oil pressure.
 - e. High oil temperature.
 - f. High compressor-discharge temperature.
 - g. Loss of condenser-fluid flow.
 - h. Loss of evaporator-fluid flow.
 - i. Motor overcurrent.
 - j. Motor overvoltage.
 - k. Motor undervoltage.
 - l. Motor phase reversal.

- m. Motor phase failure.
 - n. Sensor- or detection-circuit fault.
 - o. Processor communication loss.
 - p. Motor controller fault.
 - q. Extended compressor surge.
 - r. **<Insert manually reset safety controls>**.
6. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
 7. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
 8. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
 9. Communication Port: RS-232 port or equivalent connection capable of connecting a printer **[and a notebook computer]**.
 10. Interface with the DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display chiller status and alarms.
 - a. Hardwired Points:
 - 1) Monitoring: On-off status, **[common trouble alarm] [electrical power demand (kilowatts)] [electrical power consumption (kilowatt-hours)] [power factor] <Insert monitoring point>**.
 - 2) Control: On-off operation, **[chilled-water, discharge temperature set-point adjustment] [electrical power demand limit] <Insert control point>**.
 - b. **[ASHRAE 135 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol] <Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the DDC system for HVAC.

R. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
2. Thickness: **[3/4 inch (19 mm)] [1-1/2 inches (38 mm)] <Insert thickness>**.
3. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Factory-applied insulation over cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.

- a. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
- b. Seal seams and joints to provide a vapor barrier.
- c. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

S. Finish:

1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
 - a. Provide at least one coat of primer with a total dry film thickness of at least **2 mils** (0.05 mm).
 - b. Provide at least two coats of **[alkyd-modified, vinyl enamel] [epoxy] [polyurethane]** finish with a total dry film thickness of at least **4 mils** (0.10 mm).
 - c. Paint surfaces that are to be insulated before applying the insulation.
 - d. Paint installed insulation to match adjacent uninsulated surfaces.
 - e. Color of finish coat to be **[manufacturer's standard] [custom color selected by DEN Project Manager] <Insert color description>**.
2. Provide Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.

T. Accessories:

1. Flow Switches:
 - a. If required and not factory installed, chiller manufacturer shall furnish a switch for each **[condenser] [evaporator and condenser]** and verify field-mounting location before installation.
 - b. Paddle Flow Switches:
 - 1) Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.
 - 2) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
 - 3) Pressure rating equal to pressure rating of heat exchanger.
 - 4) Construct body and wetted parts of Type 316 stainless steel.
 - 5) House switch in a NEMA 250, **[Type 4] <Insert type>** enclosure constructed of die-cast aluminum.
 - 6) Vane length to suit installation.
 - c. Pressure Differential Switches:
 - 1) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.

- 2) Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
- 3) Set Point: Screw type, field adjustable.
- 4) Electrical Connections: Internally mounted screw-type terminal blocks.
- 5) Switch Enclosure: NEMA 250, [Type 4] <Insert type>.
- 6) Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

2. Vibration Isolation:

- a. Chiller manufacturer shall furnish vibration isolation for each chiller.
- b. Neoprene Pad:
 - 1) Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
 - 2) Fabricate pads from 40- to 50-durometer neoprene.
 - 3) Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.
- c. Spring Isolator:
 - 1) Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions. Isolators shall be designed such that the Kx/Ky ratio shall be 1.0 or more for stability.
 - 2) Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.
 - 3) Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate. An elastomeric pad with a minimum thickness of 0.25 inch (6 mm) shall be bonded to the baseplate.
 - 4) Spring assembly shall be removable and shall fit within a welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.
 - 5) Isolators shall be selected for a nominal [1-inch (25-mm)] [2-inch (50-mm)] <Insert dimension> deflection.

3. Sound Barrier:

- a. Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.

- b. Provide for repeated installation and removal without use of tape or caulk.
 - c. Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.
 - d. Covers shall be double sewn and lock stitched with edges folded and sewn so no raw cut edges are exposed.
 - e. Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.
 - f. Continuously lap all exposed seams at least **2 inches (50 mm)** for better sound containment.
 - g. Permanently label each section of cover to indicate its location, description, size, and number sequence.
 - h. Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.
4. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

U. Capacities and Characteristics:

1. Capacity: **<Insert tons (kW)>**.
2. Full-Load Efficiency (COP): **<Insert value>**.
3. Full-Load Efficiency (EER): **<Insert value>**.
4. Full-Load Efficiency (Power Input/Cooling Output): **<Insert kW/ton (kW/kW)>**.
5. Part-Load Efficiency (IPLV): **<Insert value>**.
6. Part-Load Efficiency (NPLV): **<Insert value>**.
7. Evaporator:
 - a. Pressure Rating: **<Insert psig (kPa)>**.
 - b. Number of Passes: **[One] [Two] [Three]**.
 - c. Fluid Type: **[Water] <Insert fluid type>**.
 - d. Design Fluid Flow Rate: **<Insert gpm (L/s)>**.
 - e. Minimum Fluid Flow Rate: **<Insert gpm (L/s)>**.
 - f. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - g. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - h. Fluid Pressure Drop: **<Insert feet of head (kPa)>**.
 - i. Fluid Velocity: **<Insert fps (m/s)>**.
 - j. Fouling Factor: **[0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>**.
8. Condenser:
 - a. Pressure Rating: **<Insert psig (kPa)>**.
 - b. Number of Passes: **[One] [Two] [Three]**.
 - c. Fluid Type: **[Water] <Insert fluid type>**.
 - d. Design Fluid Flow Rate: **<Insert gpm (L/s)>**.

- e. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - f. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 - g. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 - h. Fluid Velocity: <Insert fps (m/s)>.
 - i. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg F/Btu (0.00022 sq. m x deg C/W)] <Insert value>.
9. Heat-Reclaim Condenser:
- a. Pressure Rating: <Insert psig (kPa)>.
 - b. Number of Passes: [One] [Two] [Three].
 - c. Fluid Type: [Water] <Insert fluid type>.
 - d. Design Fluid Flow Rate: <Insert gpm (L/s)>.
 - e. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - f. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 - g. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 - h. Fluid Velocity: <Insert fps (m/s)>.
 - i. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] <Insert value>.
10. Compressor:
- a. Rated Load Amperes: <Insert value>.
 - b. Locked-Rotor Amperes: <Insert value>.
11. Chiller Electrical Requirements:
- a. Power Input: <Insert kilowatts>.
 - b. Power Factor: [0.90] [0.95] <Insert value>.
 - c. Minimum Circuit Ampacity: <Insert value>.
 - d. Maximum Overcurrent Protection Device: <Insert amperage>.
 - e. Volts: [208] [240] [480] [600] [2300] [4160] <Insert value>.
 - f. Phase: Three.
 - g. Hertz: 60.
12. Noise Rating: [85] <Insert dBA> sound power level when measured according to ARI 575. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.2 PACKAGED, WATER-COOLED, MULTIPLE-COMPRESSOR CHILLERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- 1. [Carrier Corporation](#).
 - 2. [Dunham-Bush](#).
 - 3. [McQuay International](#).

4. [York International Corporation](#).
 5. **<Insert manufacturer's name>**.
 6. or approved equal.
- B. Description: Factory-assembled and **[run]**-tested chiller with compressor(s), compressor motors and motor controllers, evaporator, condenser where indicated, electrical power, controls, and indicated accessories.
1. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
- C. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.
- D. Compressors:
1. Description: Positive displacement, hermetically sealed.
 2. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
 3. Rotors: Manufacturer's standard one- or two-rotor design.
- E. Service: Easily accessible for inspection and service.
1. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
 2. Provide lifting lugs or eyebolts attached to casing.
- F. Capacity Control: On-off compressor cycling and modulating slide-valve assembly or port unloaders combined with hot-gas bypass, if necessary, to achieve performance indicated.
1. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
 2. Operating Range: From 100 to **[20] [15] [10] [5] [zero] <Insert number>** percent of design capacity.
 3. Condenser-Fluid Unloading Requirements over Operating Range:
[Constant-design entering condenser-fluid temperature] [Drop-in entering condenser-fluid temperature of 2.5 deg F (1.4 deg C) drop for each 10 percent in capacity reduction] <Insert conditions>.
- G. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
 2. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
 3. Factory-installed and pressure-tested piping with isolation valves and accessories.
 4. Oil compatible with refrigerant and chiller components.

5. Positive visual indication of oil level.

H. Vibration Control:

1. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.

a. Overspeed Test: 25 percent above design operating speed.

2. Isolation: Mount individual compressors on vibration isolators.

I. Sound Control: Sound-reduction package shall consist of removable acoustic enclosures around the compressors and drive assemblies that are designed to reduce sound levels without affecting performance.

J. Compressor Motors:

1. Hermetically sealed and cooled by refrigerant suction gas.

2. High-torque, induction type with inherent thermal-overload protection on each phase.

K. Refrigerant Circuits:

1. Refrigerant: Type as indicated on Drawings.

2. Refrigerant Type: **[R-22] [R-134a] [or] [any HFC] <Insert type>**. Classified as Safety Group A1 according to ASHRAE 34.

3. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

4. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor[**suction**] and discharge shutoff valves, a liquid-line shutoff valve, a[**replaceable-core**] filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.

5. Pressure Relief Device:

a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.

6. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line to the condenser and the refrigerant liquid-line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell.

L. Evaporator:

1. Description: Shell-and-tube design.

- a. Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell.
 - b. Flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.
2. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 3. Shell Material: Carbon steel.
 4. Shell Heads: Removable carbon-steel heads with multipass baffles, and located at each end of the tube bundle.
 5. Fluid Nozzles: Terminated with mechanical-coupling or flanged end connections for connection to field piping.
 6. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
- M. Condenser:
1. Shell and tube, or without integral condenser; as indicated.
 2. Shell and Tube:
 - a. Description: Shell-and-tube design with refrigerant flowing through shell, and fluid flowing through tubes within shell.
 - b. Provides positive subcooling of liquid refrigerant.
 - c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - d. Shell Material: Carbon steel.
 - e. Water Boxes: Removable, of carbon-steel construction, located at each end of the tube bundle with fluid nozzles terminated with mechanical-coupling end connections for connection to field piping.
 - f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
 - g. Provide each condenser with a pressure relief device, purge cock, and liquid-line shutoff valve.
 3. Provide chiller without an integral condenser and design chiller for field connection to remote condenser. Coordinate requirements with Section 236313 "Air-Cooled Refrigerant Condensers."
- N. Electrical Power:
1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a **[multipoint] [single-point]**, field-power connection to chiller.
 2. House in a unit-mounted, NEMA 250, **[Type 1] <Insert type>** enclosure with hinged access door **[with lock and key or padlock and key]**.
 3. Wiring shall be numbered **[and color-coded]** to match wiring diagram.
 4. Install factory wiring outside of an enclosure in a raceway.
 5. Field-power interface shall be to **[wire lugs] [NEMA KS 1, heavy-duty, nonfused disconnect switch] [NEMA AB 1, instantaneous-trip circuit breaker with lockable handle]**.

- a. Disconnect means shall be interlocked with door operation.
 - b. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [42,000] [65,000] [100,000] <Insert value> A.
6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
- a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
7. Provide each motor with overcurrent protection.
8. Overload relay sized according to UL 1995 or an integral component of chiller control microprocessor.
9. Phase-Failure and Undervoltage Relays: Solid-state sensing with adjustable settings.
10. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
11. Control Relays: Auxiliary and adjustable time-delay relays.
12. For chiller electrical power supply, indicate the following:
- a. Current and phase to phase for all three phases.
 - b. Voltage, phase to phase, and phase to neutral for all three phases.
 - c. Three-phase real power (kilowatts).
 - d. Three-phase reactive power (kilovolt amperes reactive).
 - e. Power factor.
 - f. Running log of total power versus time (kilowatt-hours).
 - g. Fault log, with time and date of each.
 - h. <Insert features>.
- O. Compressor Motor Controllers:
1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing[, **or solid state**].
 2. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed or open transition[, **or solid state**].
- P. Controls:
1. Standalone and microprocessor based.
 2. Enclosure: Share enclosure with electrical-power devices or provide a separate enclosure of matching construction.
 3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:

- a. Date and time.
 - b. Operating or alarm status.
 - c. Fault history with not less than last 10 faults displayed.
 - d. Set points of controllable parameters.
 - e. Trend data.
 - f. Operating hours.
 - g. Number of chiller starts.
 - h. Outdoor-air temperature or space temperature if required for chilled-water reset.
 - i. Temperature and pressure of operating set points.
 - j. Entering- and leaving-fluid temperatures of evaporator and condenser.
 - k. Difference in fluid temperatures of evaporator and condenser.
 - l. Refrigerant pressures in evaporator and condenser.
 - m. Refrigerant saturation temperature in evaporator and condenser.
 - n. No cooling load condition.
 - o. Elapsed time meter (compressor run status).
 - p. Pump status.
 - q. Antirecycling timer status.
 - r. Percent of maximum motor amperage.
 - s. Current-limit set point.
 - t. Number of compressor starts.
 - u. Compressor refrigerant suction and discharge temperature.
 - v. Oil temperature.
 - w. Oil discharge pressure.
 - x. Phase current.
 - y. Percent of motor rated load amperes.
 - z. Phase voltage.
 - aa. **<Insert items>**.
4. Control Functions:
- a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Chilled-water leaving temperature shall be reset based on **[return-water] [outdoor-air] [space]** temperature.
 - c. Current limit and demand limit.
 - d. Condenser-fluid temperature.
 - e. External chiller emergency stop.
 - f. Antirecycling timer.
 - g. Automatic lead-lag switching.
 - h. Variable evaporator flow.
 - i. Thermal storage.
 - j. **<Insert control functions>**.
5. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
- a. Low evaporator pressure, or high condenser pressure.
 - b. Low chilled-water temperature.
 - c. Refrigerant high pressure.

- d. High or low oil pressure.
 - e. High oil temperature.
 - f. Loss of chilled-water flow.
 - g. Loss of condenser-fluid flow.
 - h. Control device failure.
 - i. **<Insert manually reset safety controls>**.
6. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
 7. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
 8. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
 9. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display chiller status and alarms.
 - a. Hardwired Points:
 - 1) Monitoring: On-off status, [**common trouble alarm**] [**electrical power demand (kilowatts)**] [**electrical power consumption (kilowatt-hours)**] **<Insert monitoring point>**.
 - 2) Control: On-off operation, [**chilled-water, discharge temperature set-point adjustment**] [**electrical power demand limit**] **<Insert control point>**.
 - b. [**ASHRAE 135 (BACnet)**] [**LonTalk**] [**Modbus**] [**Industry-accepted, open-protocol**] **<Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the DDC system for HVAC.

Q. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
2. Thickness: [**3/4 inch (19 mm)**] **<Insert thickness>**.
3. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Factory-applied insulation over cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
 - a. Before insulating steel surfaces, prepare surfaces for paint, prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.

- b. Seal seams and joints to provide a vapor barrier.
- c. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

R. Finish:

1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
 - a. Provide at least one coat of primer.
 - b. Provide finish coat of **[alkyd-modified, vinyl enamel]** <Insert type>.
 - c. Paint surfaces that are to be insulated before applying the insulation.
 - d. Paint installed insulation to match adjacent uninsulated surfaces.

S. Accessories:

1. Factory-furnished, chilled-[**and condenser-**]water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigerant circuit.
3. Factory-furnished **[neoprene]** [or] **[spring]** isolators for field installation.
4. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

T. Capacities and Characteristics:

1. Capacity: <Insert tons (kW)>.
2. Full-Load Efficiency (COP): <Insert value>.
3. Full-Load Efficiency (EER): <Insert value>.
4. Full-Load Efficiency (Power Input/Cooling Output): <Insert kW/ton (kW/kW)>.
5. Part-Load Efficiency (IPLV): <Insert value>.
6. Part-Load Efficiency (NPLV): <Insert value>.
7. Evaporator:
 - a. Pressure Rating: <Insert psig (kPa)>.
 - b. Number of Passes: **[One]** **[Two]** **[Three]**.
 - c. Fluid Type: **[Water]** <Insert fluid type>.
 - d. Design Fluid Flow Rate: <Insert gpm (L/s)>.
 - e. Minimum Fluid Flow Rate: <Insert gpm (L/s)>.
 - f. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - g. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 - h. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 - i. Fluid Velocity: <Insert fps (m/s)>.
 - j. Fouling Factor: **[0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)]** **[0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)]** **[0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)]** <Insert value>.

8. Condenser:
 - a. Pressure Rating: <Insert psig (kPa)>.
 - b. Fluid Type: **[Water]** <Insert fluid type>.
 - c. Design Fluid Flow Rate: <Insert gpm (L/s)>.
 - d. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - e. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 - f. Fluid Pressure Drop: <Insert feet of head (kPa)>.
 - g. Fluid Velocity: <Insert fps (m/s)>.
 - h. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] [0.001 sq. ft. x h x deg F/Btu (0.00022 sq. m x deg C/W)] <Insert value>.
9. Number of Refrigerant Circuits: **[One]** **[Two]**.
10. Compressors:
 - a. Number of Compressors: <Insert number>.
 - b. Rated Load Amperes: <Insert value>.
 - c. Locked-Rotor Amperes: <Insert value>.
11. Control Electrical Requirements:
 - a. Power Connection: **[Fed through integral transformer]** **[Separate field-power connection]**.
 - b. Power Input: <Insert kilowatts>.
 - c. Minimum Circuit Ampacity: <Insert value>.
 - d. Maximum Overcurrent Protection Device: <Insert amperage>.
 - e. Volts: **[120]** <Insert value>-V ac.
 - f. Phase: **[Single]** **[Three]**.
 - g. Hertz: 60.
12. Chiller Electrical Requirements:
 - a. Power Input: <Insert kilowatts>.
 - b. Power Factor: <Insert value>.
 - c. Minimum Circuit Ampacity: <Insert value>.
 - d. Maximum Overcurrent Protection Device: <Insert amperage>.
 - e. Volts: **[208]** **[240]** **[480]** **[600]** <Insert value>.
 - f. Phase: Three.
 - g. Hertz: 60.
13. Noise Rating: <Insert dBA> sound power level when measured according to ARI 575. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.3 PACKAGED, AIR-COOLED CHILLERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Carrier Corporation.](#)
 2. [Dunham-Bush.](#)
 3. [McQuay International.](#)
 4. [Trane.](#)
 5. [York International Corporation.](#)
 6. **<Insert manufacturer's name>.**
 7. or approved equal.
- B. Description: Factory-assembled and run-tested chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
- C. Fabricate base, frame, and attachment to chiller components strong enough to resist chiller movement during a seismic event when chiller base is anchored to field support structure.
- D. Cabinet:
1. Base: Galvanized-steel base extending the perimeter of chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
 2. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported by base.
 3. Casing: Galvanized steel.
 4. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a [500] [1000] **<Insert number>**-hour salt-spray test according to ASTM B 117.
 5. Sound-reduction package designed to reduce sound level without affecting performance and consisting of the following:
 - a. Acoustic enclosure around compressors.
 - b. Reduced-speed fans with acoustic treatment.
 6. Security Package: Provide removable [**grilles**] [**louvered panels**] with fasteners for additional protection of compressors, evaporator, and condenser coils without inhibiting service access. Finish to match cabinet.
- E. Compressors:
1. Description: Positive displacement, hermetically sealed.
 2. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
 3. Rotors: Manufacturer's standard one- or two-rotor design.
 4. Each compressor provided with[**suction and**] discharge shutoff valves, crankcase oil heater, and suction strainer.
- F. Service: Easily accessible for inspection and service.

- G. Capacity Control: On-off compressor cycling and modulating slide-valve assembly or port unloaders combined with hot-gas bypass, if necessary, to achieve performance indicated.
1. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
 2. Operating Range: From 100 to [20] [15] [10] [5] [zero] <Insert number> percent of design capacity.
 3. Condenser-Air Unloading Requirements over Operating Range:
[Constant-design entering condenser-air temperature] [Drop-in entering condenser-air temperature of 5 deg F (3 deg C) drop for each 10 percent in capacity reduction] <Insert conditions>.
 4. For units equipped with a variable frequency controller, capacity control shall be both "valveless" and "stepless," requiring no slide valve or capacity-control valve(s) to operate at reduced capacity.
- H. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
 2. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
 3. Factory-installed and pressure-tested piping with isolation valves and accessories.
 4. Oil compatible with refrigerant and chiller components.
 5. Positive visual indication of oil level.
- I. Vibration Control:
1. Vibration Balance: Balance chiller compressors and drive assemblies to provide a precision balance that is free of noticeable vibration over the entire operating range.
 - a. Overspeed Test: 25 percent above design operating speed.
 2. Isolation: Mount individual compressors on vibration isolators.
- J. Compressor Motors:
1. Hermetically sealed and cooled by refrigerant suction gas.
 2. High-torque, induction type with inherent thermal-overload protection on each phase.
- K. Compressor Motor Controllers:
1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing[, **or solid state**].
 2. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition[, **or solid state**].

3. Variable Frequency Controller:

- a. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
- b. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
- c. Enclosure: Unit mounted, NEMA 250, [**Type 3R**] <Insert type>, with hinged full-front access door with lock and key.
- d. Integral Disconnecting Means: [**Door-interlocked**,]NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] [**100,000**] <Insert value> A.
- e. Technology: Pulse width modulated (PWM) output suitable for constant or variable torque loads.
- f. Motor current at start shall not exceed the rated load amperes, providing no electrical inrush.

L. Refrigerant Circuits:

1. Refrigerant: Type as indicated on Drawings.
2. Refrigerant Type: [**R-22**] [**R-134a**] [**R-407c**] [**or**] [**any HFC**] <Insert type>. Classified as Safety Group A1 according to ASHRAE 34.
3. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
4. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor[**suction**] and discharge shutoff valves, a liquid-line shutoff valve, a [**replaceable-core**]filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
5. Pressure Relief Device:
 - a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.

M. Evaporator:

1. Description: Shell-and-tube design.
 - a. Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell.
 - b. Flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.
2. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Shell Material: Carbon steel.

4. Shell Heads: Removable carbon-steel heads located at each end of the tube bundle.
5. Fluid Nozzles: Terminated with **[mechanical-coupling] [flanged]** end connections for connection to field piping.
6. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
7. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to **minus 20 deg F** (minus 29 deg C).
8. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.

N. Air-Cooled Condenser:

1. Plate-fin coil with integral subcooling on each circuit, rated at **450 psig** (3103 kPa).
 - a. Construct coil casing of **[galvanized] [or] [stainless]** steel.
 - b. Construct coils of copper tubes mechanically bonded to **[aluminum] [aluminum with precoated epoxy-phenolic] [copper]** fins.
 - c. Coat coils with a baked-epoxy, corrosion-resistant coating after fabrication.
 - d. Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.
2. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
3. Fan Motors: Totally enclosed nonventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings. Equip each motor with overload protection integral to either the motor or chiller controls.
4. Fan Guards: Steel safety guards with corrosion-resistant coating.

O. Electrical Power:

1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a **[multipoint] [single-point]**, field-power connection to chiller.
2. House in a unit-mounted, NEMA 250, **[Type 3R] <Insert type>** enclosure with hinged access door **[with lock and key or padlock and key]**.
3. Wiring shall be numbered **[and color-coded]** to match wiring diagram.
4. Install factory wiring outside of an enclosure in a raceway.
5. Field-power interface shall be to **[wire lugs] [NEMA KS 1, heavy-duty, nonfused disconnect switch] [NEMA AB 1, instantaneous-trip circuit breaker with lockable handle]**.
 - a. Disconnect means shall be interlocked with door operation.
 - b. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[42,000] [65,000] [100,000] <Insert value> A**.
6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:

- a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 - b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
7. Provide each motor with overcurrent protection.
 8. Overload relay sized according to UL 1995 or an integral component of chiller control microprocessor.
 9. Phase-Failure and Undervoltage Relays: Solid-state sensing with adjustable settings.
 10. Provide power factor correction capacitors to correct power factor to **[0.90] [0.95]** **<Insert value>** at full load.
 11. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
 - a. Power unit-mounted controls where indicated.
 - b. Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.
 12. Control Relays: Auxiliary and adjustable time-delay relays.
 13. For chiller electrical power supply, indicate the following:
 - a. Current and phase to phase for all three phases.
 - b. Voltage, phase to phase, and phase to neutral for all three phases.
 - c. Three-phase real power (kilowatts).
 - d. Three-phase reactive power (kilovolt amperes reactive).
 - e. Power factor.
 - f. Running log of total power versus time (kilowatt-hours).
 - g. Fault log, with time and date of each.
 - h. **<Insert features>**.

P. Controls:

1. Standalone and microprocessor based.
2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure[**for remote mounting in the field**].
3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Operating hours.
 - d. Outdoor-air temperature if required for chilled-water reset.
 - e. Temperature and pressure of operating set points.
 - f. Entering and leaving temperatures of chilled water.
 - g. Refrigerant pressures in evaporator and condenser.
 - h. Saturation temperature in evaporator and condenser.

- i. No cooling load condition.
 - j. Elapsed time meter (compressor run status).
 - k. Pump status.
 - l. Antirecycling timer status.
 - m. Percent of maximum motor amperage.
 - n. Current-limit set point.
 - o. Number of compressor starts.
 - p. **<Insert items>**.
4. Control Functions:
 - a. Manual or automatic startup and shutdown time schedule.
 - b. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Chilled-water leaving temperature shall be reset based on **[return-water] [outdoor-air] [space]** temperature.
 - c. Current limit and demand limit.
 - d. External chiller emergency stop.
 - e. Antirecycling timer.
 - f. Automatic lead-lag switching.
 - g. Variable evaporator flow.
 - h. Thermal storage.
 - i. **<Insert control functions>**.
5. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
 - a. Low evaporator pressure or high condenser pressure.
 - b. Low chilled-water temperature.
 - c. Refrigerant high pressure.
 - d. High or low oil pressure.
 - e. High oil temperature.
 - f. Loss of chilled-water flow.
 - g. Control device failure.
 - h. **<Insert manually reset safety controls>**.
6. Trending: Capability to trend analog data of up to **[five] <Insert number>** parameters simultaneously over an adjustable period and frequency of polling.
7. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
8. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
9. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display chiller status and alarms.
 - a. Hardwired Points:

- 1) Monitoring: On-off status, [**common trouble alarm**] [**electrical power demand (kilowatts)**] [**electrical power consumption (kilowatt-hours)**] <Insert monitoring point>.
- 2) Control: On-off operation, [**chilled-water, discharge temperature set-point adjustment**] [**electrical power demand limit**] <Insert control point>.

- b. [**ASHRAE 135 (BACnet)**] [**LonTalk**] [**Modbus**] [**Industry-accepted, open-protocol**] <Insert type of interface> communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the DDC system for HVAC.

Q. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
2. Thickness: [**3/4 inch (19 mm)**] [**1-1/2 inches (38 mm)**] <Insert thickness>.
3. Factory-applied insulation over cold surfaces of chiller components.
 - a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Apply protective coating to exposed surfaces of insulation to protect insulation from weather.

R. Accessories:

1. Factory-furnished, chilled-water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigerant circuit.
3. Factory-furnished [**neoprene**] [**or**] [**spring**] isolators for field installation.
4. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

S. Capacities and Characteristics:

1. Capacity: <Insert tons (kW)>.
2. Full-Load Efficiency (COP): <Insert value>.
3. Full-Load Efficiency (EER): <Insert value>.
4. Full-Load Efficiency (Power Input/Cooling Output): <Insert kW/ton (kW/kW)>.
5. Part-Load Efficiency (IPLV): <Insert value>.
6. Part-Load Efficiency (NPLV): <Insert value>.
7. Low Ambient Operation: Chiller designed for operation to [**0 deg F (minus 18 deg C)**] <Insert temperature>.

8. High Ambient Operation: Chiller designed for operation to [115 deg F (46 deg C)] **<Insert temperature>**.
9. Evaporator:
 - a. Configuration: [Integral to chiller] [Shipped loose for field installation].
 - b. Pressure Rating: [150 psig (1034 kPa)] [300 psig (2068 kPa)] **<Insert value>**.
 - c. Fluid Type: [Water] **<Insert fluid type>**.
 - d. Design Fluid Flow Rate: **<Insert gpm (L/s)>**.
 - e. Minimum Fluid Flow Rate: **<Insert gpm (L/s)>**.
 - f. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - g. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - h. Fluid Pressure Drop: **<Insert feet of head (kPa)>**.
 - i. Fluid Velocity: **<Insert fps (m/s)>**.
 - j. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)] [0.0005 sq. ft. x h x deg F/Btu (0.00011 sq. m x deg C/W)] **<Insert value>**.
10. Condenser Entering-Air Temperature: **<Insert deg F (deg C)>**.
11. Condenser Fan External Static Pressure: **<Insert wg (Pa)>**.
12. Site Altitude: **<Insert feet (m)>**.
13. Number of Refrigerant Circuits: [Two] [Each compressor on an independent circuit] **<Insert requirement>**.
14. Compressor:
 - a. Number of Compressors: **<Insert number>**.
 - b. Rated Load Amperes: **<Insert value>**.
 - c. Locked-Rotor Amperes: **<Insert value>**.
15. Control Electrical Requirements:
 - a. Power Connection: [Fed through integral transformer] [Separate field-power connection].
 - b. Power Input: **<Insert kilowatts>**.
 - c. Minimum Circuit Ampacity: **<Insert value>**.
 - d. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - e. Volts: [120] **<Insert value>**-V ac.
 - f. Phase: Single.
 - g. Hertz: 60.
16. Chiller Electrical Requirements:
 - a. Power Input: **<Insert kilowatts>**.
 - b. Power Factor: **<Insert value>**.
 - c. Minimum Circuit Ampacity: **<Insert value>**.
 - d. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - e. Volts: [208] [240] [480] [600] **<Insert value>**.
 - f. Phase: Three.
 - g. Hertz: 60.

17. Noise Rating: **<Insert dBA>** sound power level when measured according to ARI 370. Provide factory-installed sound treatment if necessary to achieve the performance indicated.

2.4 PACKAGED REFRIGERANT RECOVERY UNITS

- A. Packaged portable unit consisting of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest chiller furnished.

2.5 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

- A. Furnish for field installation a brush-cleaning system on each chiller **[condenser]** **<Insert heat exchanger>** for tube cleaning and improved heat transfer.
- B. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
- C. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
- D. Components:
 1. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed **0.025 inch (0.6 mm)**.
 2. Basket: Single-piece polypropylene basket with neck OD to press fit ID of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
 3. Four-Way Valve:
 - a. Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
 - b. Configure valve with parallel flow connections to minimize field installation piping.
 - c. Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.
 - d. Pipe connections shall be flanged.
 - e. Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
 - f. Hydrostatically test to 1.5 times the design working pressure.

- g. Design the valve to cause no more than **0.5-psig (3-kPa)** pressure drop at design flow conditions.
 - h. Provide valve with valve-mounted indicating/warning light, which shall light before valve begins rotation.
 - i. Valve Actuator: Mount electric actuator to operate valve.
 - j. Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.
 - k. Position Switches: Factory mount microswitches on valve to indicate the complete turn of valve in both normal and reverse flow.
4. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:
 - a. NEMA 250, [**Type 1**] [**Type 4**] [**Type 4x**] [**Type 12**] enclosure.
 - b. Timer to automatically initiate the cleaning cycle over a 24-hour period.
 - c. Manual override of preset cleaning cycle.
 - d. Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow turn or incomplete valve turn.
 - e. For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
 - f. Flow switch bypass.
 - g. Unloading signal to chiller.

2.6 SOURCE QUALITY CONTROL

- A. Perform functional tests of chillers before shipping.
- B. Factory run test each air-cooled chiller with water flowing through evaporator.
- C. Factory performance test water-cooled chillers, before shipping, according to ARI 506/110.
 1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Reduction in capacity from design to minimum load in steps of [**10**] [**25**] [**33**] **<Insert number>** with condenser fluid at design conditions.
 - c. Reduction in capacity from design to minimum load in steps of [**10**] [**25**] [**33**] **<Insert number>** with varying entering condenser-fluid temperature from design to minimum conditions in [**5 deg F (3 deg C)**] **<Insert temperature>** increments.
 - d. At [**one**] [**two**] [**three**] [**four**] [**five**] [**10**] **<Insert number>** point(s) of varying part-load performance to be selected by Owner at time of test.
 2. Allow [**Owner**] **<Insert entity>** access to place where chillers are being tested. Notify DEN Project Manager [**14**] **<Insert number>** days in advance of testing.
 3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

- D. Factory performance test air-cooled chillers, before shipping, according to ARI 506/110.
1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Reduction in capacity from design to minimum load in steps of [10] [25] [33] <Insert number> with condenser air at design conditions.
 - c. At [one] [two] [three] [four] [five] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.
 2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify DEN Project Manager [14] <Insert number> days in advance of testing.
 3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- E. Factory sound test [water-cooled chillers, before shipping, according to ARI 575] [air-cooled chillers, before shipping, according to ARI 370].
1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Chiller operating at calculated worst-case sound condition.
 - c. At [one] [two] [three] [four] [five] <Insert number> point(s) of varying part-load performance to be selected by Owner at time of test.
 2. Allow [Owner] <Insert entity> access to place where chillers are being tested. Notify DEN Project Manager [14] <Insert number> days in advance of testing.
 3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- F. Factory test and inspect evaporator[and condenser] [, condenser, and heat-reclaim condenser] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- G. For chillers located indoors, rate sound power level according to ARI 575.
- H. For chillers located outdoors, rate sound power level according to ARI 370.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine chillers before installation. Reject chillers that are damaged.
- B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install chillers on support structure indicated.
- C. Equipment Mounting:
1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Maintain manufacturer's recommended clearances for service and maintenance.
- E. Charge chiller with refrigerant and fill with oil if not factory installed.
- F. Install separate devices furnished by manufacturer and not factory installed.
- G. Provide connections to chilled water piping.
1. On inlet, provide:
 - a. Thermometer well for temperature controller.
 - b. Thermometer.
 - c. Strainer.
 - d. Flow switch.
 - e. Flexible pipe connector.
 - f. Pressure gage.
 - g. Shut-off valve.
 2. On outlet, provide:
 - a. Thermometer.
 - b. Flexible pipe connector.
 - c. Pressure gage.
 - d. [**Shut-off**] [**Balancing**] valve.

3.3 HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

- A. Install brush-cleaning system control panel adjacent to chiller control panel.
- B. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
- C. Provide field electric power, as required, to each system control panel and electric actuated valve.
- D. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
- E. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
- F. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

3.4 CONNECTIONS

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping," Section 232116 Hydronic Piping Specialties," **[and] [Section 232300 "Refrigerant Piping"]**. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to chiller to allow service and maintenance.
- C. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with shutoff valve and pressure gage, **[flow meter,]** and drain connection with valve. Make connections to chiller with a **[flange] [or] [mechanical coupling]**.
- D. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with shutoff valve and pressure gage, **[flow meter,]** and drain connection with valve. Make connections to chiller with a **[flange] [or] [mechanical coupling]**.
- E. Heat-Reclaim Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, **[strainer,] [flexible connector,]** thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, **[flexible connector,]** flow switch, thermometer, plugged tee with shutoff valve and pressure gage, **[flow meter,]** and drain connection with valve. Make connections to chiller with a **[flange] [or] [mechanical coupling]**.

- F. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend **[vent piping] [separate vent piping for each chiller]** to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect vent to chiller pressure relief device with flexible connector and dirt leg with drain valve.
- G. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service. Supply service of factory trained representative for a period of **<Insert number>** days to supervise testing, dehydration and charging of machine, start-up, and instruction on operation and maintenance.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
 - 3. Verify that pumps are installed and functional.
 - 4. Verify that thermometers and gages are installed.
 - 5. Operate chiller for run-in period.
 - 6. Check bearing lubrication and oil levels.
 - 7. For chillers installed indoors, verify that refrigerant pressure relief device is vented outdoors.
 - 8. Verify proper motor rotation.
 - 9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
 - 10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator[**and condenser**] [, **condenser, and heat-reclaim condenser**].
 - 11. Verify and record performance of chiller protection devices.
 - 12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
- C. Prepare test and inspection startup reports.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain chillers.[**Video record the training sessions.**]
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236426

SECTION 236500 - COOLING TOWERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Closed-circuit, forced-draft, counterflow cooling towers.
 - 2. Closed-circuit, induced-draft, combined-flow cooling towers.
 - 3. Closed-circuit, induced-draft, counterflow cooling towers.
 - 4. Open-circuit, forced-draft, counterflow cooling towers.
 - 5. Open-circuit, induced-draft, counterflow cooling towers.
 - 6. Open-circuit, induced-draft, crossflow cooling towers.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. BMS: Building management system.
- B. FRP: Fiber-reinforced polyester.

1.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design cooling tower support structure[**and seismic restraints**] [**and wind restraints**], including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Structural Performance: Cooling tower support structure shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated according to [SEI/ASCE 7] <Insert requirement>.
 - 1. Dead Loads: <Insert loads>.
 - 2. Live Loads: <Insert loads>.
 - 3. Roof Loads: <Insert loads>.
 - 4. Snow Loads: <Insert loads>.
 - 5. Seismic Loads: <Insert loads>.

6. Wind Loads: **<Insert loads>**.
7. **<Insert loads or load combinations>**.
8. Deflection Limits: Design system to withstand design loads without deflections greater than the following:

- a. **<Insert deflection limits>**.

- C. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to [SEI/ASCE 7] **<Insert requirement>**.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, dimensions, weights and point loadings, required clearances, electrical requirements and wiring diagrams, location and size of field connections, pressure drop, fan performance data, rating curves with selected points indicated, furnished specialties, and accessories. Submit schematic indicating capacity controls.

1. Maximum flow rate.
2. Minimum flow rate.
3. Drift loss as percent of design flow rate.
4. Volume of water in suspension for purposes of sizing a remote storage tank.
5. Sound power levels in eight octave bands for operation with fans off, fans at minimum, and design speed, at a distance of 10 feet from the tower on all sides and above.
6. Performance curves for the following:
 - a. Varying entering-water temperatures from design to minimum.
 - b. Varying ambient wet-bulb temperatures from design to minimum.
 - c. Varying water flow rates from design to minimum.
 - d. Varying fan operation (off, minimum, and design speed).
7. Fan airflow, brake horsepower, and drive losses.
8. Pump flow rate, head, brake horsepower, and efficiency.
9. Motor amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
10. Electrical power requirements for each cooling tower component requiring power.
11. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: Complete set of manufacturer's prints of cooling tower assemblies, control panels, sections and elevations, and unit isolation. Include the following:

1. Assembled unit dimensions.
2. Weight and load distribution.
3. Required clearances for maintenance and operation.

4. Sizes and locations of piping and wiring connections.
 5. Wiring Diagrams: For power, signal, and control wiring.
 6. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
- C. Delegated-Design Submittal: For cooling tower support structure indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Detail fabrication and assembly of support structure.
 2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 3. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] [**and wind restraints**] and for designing vibration isolation bases.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
1. Structural supports.
 2. Piping roughing-in requirements.
 3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
- B. Certificates: For certification required in "Quality Assurance" Article.
- C. Manufacturer's Certificate: Certify that cooling tower performance, based on [**CTI ATC-105**] [**CTI STD-201**] [**or**] [**ASME PTC-23**] meet or exceed specified requirements and submit performance curve plotting leaving water temperature against wet bulb temperature.
- D. Seismic Qualification Certificates: For cooling towers, accessories, and components, from manufacturers.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- E. Source quality-control reports.
- F. Field quality-control reports.
- G. Startup service reports.
- H. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each cooling tower to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 EXTRA MATERIALS

- A. Provide [**two (2)**] <Insert number> sets of matched fan belts.
- B. Provide [**two (2)**] <Insert number> spray nozzles for each cell.
- C. Provide [**one (1)**] <Insert number> valve seat for each make-up or control valve.

1.9 QUALITY ASSURANCE

- A. Testing Agency Qualifications: [**Certified by CTI**] [**An NRTL**].
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- D. ASME Compliance: Fabricate and label heat-exchanger coils to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- E. CTI Certification: Cooling tower thermal performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."
- F. FMG approval and listing in the latest edition of FMG's "Approval Guide."

1.10 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.11 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Factory assemble entire unit. For shipping, disassemble into as large as practical sub-assemblies so that minimum amount of field work is required for re-assembly.
- C. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace the following components of cooling towers that fail in materials or workmanship within specified warranty period:
 - 1. Fan assembly including fan, drive, and motor.
 - 2. All components of cooling tower.
 - 3. **<Insert components requiring extended warranty>**.
 - 4. Warranty Period: Minimum [**five (5)**] **<Insert number>** years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CLOSED-CIRCUIT, FORCED-DRAFT, COUNTERFLOW COOLING TOWERS

- A. **Products: Subject to compliance with requirements, provide one of the following:**
 - 1. **Baltimore Aircoil Company**; Models VFL and VF1.

2. [Delta Cooling Towers, Inc](#); Model Pioneer.
 3. [EVAPCO, Inc](#); Models LSWA and LRW.
 4. [Recold](#); Models JM and JW.
 5. **<Insert manufacturer's name; product name or designation>**.
 6. or approved equal.
- B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.
- C. Cooling tower designed to resist wind load of [30 lbf/sq. ft. (1.44 kPa)] **<Insert value>**.
- D. Casing and Frame:
1. Casing[and Frame] Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
 2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
 3. Fasteners: [Galvanized] [Stainless] steel.
 4. Joints and Seams: Sealed watertight.
 5. Welded Connections: Continuous and watertight.
- E. Collection Basin: Configure tower for installation with a field-constructed collection basin.
- F. Collection Basin:
1. Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
 2. Strainer: Removable[stainless-steel] strainer with openings smaller than nozzle orifices.
 3. Overflow and drain connections.
 4. Makeup water connection.
 5. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: [PVC] **<Insert material>**.
 - b. Nozzle Material: [Plastic] **<Insert material>**.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, [Type 4] [Type 4X] **<Insert type>**.

2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide **[control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level]**.
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel]**.
 5. Solenoid Valve: Slow closing **[with stainless-steel body]**, controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each cooling tower cell.
 3. Enclosure: NEMA 250, **[Type 3R] [Type 4] [Type 4X]**.
 4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]** and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- J. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- K. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- L. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Water Distribution Piping: Main header and lateral branch piping designed for even distribution over fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
1. Pipe Material: **[Fiberglass] [PVC] [Galvanized steel] <Insert material>**.
 2. Spray Nozzle Material: **[Plastic] [Polypropylene] [PVC] <Insert material>**.
 3. Piping Supports: Corrosion-resistant hangers and supports designed to resist movement during operation and shipment.

- N. Recirculating Piping: **[PVC] <Insert pipe material>[, with connections for separately provided, remote spray pump].**
- O. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
1. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
 2. Motor Enclosure: **[Totally enclosed] [Totally enclosed nonventilated (TENV)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].**
 3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].**
 4. Service Factor: **[1.0] [1.15] <Insert value>.**
- P. Heat-Exchanger Coils:
1. Tube and Tube Sheet Materials: **[Copper tube with stainless-steel sheet] [Stainless-steel tube and sheet] [Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication].**
 2. Heat-Exchanger Arrangement: **[Serpentine tubes] [Serpentine tubes with removable cover plate on inlet and outlet headers] [Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube];** and sloped for complete drainage of fluid by gravity.
 3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
 4. Field Piping Connections: Vent, supply, and return **[suitable for mating to ASME B16.5, Class 150 flange].**
- Q. **[Removable]** Drift Eliminator:
1. Material: **[FRP] [PVC] [FRP or PVC] <Insert material>**; with maximum flame-spread index of **[5] [25] <Insert value>** according to ASTM E 84.
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
- R. **[Removable]** Air-Intake Screens: **[Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.**
- S. Centrifugal Fan: Double-width, double-inlet, forward-curved blades, and statically and dynamically balanced at the factory after assembly.
1. Number of Fans: Each cooling tower cell shall have a single fan or multiple fans connected to a common shaft.
 2. Fan Wheel and Housing Materials: Galvanized steel.
 3. Fan Shaft: Steel, coated to resist corrosion.

4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
5. Fan Shaft Bearings: Self-aligning, grease-lubricated ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of **[40,000] [50,000] <Insert value>** hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

T. Belt Drive:

1. Belt-Drive Service Factor: **[1.5] <Insert value>** based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
3. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
4. Belt: One-piece, multigrooved, solid-back belt.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.
7. Two-Motor, Single-Fan Drive:
 - a. Two single-speed motors per fan, one sized for full speed and load, and the other sized for **[67] <Insert value>** percent of full-load speed.
 - b. Belt Drives: Each motor shall have belt drive complying with requirements for belt drives and configured for operation when other motor fails.
 - c. Motor controller and wiring same as two-speed, two-winding motor.

U. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: **[Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish]**.
3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient]**.
4. Service Factor: **[1.15] <Insert value>**.
5. Insulation: **[Class F] [Class H] <Insert class>**.
6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
7. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C.)
 - c. Internal heater automatically energized when motor is de-energized.

8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
- V. Discharge Hoods:
1. Hood Configuration: **[Tapered]** **[Straight]**; totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed **[insulation and]**access doors.
 2. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
 - a. Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.
- W. Capacity-Control Dampers: **[Galvanized-steel]** **[Stainless-steel]** **<Insert material>** dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.
- X. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, **[Type 4]** **[Type 4X]** **<Insert type>**.
 2. Vibration Detection: Sensor with a field-adjustable acceleration sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch **[with manual-reset button]** for **[field connection to a BMS and]**hardwired connection to fan motor electrical circuit.
 4. Switch shall, on sensing excessive vibration, **[signal an alarm through the BMS and]** shut down the fan.
- Y. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- Z. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
1. NEMA 250, **[Type 3R]** **[Type 4]** **[Type 4X]** enclosure with removable internally mount backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
 4. Microprocessor-based controller for automatic control of fan **[and spray pump]** based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
 5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
 6. Collection basin, electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.

7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.
10. Power and controls to open discharge hood dampers when pump is energized and close dampers when pump is de-energized.
11. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell]**.
 - a. Branch power circuit to each motor and electric basin heater and to controls **[with a disconnect switch or circuit breaker]**.
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
12. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
13. Visual indication of status and alarm **[with momentary test push button]** for each motor.
14. Audible alarm and silence switch.
15. Visual indication of elapsed run time, graduated in hours for each motor.
16. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Position of dampers.
 - c. Cooling tower leaving-fluid temperature.
 - d. Fan vibration alarm.
 - e. Collection basin **[high] [low] [high- and low]-water-level** alarms.
 - f. **<Insert conditions to be monitored>**.

AA. Personnel Access Components:

1. Doors: Large enough for personnel to access cooling tower internal components from **[both]cooling tower end walls.[Doors shall be operable from both sides of the door.]**
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard at platforms and around top of cooling tower. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.

- a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.

BB. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Maximum Drift Loss: **[0.005]** **<Insert number>** percent of design water flow.
3. Heat-Exchanger Coil:
 - a. Fluid Type: **[Water]** **<Insert type>**.
 - b. Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - c. Minimum Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - d. Fluid Pressure Drop: **<Insert psig (kPa)>**.
 - e. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - f. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - g. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
4. Economizer Mode:
 - a. Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - c. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
5. Fan Location: **[Bottom]** **[Side]**.
6. Fan Motor:
 - a. Type: **[Single speed]** **[Two speed, single winding]** **[Two speed, two winding]** **[Variable speed]**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[208]** **[240]** **[480]** **<Insert value>**-V ac, 3 phase, 60 Hz.
7. Spray Pump and Motor:
 - a. Water Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[120]** **[208]** **[240]** **[277]** **[480]** **<Insert value>**-V ac, **[single]** **[3]** phase, 60 Hz.
8. Sound Pressure Level: **<Insert dBA>** at **<Insert distance in feet (m)>** **[when measured according to CTI ATC 128]**.

9. Basin Heater:

- a. Basin Water Temperature: [40 deg F (5 deg C)] <Insert deg F (deg C)>.
- b. Outdoor Ambient Temperature: [0 deg F (minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert deg F (deg C)>.
- c. Capacity/Cell: <Insert kilowatts>.
- d. Full-Load Ampacity: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection Device: <Insert amperage>.
- g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
- h. Capacity/Cell: <Insert MBtu/h (kW)>.
- i. Entering-Fluid Temperature: <Insert deg F (deg C)>.
- j. Fluid Flow Rate: <Insert gpm (L/s)>.
- k. Fluid Pressure Drop: <Insert psig (kPa)>.
- l. Capacity/Cell: <Insert MBtu/h (kW)>.
- m. Steam Flow: <Insert lb/h (L/s)>.
- n. Steam Pressure: <Insert psig (kPa)>.

2.2 CLOSED-CIRCUIT, INDUCED-DRAFT, COMBINED-FLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, provide one of the following:

1. [Baltimore Aircoil Company](#); Model FXV.
2. [Marley Cooling Technologies](#); Model MH.
3. <Insert manufacturer's name; product name or designation>.
4. or approved equal.

B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

C. Cooling tower designed to resist wind load of [30 lbf/sq. ft. (1.44 kPa)] <Insert value>.

D. Casing and Frame:

1. Casing[and Frame] Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
3. Fasteners: [Galvanized] [Stainless] steel.
4. Joints and Seams: Sealed watertight.
5. Welded Connections: Continuous and watertight.

E. Collection Basin: Configure tower for installation with a field-constructed collection basin.

- F. Collection Basin:
1. Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.
 2. Strainer: Removable **[stainless-steel]** strainer with openings smaller than nozzle orifices.
 3. Overflow and drain connections.
 4. Makeup water connection.
 5. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: **[PVC] <Insert material>**.
 - b. Nozzle Material: **[Plastic] <Insert material>**.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide **[control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level]**.
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel]**.
 5. Solenoid Valve: Slow closing **[with stainless-steel body]**, controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal **[for connection to BMS]**.
 3. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel]**.
 4. Solenoid Valve: Slow closing **[with stainless-steel body]**, controlled and powered through level controller in response to water-level set point.
 5. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- J. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.

2. Heater Control Panel: Mounted on the side of each cooling tower cell.
 3. Enclosure: NEMA 250, **[Type 3R]** **[Type 4]** **[Type 4X]**.
 4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a **[fused disconnect switch]** **[nonfused disconnect switch]** **[circuit breaker]** and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- K. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- L. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- N. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
1. Material: **[FRP with UV inhibitors]** **[Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating]** **[Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating]** **[Polymer-coated galvanized steel]** **[Stainless steel]**.
 2. Location: Over each bank of fill with easily replaceable **[plastic]** **<Insert material>** spray nozzles mounted in bottom of basin.
 3. Joints and Seams: Sealed watertight.
 4. Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
 5. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable **[corrosion-resistant]** **[stainless-steel]** hardware.
 6. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity water distribution basin.
- O. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
1. Pipe Material: **[PVC]** **[Galvanized steel]** **<Insert material>**.
 2. Spray Nozzle Material: **[Plastic]** **[Polypropylene]** **<Insert material>**.

3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
- P. Recirculating Piping: **[PVC] <Insert pipe material>[, with connections for separately provided, remote spray pump].**
- Q. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
1. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
 2. Motor Enclosure: **[Totally enclosed] [Totally enclosed nonventilated (TENV)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].**
 3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].**
 4. Service Factor: **[1.0] [1.15] <Insert value>.**
- R. Fill:
1. Materials: **[PVC] <Insert material>**, with maximum flame-spread index of **[5] [25] <Insert value>** according to ASTM E 84.
 2. Minimum Thickness: **[15 mils (0.4 mm)] [20 mils (0.5 mm)] <Insert value>**, before forming.
 3. Fabrication: Fill-type sheets fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
 4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through **[120 deg F (49 deg C)] <Insert temperature>.**
- S. Heat-Exchanger Coils:
1. Tube and Tube Sheet Materials: **[Copper tube with stainless-steel sheet] [Stainless-steel tube and sheet] [Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication].**
 2. Heat-Exchanger Arrangement: **[Serpentine tubes] [Serpentine tubes with removable cover plate on inlet and outlet headers] [Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube];** and sloped for complete drainage of fluid by gravity.
 3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
 4. Field Piping Connections: Vent, supply, and return **[suitable for mating to ASME B16.5, Class 150 flange].**
- T. Drift Eliminator:
1. Material: **[FRP] [PVC] [FRP or PVC] <Insert material>**; with maximum flame-spread index of **[5] <Insert value>** according to ASTM E 84.

2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
 4. Fill Drift Eliminators: **[Integral to] [Separate and removable from]** fill.
 5. Heat-Exchanger Coil Drift Eliminators: Located on discharge side and removable.
- U. Air-Intake Louvers:
1. Material: **[FRP] [PVC] [Matching casing]**.
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
 4. Location: **[Integral to] [Separate from]** fill.
- V. **[Removable]** Air-Intake Screens: **[Galvanized] [Polymer-coated, galvanized] [Stainless]**-steel wire mesh.
- W. Axial Fan: Balanced at the factory after assembly.
1. Blade Material: **[Aluminum] [FRP]**.
 2. Hub Material: **[Aluminum] [FRP]**.
 3. Blade Pitch: Field adjustable.
 4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
 5. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of **[40,000] [50,000] <Insert value>** hours.
 6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
- X. Belt Drive:
1. Service Factor: **[1.5] <Insert value>** based on motor nameplate horsepower.
 2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
 3. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
 4. Belt: One-piece, multigrooved, solid-back belt.
 5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
 6. Belt-Drive Guard: Comply with OSHA regulations.
 7. Two-Motor, Single-Fan Drive:
 - a. Two single-speed motors per fan, one sized for full speed and load and the other sized for **[67] <Insert value>** percent of full-load speed.
 - b. Each motor with belt drive and configured for operation when other motor fails.
 - c. Controls and wiring same as two-speed, two-winding motor.

- Y. Gear Drive: Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.
1. Gear Drive and Coupling Service Factor: **[2.0] <Insert value>** based on motor nameplate horsepower.
 2. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds.
 3. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
 4. Operation: Able to operate both forward and in reverse.
 5. Drive-to-Motor Connection: **[Close coupled to motor using a flexible coupling] [Connected to motor located outside of cooling tower casing by a full-floating drive shaft].**
 6. Drive Shaft Material: **[Corrosion resistant] [Stainless steel]**, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
 7. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.
- Z. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
 2. Motor Enclosure: **[Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].**
 3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].**
 4. Service Factor: **[1.15] <Insert value>**.
 5. Insulation: **[Class F] [Class H] <Insert class>**.
 6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
 7. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
 8. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C.)
 - c. Internal heater automatically energized when motor is de-energized.
 9. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
- AA. Fan Discharge Stack: Material shall match casing, **[manufacturer's standard] [velocity recovery]** design.

1. Stack Extension: Fabricated to extend above fan deck **<Insert distance>** unless otherwise indicated.
 2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
- BB. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch **[with manual-reset button]** for **[field connection to a BMS and]**hardwired connection to fan motor electrical circuit.
 4. Switch shall, on sensing excessive vibration, **[signal an alarm through the BMS and]** shut down the fan.
- CC. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch **[for connection to a BMS]**.
1. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm **[through the BMS]**.
- DD. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- EE. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
1. NEMA 250, **[Type 3R] [Type 4] [Type 4X]** enclosure with removable internally mount backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
 4. Microprocessor-based controller for automatic control of fan **[and spray pump]** based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
 5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
 6. Collection basin level controller complying with requirements in **["Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve"] ["Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve"]** Paragraph.
 7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
 8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
 9. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.

10. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell]**.
 - a. Branch power circuit to each motor and electric basin heater and to controls **[with a disconnect switch or circuit breaker]**.
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
11. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
12. Visual indication of status and alarm **[with momentary test push button]** for each motor.
13. Audible alarm and silence switch.
14. Visual indication of elapsed run time, graduated in hours for each motor.
15. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Position of dampers.
 - c. Cooling tower leaving-fluid temperature.
 - d. Fan vibration alarm.
 - e. Oil-level alarm.
 - f. Collection basin **[high] [low] [high- and low]-**water-level alarms.
 - g. **<Insert conditions to be monitored>**.

FF. Personnel Access Components:

1. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
 - b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

GG. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Air-Inlet Arrangement: **[Single side] [Two sides] [Sides and top]**.
3. Maximum Drift Loss: **[0.005] <Insert number>** percent of design water flow.
4. Heat-Exchanger Coil:
 - a. Fluid Type: **[Water] <Insert type>**.
 - b. Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - c. Minimum Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - d. Fluid Pressure Drop: **<Insert psig (kPa)>**.
 - e. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - f. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - g. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
5. Economizer Mode:
 - a. Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - c. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
6. Fan Drive: Belt or gear.
7. Fan Motor:
 - a. Type: **[Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed]**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
8. Spray Pump and Motor:
 - a. Water Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[120] [208] [240] [277] [480] <Insert value>**-V ac, **[single] [3]** phase, 60 Hz.
9. Sound Pressure Level: **<Insert dBA>** at **<Insert distance in feet (m)>** **[when measured according to CTI ATC 128]**.
10. Basin Heater:
 - a. Basin Water Temperature: **[40 deg F (5 deg C)] <Insert deg F (deg C)>**.

- b. Outdoor Ambient Temperature: [0 deg F (minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert deg F (deg C)>.
- c. Capacity/Cell: <Insert kilowatts>.
- d. Full-Load Ampacity: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection Device: <Insert amperage>.
- g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
- h. Capacity/Cell: <Insert MBtu/h (kW)>.
- i. Entering-Fluid Temperature: <Insert deg F (deg C)>.
- j. Fluid Flow Rate: <Insert gpm (L/s)>.
- k. Fluid Pressure Drop: <Insert psig (kPa)>.
- l. Capacity/Cell: <Insert MBtu/h (kW)>.
- m. Steam Flow: <Insert lb/h (L/s)>.
- n. Steam Pressure: <Insert psig (kPa)>.

2.3 CLOSED-CIRCUIT, INDUCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, provide one of the following:

- 1. [EVAPCO, Inc](#); Models ATW, ESW, and UBW.
- 2. [Recold](#); Model MW.
- 3. <Insert manufacturer's name; product name or designation>.
- 4. or approved equal.

B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

C. Cooling tower designed to resist wind load of [30 lbf/sq. ft. (1.44 kPa)] <Insert value>.

D. Casing and Frame:

- 1. Casing[and Frame] Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Stainless steel].
- 2. Frame Material: [FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].
- 3. Fasteners: [Galvanized] [Stainless] steel.
- 4. Joints and Seams: Sealed watertight.
- 5. Welded Connections: Continuous and watertight.

E. Collection Basin: Configure tower for installation with a field-constructed collection basin.

F. Collection Basin:

1. Material: [**Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating**] [**Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating**] [**Stainless steel**].
 2. Overflow and drain connections.
 3. Makeup water connection.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, [**Type 4**] [**Type 4X**] <Insert type>.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide [**control of water makeup valve**] [**control of water makeup valve and low-level alarm**] [**control of water makeup valve and low- and high-level alarms**] [**control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level**].
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: [**Corrosion-resistant material**] [**FRP**] [**Galvanized steel**] [**PVC pipe**] [**Stainless steel**].
 5. Solenoid Valve: Slow closing[**with stainless-steel body**]; controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each cooling tower cell.
 3. Enclosure: NEMA 250, [**Type 3R**] [**Type 4**] [**Type 4X**].
 4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**] and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- J. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- K. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

- L. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
1. Pipe Material: **[Fiberglass] [PVC] [Galvanized steel] <Insert material>**.
 2. Spray Nozzle Material: **[Plastic] [Polypropylene] [PVC] <Insert material>**.
 3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
- N. Recirculating Piping: **[PVC] <Insert pipe material>[, with connections for separately provided, remote spray pump]**.
- O. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
- P. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
1. Motor Enclosure: **[Totally enclosed] [Totally enclosed nonventilated (TENV)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish]**.
 2. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient]**.
 3. Service Factor: **[1.0] [1.15] <Insert value>**.
- Q. Heat-Exchanger Coils:
1. Tube and Tube Sheet Materials: **[Copper tube with stainless-steel sheet] [Stainless-steel tube and sheet] [Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication]**.
 2. Heat-Exchanger Arrangement: **[Serpentine tubes] [Serpentine tubes with removable cover plate on inlet and outlet headers] [Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube]**; and sloped for complete drainage of fluid by gravity.
 3. ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
 4. Field Piping Connections: Vent, supply, and return **[suitable for mating to ASME B16.5, Class 150 flange]**.
- R. **[Removable]** Drift Eliminator:
1. Material: **[FRP] [PVC] [FRP or PVC] <Insert material>**; with maximum flame-spread index of **[5] [25] <Insert value>** according to ASTM E 84.

2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.

S. Air-Intake Louvers:

1. Material: **[FRP] [PVC] [Matching casing]**.
2. UV Treatment: Treat louvers with inhibitors to protect against damage caused by UV radiation.
3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out during all modes of operation including operation with fans off.

T. Axial Fan: Balanced at the factory after assembly.

1. Blade Material: **[Aluminum] [FRP] [Galvanized steel]**.
2. Hub Material: **[Aluminum] [FRP] [Galvanized steel]**.
3. Blade Pitch: Field adjustable.
4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
5. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of **[40,000] [50,000] <Insert value>** hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

U. Belt Drive:

1. Service Factor: **[1.5] <Insert value>** based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
3. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
4. Belt: One-piece, multigrooved, solid-back belt.
5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.
7. Two-Motor, Single-Fan Drive:
 - a. Two single-speed motors per fan, one sized for full speed and load and the other sized for **[67] <Insert value>** percent of full-load speed.
 - b. Each motor with belt drive and configured for operation when other motor fails.
 - c. Controls and wiring same as two-speed, two-winding motor.

V. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.

2. Motor Enclosure: [**Totally enclosed**] [**Totally enclosed air over (TEAO)**] [**Totally enclosed fan cooled (TEFC)**] [**with epoxy or polyurethane finish**].
 3. Energy Efficiency: [**Comply with ASHRAE/IESNA 90.1**] [**NEMA Premium Efficient**].
 4. Service Factor: [**1.15**] <Insert value>.
 5. Insulation: [**Class F**] [**Class H**] <Insert class>.
 6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
 7. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** ((minus 29 and plus 149 deg C).)
 - c. Internal heater automatically energized when motor is de-energized.
 8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
- W. Fan Discharge Stack: Material shall match casing, [**manufacturer's standard**] [**velocity recovery**] design.
1. Stack Extension: Fabricated to extend above fan deck <Insert distance> unless otherwise indicated.
 2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
- X. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, [**Type 4**] [**Type 4X**] <Insert type>.
 2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch[**with manual-reset button**] for [**field connection to a BMS and**]hardwired connection to fan motor electrical circuit.
 4. Switch shall, on sensing excessive vibration,[**signal an alarm through the BMS and**] shut down the fan.
- Y. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- Z. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
1. NEMA 250, [**Type 3R**] [**Type 4**] [**Type 4X**] enclosure with removable internally mount backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

4. Microprocessor-based controller for automatic control of fan[**and spray pump**] based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
 5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
 6. Collection basin electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.
 7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
 8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
 9. Single-point, field-power connection to a [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**] [**for each cooling tower cell**].
 - a. Branch power circuit to each motor and electric basin heater and to controls[**with a disconnect switch or circuit breaker**].
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
 10. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
 11. Visual indication of status and alarm[**with momentary test push button**] for each motor.
 12. Audible alarm and silence switch.
 13. Visual indication of elapsed run time, graduated in hours for each motor.
 14. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Cooling tower leaving-fluid temperature.
 - c. Fan vibration alarm.
 - d. Collection basin [**high**] [**low**] [**high- and low**]-water-level alarms.
 - e. **<Insert conditions to be monitored>**.
- AA. Personnel Access Components:
1. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
 2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
 3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.

4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
 - b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

BB. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Maximum Drift Loss: **[0.005] <Insert number>** percent of design water flow.
3. Heat-Exchanger Coil:
 - a. Fluid Type: **[Water] <Insert type>**.
 - b. Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - c. Minimum Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - d. Fluid Pressure Drop: **<Insert psig (kPa)>**.
 - e. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - f. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - g. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
4. Economizer Mode:
 - a. Fluid Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - c. Leaving-Fluid Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
5. Fan Motor:
 - a. Type: **[Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed]**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
6. Spray Pump and Motor:
 - a. Water Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Horsepower/Cell: **<Insert horsepower>** .
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.

- e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[120] [208] [240] [277] [480] <Insert value>**-V ac, **[single] [3]** phase, 60 Hz.
7. Sound Pressure Level: **<Insert dBA>** at **<Insert distance in feet (m)>** **[when measured according to CTI ATC 128]**.
8. Basin Heater:
- a. Basin Water Temperature: **[40 deg F (5 deg C)] <Insert deg F (deg C)>**.
 - b. Outdoor Ambient Temperature: **[0 deg F (minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert deg F (deg C)>**.
 - c. Capacity/Cell: **<Insert kilowatts>**.
 - d. Full-Load Ampacity: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - g. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
 - h. Capacity/Cell: **<Insert MBtu/h (kW)>**.
 - i. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - j. Fluid Flow Rate: **<Insert gpm (L/s)>**.
 - k. Fluid Pressure Drop: **<Insert psig (kPa)>**.
 - l. Capacity/Cell: **<Insert MBtu/h (kW)>**.
 - m. Steam Flow: **<Insert lb/h (L/s)>**.
 - n. Steam Pressure: **<Insert psig (kPa)>**.

2.4 OPEN-CIRCUIT, FORCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, provide one of the following:

- 1. [Baltimore Aircoil Company](#); Models VTL, VTO, and VT1.
- 2. [Delta Cooling Towers, Inc](#); Model Pioneer.
- 3. [EVAPCO, Inc](#); Models LRT and LSTA.
- 4. [Tower Tech, Inc](#); Model TTXE.
- 5. **<Insert manufacturer's name; product name or designation>**.
- 6. or approved equal.

B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

C. Cooling tower designed to resist wind load of **[30 lbf/sq. ft. (1.44 kPa)] <Insert value>**.

D. Casing and Frame:

- 1. Casing[and Frame] Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.

2. Frame Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].**
 3. Fasteners: **[Galvanized] [Stainless]** steel.
 4. Joints and Seams: Sealed watertight.
 5. Welded Connections: Continuous and watertight.
- E. Collection Basin: Configure tower for installation with a field-constructed collection basin.
- F. Collection Basin:
1. Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel].**
 2. Strainer: Removable **[stainless-steel]** strainer with openings smaller than nozzle orifices.
 3. Overflow and drain connections.
 4. Makeup water connection.
 5. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: **[PVC] <Insert material>**.
 - b. Nozzle Material: **[Plastic] <Insert material>**.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide **[control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level].**
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel].**
 5. Solenoid Valve: Slow closing **[with stainless-steel body]**, controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each cooling tower cell.
 3. Enclosure: NEMA 250, **[Type 3R] [Type 4] [Type 4X].**

4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]** and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- J. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- K. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- L. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
1. Pipe Material: **[Fiberglass] [PVC] [Galvanized steel] <Insert material>**.
 2. Spray Nozzle Material: **[Plastic] [Polypropylene] [PVC] <Insert material>**.
 3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
- N. Fill:
1. Materials: **[PVC] <Insert material>**, with maximum flame-spread index of 5 according to ASTM E 84.
 2. Minimum Thickness: **[15 mils (0.4 mm)] [20 mils (0.5 mm)] <Insert value>**, before forming.
 3. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
 4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through **[120 deg F (49 deg C)] <Insert temperature>**.
- O. **[Removable]** Drift Eliminator:
1. Material: **[FRP] [PVC] [FRP or PVC] <Insert material>**; with maximum flame-spread index of **[5] [25] <Insert value>** according to ASTM E 84.
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.

- P. **[Removable]** Air-Intake Screens: **[Galvanized]** **[Polymer-coated, galvanized]** **[Stainless]**-steel wire mesh.
- Q. Centrifugal Fan: Double-width, double-inlet, forward-curved blades, and statically and dynamically balanced at the factory after assembly.
1. Number of Fans: Each cooling tower cell shall have a single fan or multiple fans connected to a common shaft.
 2. Fan Wheel and Housing Materials: Galvanized steel.
 3. Fan Shaft: Steel, coated to resist corrosion.
 4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
 5. Fan Shaft Bearings: Self-aligning, grease-lubricated ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of **[40,000]** **[50,000]** **<Insert value>** hours.
 6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
- R. Axial Fan: Balanced at the factory after assembly.
1. Blade Material: **[FRP]** **<Insert material>**.
 2. Hub Material: **[Aluminum]** **[FRP]** **<Insert material>**.
 3. Blade Pitch: Field adjustable.
 4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
 5. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of **[40,000]** **[50,000]** **<Insert value>** hours.
 6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
- S. Belt Drive:
1. Service Factor: **[1.5]** **<Insert value>** based on motor nameplate horsepower.
 2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
 3. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
 4. Belt: One-piece, multigrooved, solid-back belt.
 5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
 6. Belt-Drive Guard: Comply with OSHA regulations.
 7. Two-Motor, Single-Fan Drive:
 - a. Two single-speed motors per fan, one sized for full speed and load and the other sized for **[67]** **<Insert value>** percent of full-load speed.
 - b. Each motor with belt drive and configured for operation when other motor fails.
 - c. Controls and wiring same as two-speed, two-winding motor.

- T. Direct Drive: Fan hub directly connected, and properly secured, to motor shaft.
- U. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
 2. Motor Enclosure: **[Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].**
 3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].**
 4. Service Factor: **[1.15] <Insert value>.**
 5. Insulation: **[Class F] [Class H] <Insert class>.**
 6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
 7. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and 300 deg F** (minus 29 and 149 deg C.)
 - c. Internal heater automatically energized when motor is de-energized.
 8. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
- V. Discharge Hoods:
1. Hood Configuration: **[Tapered] [Straight];** totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed **[insulation and]** access doors.
 2. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
 - a. Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.
- W. Capacity-Control Dampers: **[Galvanized-steel] [Stainless-steel] <Insert material>** dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.
- X. Vibration Switch: For each fan drive.
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>.**
 2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch **[with manual-reset button]** for **[field connection to a BMS and]**hardwired connection to fan motor electrical circuit.

4. Switch shall, on sensing excessive vibration, [**signal an alarm through the BMS and**] shut down the fan.

- Y. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- Z. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
 1. NEMA 250, [Type 3R] [Type 4] [Type 4X] enclosure with removable internally mount backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
 4. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
 5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
 6. Factory-installed and -wired, collection basin electric/electronic level controller.
 7. Collection basin electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.
 8. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
 9. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
 10. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.
 11. Single-point, field-power connection to a [fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell].
 - a. Branch power circuit to each motor and electric basin heater and to controls [**with a disconnect switch or circuit breaker**].
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
 12. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
 13. Visual indication of status and alarm [**with momentary test push button**] for each motor.
 14. Audible alarm and silence switch.
 15. Visual indication of elapsed run time, graduated in hours for each motor.
 16. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Position of dampers.

- c. Cooling tower leaving-fluid temperature.
- d. Fan vibration alarm.
- e. Collection basin **[high]** **[low]** **[high- and low]**-water-level alarms.
- f. **<Insert conditions to be monitored>**.

AA. Personnel Access Components:

1. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
 - b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

BB. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Air-Inlet Arrangement: **[Single side]** **[Four sides]**.
3. Maximum Drift Loss: **[0.005]** **<Insert number>** percent of design water flow.
4. Water Flow/Cell: **<Insert gpm (L/s)>**.
5. Minimum Water Flow/Cell: **<Insert gpm (L/s)>**.
6. Water Pressure Drop: **<Insert psig (kPa)>**.
7. Entering-Water Temperature: **<Insert deg F (deg C)>**.
8. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
9. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
10. Economizer Mode:
 - a. Water Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - c. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
11. Fan Location: **[Bottom]** **[Side]** **[Bottom or side]**.
12. Fan and Drive Type: Axial with direct drive or centrifugal with belt drive.
13. Fan Motor:

- a. Type: **[Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed]**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
14. Sound Pressure Level: **<Insert dBA>** at **<Insert distance in feet (m)>** **[when measured according to CTI ATC 128]**.
15. Basin Heater:
- a. Basin Water Temperature: **[40 deg F (5 deg C)] <Insert deg F (deg C)>**.
 - b. Outdoor Ambient Temperature: **[0 deg F (minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert deg F (deg C)>**.
 - c. Capacity/Cell: **<Insert kilowatts>**.
 - d. Full-Load Ampacity: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - g. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
 - h. Capacity/Cell: **<Insert MBtu/h (kW)>**.
 - i. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
 - j. Fluid Flow Rate: **<Insert gpm (L/s)>**.
 - k. Fluid Pressure Drop: **<Insert psig (kPa)>**.
 - l. Capacity/Cell: **<Insert MBtu/h (kW)>**.
 - m. Steam Flow: **<Insert lb/h (L/s)>**.
 - n. Steam Pressure: **<Insert psig (kPa)>**.

2.5 OPEN-CIRCUIT, INDUCED-DRAFT, COUNTERFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, provide one of the following:

1. [Amcot Cooling Tower Corp](#); Model ST.
2. [Delta Cooling Towers, Inc](#); Model Paragon, Premier, TM Series.
3. [EVAPCO, Inc](#); Models AT, ICT, REP, UBT, and USS.
4. [Protec Cooling Towers, Inc](#); Model PTC.
5. [Recold](#); Model MT.
6. [Thermal Care, Inc](#); Models FC and FT.
7. **<Insert manufacturer's name; product name or designation>**.
8. or approved equal.

B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

C. Cooling tower designed to resist wind load of **[30 lbf/sq. ft. (1.44 kPa)] <Insert value>**.

- D. Casing and Frame:
1. Casing[and Frame] Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Stainless steel]**.
 2. Frame Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Stainless steel]**.
 3. Fasteners: **[Galvanized] [Stainless]** steel.
 4. Joints and Seams: Sealed watertight.
 5. Welded Connections: Continuous and watertight.
- E. Collection Basin: Configure tower for installation with a field-constructed collection basin.
- F. Collection Basin:
1. Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.
 2. Strainer: Removable **[stainless-steel]** strainer with openings smaller than nozzle orifices.
 3. Overflow and drain connections.
 4. Makeup water connection.
 5. Outlet Connection: ASME B16.5, Class 150 flange.
 6. Removable equalization flume plate between adjacent cells of multiple-cell towers.
 7. Equalizer connection for field-installed equalizer piping.
 8. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: **[PVC] <Insert material>**.
 - b. Nozzle Material: **[Plastic] <Insert material>**.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide **[control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level]**.
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel]**.

5. Solenoid Valve: Slow closing[**with stainless-steel body**]; controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, [**Type 4**] [**Type 4X**] <Insert type>.
 2. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal[**for connection to BMS**].
 3. Water Stilling Chamber: [**Corrosion-resistant material**] [**FRP**] [**Galvanized steel**] [**PVC pipe**] [**Stainless steel**].
 4. Solenoid Valve: Slow closing[**with stainless-steel body**]; controlled and powered through level controller in response to water-level set point.
 5. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- J. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each cooling tower cell.
 3. Enclosure: NEMA 250, [**Type 3R**] [**Type 4**] [**Type 4X**].
 4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**] and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- K. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- L. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- N. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

1. Pipe Material: [**Fiberglass**] [**PVC**] [**Galvanized steel**] <Insert material>.
 2. Spray Nozzle Material: [**Plastic**] [**Polypropylene**] [**PVC**] <Insert material>.
 3. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
- O. Fill:
1. Materials: [**CPVC**] [**PVC**] <Insert material>, resistant to rot, decay, and biological attack; with maximum flame-spread index of [**5**] [**25**] <Insert value> according to ASTM E 84.
 2. Minimum Thickness: [**15 mils (0.4 mm)**] [**20 mils (0.5 mm)**] <Insert value> before forming.
 3. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
 4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [**120 deg F (49 deg C)**] <Insert temperature>.
- P. [**Removable**] Drift Eliminator:
1. Material: [**FRP**] [**PVC**] [**FRP or PVC**] <Insert material>; resistant to rot, decay, and biological attack; with maximum flame-spread index of [**5**] [**25**] <Insert value> according to ASTM E 84.
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
- Q. Air-Intake Louvers:
1. Material: [**FRP**] [**PVC**] [**Matching casing**].
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
- R. [**Removable**] Air-Intake Screens: [**Galvanized**] [**Polymer-coated, galvanized**] [**Stainless**]-steel wire mesh.
- S. Axial Fan: Balanced at the factory after assembly.
1. Blade Material: [**Aluminum**] [**FRP**] [**Galvanized steel**].
 2. Hub Material: [**Aluminum**] [**FRP**] [**Galvanized steel**].
 3. Blade Pitch: Field adjustable.
 4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens, complying with OSHA regulations.
 5. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of [**40,000**] [**50,000**] <Insert value> hours.
 6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

T. Belt Drive:

1. Service Factor: **[1.5] <Insert value>** based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
 - a. Belt: Multiple V-belt design with a matched set of **[cogged]** belts.
 - b. Belt: One-piece, multigrooved, solid-back belt.
 - c. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
 - d. Belt-Drive Guard: Comply with OSHA regulations.

U. Direct Drive: Fan hub directly connected, and properly secured, to motor shaft.

V. Gear Drive: Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.

1. Gear Drive and Coupling Service Factor: **[2.0] <Insert value>** based on motor nameplate horsepower.
2. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds.
3. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
4. Operation: Able to operate both forward and in reverse.
5. Drive-to-Motor Connection: **[Close coupled to motor using a flexible coupling] [Connected to motor located outside of cooling tower casing by a full-floating drive shaft].**
6. Drive Shaft Material: **[Corrosion resistant] [Stainless steel]**, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
7. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.

W. Fan Motor:

1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: **[Totally enclosed] [Totally enclosed air over (TEAO)] [Totally enclosed fan cooled (TEFC)] [with epoxy or polyurethane finish].**
3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1] [NEMA Premium Efficient].**
4. Service Factor: **[1.15] <Insert value>**.
5. Insulation: **[Class F] [Class H] <Insert class>**.
6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
7. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.

8. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C.)
 - c. Internal heater automatically energized when motor is de-energized.
9. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
- X. Fan Discharge Stack: Material shall match casing, [**manufacturer's standard**] [**velocity recovery**] design.
 1. Stack Extension: Fabricated to extend above fan deck **<Insert distance>** unless otherwise indicated.
 2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
- Y. Vibration Switch: For each fan drive.
 1. Enclosure: NEMA 250, [**Type 4**] [**Type 4X**] **<Insert type>**.
 2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch[**with manual-reset button**] for [**field connection to a BMS and**]hardwired connection to fan motor electrical circuit.
 4. Switch shall, on sensing excessive vibration,[**signal an alarm through the BMS and**] shut down the fan.
- Z. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch[**for connection to a BMS**].
 1. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm[**through the BMS**].
- AA. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- BB. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
 1. NEMA 250, [**Type 3R**] [**Type 4**] [**Type 4X**] enclosure with removable internally mount backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
 4. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.

5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
6. Collection basin level controller complying with requirements in **["Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve"] ["Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve"]** Paragraph.
7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.
10. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker] [for each cooling tower cell]**.
 - a. Branch power circuit to each motor and electric basin heater and to controls **[with a disconnect switch or circuit breaker]**.
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
11. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
12. Visual indication of status and alarm **[with momentary test push button]** for each motor.
13. Audible alarm and silence switch.
14. Visual indication of elapsed run time, graduated in hours for each motor.
15. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Position of dampers.
 - c. Cooling tower leaving-fluid temperature.
 - d. Fan vibration alarm.
 - e. Oil-level alarm.
 - f. Collection basin **[high] [low] [high- and low]-water-level** alarms.
 - g. **<Insert conditions to be monitored>**.

CC. Personnel Access Components:

1. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.

4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
 - b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

DD. Capacities and Characteristics:

1. Number of Cells: **<Insert quantity>**.
2. Air-Inlet Arrangement: All sides.
3. Maximum Drift Loss: **[0.005] <Insert number>** percent of design water flow.
4. Water Flow/Cell: **<Insert gpm (L/s)>**.
5. Minimum Water Flow/Cell: **<Insert gpm (L/s)>**.
6. Water Pressure Drop: **<Insert psig (kPa)>**.
7. Entering-Water Temperature: **<Insert deg F (deg C)>**.
8. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
9. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
10. Economizer Mode:
 - a. Water Flow/Cell: **<Insert gpm (L/s)>**.
 - b. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - c. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
11. Fan Drive: Belt, direct, or gear.
12. Fan Motor:
 - a. Type: **[Single speed] [Two speed, single winding] [Two speed, two winding] [Variable speed]**.
 - b. Horsepower/Cell: **<Insert horsepower>**.
 - c. Full-Load Ampacity: **<Insert value>**.
 - d. Minimum Circuit Ampacity: **<Insert value>**.
 - e. Maximum Overcurrent Protection Device: **<Insert amperage>**.
 - f. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
13. Sound Pressure Level: **<Insert dBA>** at **<Insert distance in feet (m)>** **[when measured according to CTI ATC 128]**.
14. Basin Heater:
 - a. Basin Water Temperature: **[40 deg F (5 deg C)] <Insert deg F (deg C)>**.
 - b. Outdoor Ambient Temperature: **[0 deg F (minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert deg F (deg C)>**.
 - c. Capacity/Cell: **<Insert kilowatts>**.

- d. Full-Load Ampacity: **<Insert value>**.
- e. Minimum Circuit Ampacity: **<Insert value>**.
- f. Maximum Overcurrent Protection Device: **<Insert amperage>**.
- g. Electrical Characteristics: **[208] [240] [480] <Insert value>**-V ac, 3 phase, 60 Hz.
- h. Capacity/Cell: **<Insert MBtu/h (kW)>**.
- i. Entering-Fluid Temperature: **<Insert deg F (deg C)>**.
- j. Fluid Flow Rate: **<Insert gpm (L/s)>**.
- k. Fluid Pressure Drop: **<Insert psig (kPa)>**.
- l. Capacity/Cell: **<Insert MBtu/h (kW)>**.
- m. Steam Flow: **<Insert lb/h (L/s)>**.
- n. Steam Pressure: **<Insert psig (kPa)>**.

2.6 OPEN-CIRCUIT, INDUCED-DRAFT, CROSSFLOW COOLING TOWERS

A. Products: Subject to compliance with requirements, provide one of the following:

1. [Amcot Cooling Tower Corp](#); Models LRC-H, LRC-LNS Series.
2. [Baltimore Aircoil Company](#); Series 1500 and 3000.
3. [Marley Cooling Technologies](#); Models Aquatower, AV series, NC Class, Primus.
4. **<Insert manufacturer's name; product name or designation>**.
5. or approved equal.

B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

C. Cooling tower designed to resist wind load of **[30 lbf/sq. ft. (1.44 kPa)] <Insert value>**.

D. Casing and Frame:

1. Casing[and Frame] Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.
2. Frame Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.
3. Fasteners: **[Galvanized] [Stainless] steel**.
4. Joints and Seams: Sealed watertight.
5. Welded Connections: Continuous and watertight.

E. Collection Basin: Configure tower for installation with a field-constructed collection basin.

F. Collection Basin:

1. Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.
2. Removable[**stainless-steel**] strainer with openings smaller than nozzle orifices.

3. Overflow and drain connections.
 4. Makeup water connection.
 5. Outlet Connection: ASME B16.5, Class 150 flange.
 6. Removable equalization flume plate between adjacent cells of multiple-cell towers.
 7. Equalizer connection for field-installed equalizer piping.
 8. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: **[PVC] <Insert material>**.
 - b. Nozzle Material: **[Plastic] <Insert material>**.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
- G. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
- H. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosures: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide **[control of water makeup valve] [control of water makeup valve and low-level alarm] [control of water makeup valve and low- and high-level alarms] [control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level]**.
 3. Electrode Probes: Stainless steel.
 4. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel]**.
 5. Solenoid Valve: Slow closing[**with stainless-steel body**], controlled and powered through level controller in response to water-level set point.
 6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- I. Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:
1. Enclosure: NEMA 250, **[Type 4] [Type 4X] <Insert type>**.
 2. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal[**for connection to BMS**].
 3. Water Stilling Chamber: **[Corrosion-resistant material] [FRP] [Galvanized steel] [PVC pipe] [Stainless steel]**.
 4. Solenoid Valve: Slow closing[**with stainless-steel body**]; controlled and powered through level controller in response to water-level set point.
 5. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
- J. Electric Basin Heater:
1. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
 2. Heater Control Panel: Mounted on the side of each cooling tower cell.
 3. Enclosure: NEMA 250, **[Type 3R] [Type 4] [Type 4X]**.

4. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
 5. Control-circuit transformer with primary and secondary side fuses.
 6. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
 7. Single-point, field-power connection to a **[fused disconnect switch] [nonfused disconnect switch] [circuit breaker]** and heater branch circuiting complying with NFPA 70.
 8. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
- K. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- L. Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- M. Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
- N. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
1. Material: **[FRP with UV inhibitors] [Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating] [Polymer-coated galvanized steel] [Stainless steel]**.
 2. Location: Over each bank of fill with easily replaceable **[plastic] <Insert material>** spray nozzles mounted in bottom of basin.
 3. Inlet Connection: ASME B16.5, Class 150 flange.
 4. Joints and Seams: Sealed watertight.
 5. Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
 6. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable **[corrosion-resistant] [stainless-steel]** hardware.
 7. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity distribution basin.
 8. Single-Inlet, Field Pipe Connection: **[Galvanized-steel] [PVC]** pipe arranged to provide balancing of flow within cooling tower cell without the need for additional balancing valves. Pipe each cooling tower cell internally to a single, field connection suitable for mating to ASME B16.5, Class 150 flange and located on the **[bottom] [side]** unless otherwise indicated.
- O. Fill:
1. Materials: PVC, with maximum flame-spread index of **[5] [25] <Insert value>** according to ASTM E 84.

2. Minimum Thickness: [15 mils (0.4 mm)] [20 mils (0.5 mm)] <Insert value>, before forming.
 3. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
 4. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [120 deg F (49 deg C)] <Insert temperature>.
- P. Drift Eliminator:
1. Material: [FRP] [PVC] [FRP or PVC] <Insert material>; with maximum flame-spread index of [5] [25] <Insert value> according to ASTM E 84.
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
 4. Location: [Integral to] [Separate and removable from] fill.
- Q. Air-Intake Louvers:
1. Material: [FRP] [PVC] [Matching casing].
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
 4. Location: [Integral to] [Separate from] fill.
- R. [Removable] Air-Intake Screens: [Galvanized] [Polymer-coated, galvanized] [Stainless]-steel wire mesh.
- S. Axial Fan: Balanced at the factory after assembly.
1. Blade Material: [Aluminum] [FRP] [Galvanized steel].
 2. Hub Material: [Aluminum] [FRP] [Galvanized steel].
 3. Blade Pitch: Field adjustable.
 4. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
 5. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of [40,000] [50,000] <Insert value> hours.
 6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
- T. Belt Drive:
1. Service Factor: [1.5] <Insert value> based on motor nameplate horsepower.
 2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
 3. Belt: Multiple V-belt design with a matched set of [cogged] belts.
 4. Belt: One-piece, multigrooved, solid-back belt.

5. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
 6. Belt-Drive Guard: Comply with OSHA regulations.
 7. Two-Motor, Single-Fan Drive:
 - a. Two single-speed motors per fan, one sized for full speed and load and the other sized for **[67]** **<Insert value>** percent of full-load speed.
 - b. Each motor with belt drive and configured for operation when other motor fails.
 - c. Controls and wiring same as two-speed, two-winding motor.
- U. Gear Drive: Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.
1. Gear Drive and Coupling Service Factor: **[2.0]** **<Insert value>** based on motor nameplate horsepower.
 2. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds.
 3. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
 4. Operation: Able to operate both forward and in reverse.
 5. Drive-to-Motor Connection: **[Close coupled to motor using a flexible coupling]** **[Connected to motor located outside of cooling tower casing by a full-floating drive shaft]**.
 6. Drive Shaft Material: **[Corrosion resistant]** **[Stainless steel]**, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
 7. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.
- V. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment" and not indicated below.
 2. Motor Enclosure: **[Totally enclosed]** **[Totally enclosed air over (TEAO)]** **[Totally enclosed fan cooled (TEFC)]** **[with epoxy or polyurethane finish]**.
 3. Energy Efficiency: **[Comply with ASHRAE/IESNA 90.1]** **[NEMA Premium Efficient]**.
 4. Service Factor: **[1.15]** **<Insert value>**.
 5. Insulation: **[Class F]** **[Class H]** **<Insert class>**.
 6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
 7. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
 8. Severe-duty rating with the following features:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.

- b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F** (minus 29 and plus 149 deg C.)
 - c. Internal heater automatically energized when motor is de-energized.
 9. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
- W. Fan Discharge Stack: Material shall match casing, [**manufacturer's standard**] [**velocity recovery**] design.
 1. Stack Extension: Fabricated to extend above fan deck **<Insert distance>** unless otherwise indicated.
 2. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
- X. Vibration Switch: For each fan drive.
 1. Enclosure: NEMA 250, [**Type 4**] [**Type 4X**] **<Insert type>**.
 2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
 3. Provide switch[**with manual-reset button**] for [**field connection to a BMS and**]hardwired connection to fan motor electrical circuit.
 4. Switch shall, on sensing excessive vibration,[**signal an alarm through the BMS and**] shut down the fan.
- Y. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch[**for connection to a BMS**].
 1. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm[**through the BMS**].
- Z. Capacity-Control Dampers: [**Galvanized-steel**] [**Stainless-steel**] **<Insert material>** dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.
- AA. Controls: Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- BB. Control Package: Factory installed and wired, and functionally tested at factory before shipment.
 1. NEMA 250, [**Type 3R**] [**Type 4**] [**Type 4X**] enclosure with removable internally mount backplate.
 2. Control-circuit transformer with primary and secondary side fuses.
 3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
 4. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating

- efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
5. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
 6. Collection basin level controller complying with requirements in ["**Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve**"] ["**Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve**"] Paragraph.
 7. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
 8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
 9. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.
 10. Single-point, field-power connection to a [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**] [**for each cooling tower cell**].
 - a. Branch power circuit to each motor and electric basin heater and to controls[**with a disconnect switch or circuit breaker**].
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
 11. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
 12. Visual indication of status and alarm[**with momentary test push button**] for each motor.
 13. Audible alarm and silence switch.
 14. Visual indication of elapsed run time, graduated in hours for each motor.
 15. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Position of dampers.
 - c. Cooling tower leaving-fluid temperature.
 - d. Fan vibration alarm.
 - e. Oil-level alarm.
 - f. Collection basin [**high**] [**low**] [**high- and low**]-water-level alarms.
 - g. **<Insert conditions to be monitored>**.

CC. Personnel Access Components:

1. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.

3. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
4. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
5. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
 - a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
 - b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

DD. Capacities and Characteristics:

1. Number of Cells: <Insert quantity>.
2. Air-Inlet Arrangement: [**Single side**] [**Two sides**].
3. Maximum Drift Loss: [**0.005**] <Insert number> percent of design water flow.
4. Water Flow/Cell: <Insert gpm (L/s)>.
5. Minimum Water Flow/Cell: <Insert gpm (L/s)>.
6. Water Pressure Drop: <Insert psig (kPa)>.
7. Entering-Water Temperature: <Insert deg F (deg C)>.
8. Leaving-Water Temperature: <Insert deg F (deg C)>.
9. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
10. Economizer Mode:
 - a. Water Flow/Cell: <Insert gpm (L/s)>.
 - b. Entering-Water Temperature: <Insert deg F (deg C)>.
 - c. Leaving-Water Temperature: <Insert deg F (deg C)>.
 - d. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
11. Fan Drive: Belt or gear.
12. Fan Motor:
 - a. Type: [**Single speed**] [**Two speed, single winding**] [**Two speed, two winding**] [**Variable speed**].
 - b. Horsepower/Cell: <Insert horsepower>.
 - c. Full-Load Ampacity: <Insert value>.
 - d. Minimum Circuit Ampacity: <Insert value>.
 - e. Maximum Overcurrent Protection Device: <Insert amperage>.
 - f. Electrical Characteristics: [**208**] [**240**] [**480**] <Insert value>-V ac, 3 phase, 60 Hz.
13. Sound Pressure Level: <Insert dBA> at <Insert distance in feet (m)> [**when measured according to CTI ATC 128**].
14. Basin Heater:
 - a. Basin Water Temperature: [**40 deg F (5 deg C)**] <Insert deg F (deg C)>.

- b. Outdoor Ambient Temperature: [0 deg F (minus 18 deg C)] [Minus 20 deg F (Minus 29 deg C)] <Insert deg F (deg C)>.
- c. Capacity/Cell: <Insert kilowatts> .
- d. Full-Load Ampacity: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection Device: <Insert amperage>.
- g. Electrical Characteristics: [208] [240] [480] <Insert value>-V ac, 3 phase, 60 Hz.
- h. Capacity/Cell: <Insert MBtu/h (kW)>.
- i. Entering-Fluid Temperature: <Insert deg F (deg C)>.
- j. Fluid Flow Rate: <Insert gpm (L/s)>.
- k. Fluid Pressure Drop: <Insert psig (kPa)>.
- l. Capacity/Cell: <Insert MBtu/h (kW)>.
- m. Steam Flow: <Insert lb/h (L/s)>.
- n. Steam Pressure: <Insert psig (kPa)>.

2.7 SOURCE QUALITY CONTROL

- A. Verification of Performance: Test and certify cooling tower performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."
- B. Factory pressure test heat exchangers after fabrication and prove to be free of leaks.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before cooling tower installation, examine roughing-in for tower support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting tower performance, maintenance, and operation.
 - 1. Cooling tower locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install cooling towers on support structure indicated.
- C. Equipment Mounting:
 - 1. Install cooling towers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [Section 033000

"Cast-in-Place Concrete." [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- D. Install anchor bolts to elevations required for proper attachment to supported equipment.
- E. Maintain manufacturer's recommended clearances for service and maintenance.
- F. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to cooling towers to allow service and maintenance.
- C. Install flexible pipe connectors at pipe connections of cooling towers mounted on vibration isolators.
- D. Provide drain piping with valve at cooling tower drain connections and at low points in piping.
- E. Connect cooling tower overflows and drains, and piping drains to sanitary sewage system.
- F. Domestic Water Piping: Comply with applicable requirements in Section 221116 "Domestic Water Piping." Connect to water-level control with shutoff valve and union, flange, or mechanical coupling at each connection.
- G. Supply and Return Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Connect to entering cooling tower connections with shutoff valve, balancing valve, thermometer, plugged tee with pressure gage, [**flow meter,**] and drain connection with valve. Connect to leaving cooling tower connection with shutoff valve. Make connections to cooling tower with a [**union**] [**flange**] [**mechanical coupling**] [**union, flange, or mechanical coupling**].
- H. Equalizer Piping: Piping requirements to match supply and return piping. Connect an equalizer pipe, full size of cooling tower connection, between tower cells. Connect to cooling tower with shutoff valve.
- I. Hot-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Connect to supply and return basin heater with shutoff valve, strainer, control valve, and union or flange on

supply connection and union or flange and balancing valve on return connection.
Provide supply and return piping with pressure gage and thermometer.

- J. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Connect steam supply to basin heater with shutoff valve, strainer, control valve, and union or flange and condensate piping with union or flange, shutoff valve, strainer, and an appropriate steam trap.

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to perform field tests and inspections.
- C. Perform tests and inspections.
1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Tests and Inspections: Comply with [**ASME PTC 23, "ASME Performance Test Codes - Code on Atmospheric Water Cooling Equipment**] [**CTI ATC 105, "Acceptance Test Code for Water Cooling Towers**]."
- E. Cooling towers will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
- C. Obtain performance data from manufacturer.
1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
- a. Clean entire unit including basins.
 - b. Verify that accessories are properly installed.
 - c. Verify clearances for airflow and for cooling tower servicing.
 - d. Check for vibration isolation and structural support.
 - e. Lubricate bearings.

- f. Verify fan rotation for correct direction and for vibration or binding and correct problems.
 - g. Adjust belts to proper alignment and tension.
 - h. Verify proper oil level in gear-drive housing. Fill with oil to proper level.
 - i. Operate variable-speed fans through entire operating range and check for harmonic vibration imbalance. Set motor controller to skip speeds resulting in abnormal vibration.
 - j. Check vibration switch setting. Verify operation.
 - k. Verify water level in tower basin. Fill to proper startup level. Check makeup water-level control and valve.
 - l. Verify operation of basin heater and control.
 - m. Verify that cooling tower air discharge is not recirculating air into tower or HVAC air intakes. Recommend corrective action.
 - n. Replace defective and malfunctioning units.
- D. Start cooling tower and associated water pumps. Follow manufacturer's written starting procedures.
- E. Prepare a written startup report that records the results of tests and inspections.

3.6 ADJUSTING

- A. Set and balance water flow to each tower inlet.
- B. Adjust water-level control for proper operating level.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain cooling towers.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work

described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236500

SECTION 236533.13 - LIQUID COOLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes packaged liquid coolers using evaporative cooling, and including a circulating pump, and accessories.
 - 1. Liquid cooler.
 - 2. Controls.
 - 3. Ladders and handrails.
 - 4. Inside Sump.
 - 5. Circulating pump.
 - 6. Sound attenuators.
 - 7. Discharge hood.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Provide rated capacities, dimensions, weights and point loadings, accessories, required clearances, electrical requirements and wiring diagrams, and location and size of field connections. Submit schematic indicating capacity controls.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings (required only for equipment other than the selections shown on drawing layouts and specified in detail by manufacturer/model number in equipment schedules):
 - 1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - 2. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - 3. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

- C. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
- B. Certificates: Certify that liquid cooler performance [, **based on ASME PTC-23**] meet or exceed specified requirements and submit performance curve plotting leaving water temperature against wet bulb temperature.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For liquid coolers to include in emergency, operation, and maintenance manuals.
 - 1. Include start-up instructions, maintenance data, parts lists, controls, and accessories. Include cleaning methods and cleaning materials recommended.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fan Belts: [**Two (2)**] <Insert number> sets of matched fan belts.
 - 2. Provide [**twelve (12)**] <Insert number> spray nozzles.
 - 3. Provide [**one (1)**] <Insert number> valve seat for each make-up valve, [**one (1)**] <Insert number> strainer screen, [**one (1)**] <Insert number> float.
 - 4. Provide [**one (1)**] <Insert number> pump seal, and [**one (1)**] <Insert number> set of pump gaskets.

1.7 QUALITY ASSURANCE

- A. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- B. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 DELIVERY, STORAGE, AND PROTECTION

- A. Comply with requirements of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Factory assemble entire unit. For shipping, disassemble into as large as practical sub-assemblies so that minimum amount of field work is required for re-assembly.
- C. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Minimum **[five (5)]** <Insert number> years from date of Substantial Completion.
 - 2. Warranty to include coverage for **[liquid cooler package] [fan drive] [motor] [pan, casing and cooler coil] [labor only] [materials only] [labor and materials]**.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. Baltimore Aircoil Co.
 - 2. Evapco, Inc.
 - 3. Bohn Heat Transfer, Inc.
 - 4. Recold.
 - 5. **<Insert manufacturer's name>**.
 - 6. or approved equal.

2.2 MANUFACTURED UNITS

- A. Provide **[outdoor] [indoor]** units, factory assembled, sectional, counterflow, vertical discharge, **[forced draft] [induced draft]** design, with fan assemblies built into pan

and casing.

2.3 COMPONENTS

- A. Pan and Casing: Galvanized steel, **[12 gage]** **[14 gage]** for casing and 8 gage for reinforcing angles and channels.
1. Access doors at both ends of cooler to air plenum.
 2. Lift out steel strainer.
 3. Bleed line (from pump discharge) with valve.
 4. Inlet and outlet silencers.
 5. Discharge hood with access doors.
 6. Duct flanges on inlet and outlet.
- B. Cooler Coil: Steel tubing, air tested under water to 350 psig, sloped to ensure drainage, encased in steel framework. **[Provide cleanable [header] [tube]** unit with removable cover plates on header to access tubular coil].
- C. Fans: **[Multi blade, cast aluminum, axial type]** **[Forward curve centrifugal type mounted on steel shaft]**, with belt drive, bearings with ABMA 9 or ABMA 11 L-10 life expectancy at 30,000 hours, with grease fittings extended to outside of casing.
- D. Fan Motors: **[Single]** **[Two]** speed **[(1800/900 rpm)]** mounted on adjustable steel base, **[totally enclosed air over (TEAO) type with special moisture protection.]** **[totally enclosed fan cooled (TEFC) type with special moisture protection and insulation for cooling tower duty.][Refer to Section 16486 - Electric Motors.]**
- E. Unit Wiring of Electrical Components and Accessories: All electrical equipment, accessories, control devices, and interconnecting wiring required for components forming parts of the equipment specified under this Section shall be either factory installed or field-installed as work of this Section, including required contactors, overcurrent protection, and disconnect switches; and including motor controllers where indicated as unit-installed (refer to Division 26 sections for requirements governing separately-installed controllers). The completed installation shall conform to all Division 26 requirements, and shall provide for single points of connection under other Sections for:
1. Power supply branch circuit serving motor(s), sump heaters, and any powered accessory items, as applicable.
 2. Vibration switch output terminals, where motor controllers are remotely installed.
- F. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, keyed. **[Fixed]** **[Variable and adjustable]** pitch sheave for motors 15 hp and under, selected so required rpm is obtained with sheaves set at mid-position. Fixed sheave for 20 hp and over, matched belts. Drive rated minimum 1.5 times nameplate rating of motor.
- G. Fan Guard: Removable, welded steel rod and wire guard.
- H. Distribution Section: **[Polyvinyl] chloride]** **[Galvanized steel]** piping header and

branches with **[ABS]** plastic spray nozzles.

- I. Drift Eliminators: Two or three pass formed galvanized steel, minimum 24 gage, to limit drift loss to **[0.7]** **[0.2]** percent of total water circulated.
- J. Float Valves: Brass or bronze **[balanced piston type]** make-up valve with plastic or copper float.
- K. Finish: Electrostatically sprayed thermosetting polymer.
- L. Hardware: **[Galvanized steel.]** **[Stainless steel.]** **[Phenolic epoxy coated, cadmium plated washer head fasteners.]**

2.4 INSIDE SUMP

- A. Pan and Casing: Galvanized steel, 12 gage for casing and 8 gage for reinforcing angles and channels with lift out steel strainer.
- B. Finish: Electrostatically sprayed thermosetting polymer.
- C. Float Valves: Brass or bronze **[balanced piston type]** make-up valve with plastic or copper float.
- D. Capacity: Minimum <Insert number> gallons, size **<Insert number>** x **<Insert number>** x **<Insert number>** inches deep.

2.5 CIRCULATING PUMP

- A. Pump: Close coupled, bronze fitted, centrifugal pump with mechanical seal, mounted on piping **[controlled by pan mounted immersion thermostat set at [140 degrees F] [180 degrees F]]**.
- B. Pump motor: **[Single]** **[Two] speed [(1800/900 rpm)]** open drip proof mounted on pump body.
- C. Pump: As shown on the drawings.

2.6 ACCESSORIES

- A. Electric Immersion Heaters: In pan suitable to maintain temperature of water in basin at 42 degrees F when outside temperature is 0 degrees F and wind velocity is 15 mph; immersion thermostat and float control to operate heaters on low temperature when pan is filled.
- B. Electric Temperature Controller: In leaving coil-water piping, set at 74 to 78 degrees F; with sensor to cycle fans and start and stop spray pump.
- C. Time Delay Relay: Limits fan motor starts to not more than six per hour.

- D. Capacity Control: Scroll damper and modulating electronic damper motor controlled by temperature controller.
- E. Vibration Switch: Provide factory installed vibration switch, for field wiring, to automatically shut off fan operation when excessive vibration occurs.

2.7 FACTORY FINISH

- A. Finish of steel components: ASTM A 90 G210 hot dipped galvanized steel with [**zinc chromated aluminum paint**] [**electrostatically sprayed thermosetting polymer**].

2.8 PERFORMANCE

- A. Capacity: As indicated on Drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that openings are ready to receive work.
- B. Verify field measurements are as shown on Drawings.
- C. Verify that required utilities are available, in proper location, and ready to use.
- D. Beginning of installation means installer accepts existing conditions.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install cooler on structural steel beams as instructed by manufacturer.
- C. Install cooler on vibration isolators. Refer to Section 230548.13 "Vibration Controls for HVAC".
- D. Connect cooler water piping with flanged connections to cooler. Refer to Section 232113 "Hydronic Piping".
- E. Connect make-up water piping with flanged or union connections to cooler. Pitch to cooler. Pipe drain, overflow drain, and bleed lint to nearest floor drain.

3.3 ELECTRICAL WIRING AND CONNECTIONS

- A. Provide for any field-installed electrical accessories and wiring required to yield a

fully-wired assembly; refer to Part 2 above.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Prepare and start systems.
 - 2. Inspect cooler after installation and submit report prior to start-up, verifying installation is in accordance with specifications and manufacturer's recommendations.
 - 3. Supervise rigging, hoisting, and installation; include **<Insert number>** eight-hour days per cooler.
 - 4. Allow **<Insert number>** eight-hour days per cooler for start-up and instructions for DEN Project Managers operating personnel.
 - 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 6. Verify bearing lubrication.
 - 7. Verify proper motor rotation.
 - 8. Test Reports: Prepare a written report to record the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- C. Liquid coolers will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Adjust water level float valves and float controls for proper operating level.
- B. Adjust bleed valve for proportion of circulated water.
- C. Adjust temperature controls and verify operation.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain dry type liquid coolers.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236533.13

SECTION 236533.16 - DRY TYPE LIQUID COOLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes dry coolers for closed systems, with horizontal cores and up-blast fans.
 - 1. Dry coolers.
 - 2. Controls.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Provide rated capacities, dimensions, weights and point loadings, accessories, required clearances, electrical requirements and wiring diagrams, and location and size of field connections. Submit schematic indicating capacity controls.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Shop Drawings (required only for equipment other than the selections shown on drawing layouts and specified in detail by manufacturer/model number in equipment schedules):
 - 1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

- B. Certificates: Certify that liquid cooler performance [, **based on ASME PTC-23**] meet or exceed specified requirements and submit performance curve plotting leaving water temperature against dry bulb temperature.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For dry type liquid coolers to include in emergency, operation, and maintenance manuals.
 - 1. Include start-up instructions, maintenance data, parts lists, controls, and accessories. Include cleaning methods and cleaning materials recommended.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fan Belts: [**Two (2)**] <Insert number> sets of matched fan belts.
 - 2. Provide [**twelve (12)**] <Insert number> spray nozzles.
 - 3. Provide [**one (1)**] <Insert number> valve seat for each make-up valve, [**one (1)**] <Insert number> strainer screen, [**one (1)**] <Insert number> float.
 - 4. Provide [**one (1)**] <Insert number> pump seal, and [**one (1)**] <Insert number> set of pump gaskets.

1.7 QUALITY ASSURANCE

- A. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- B. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.8 DELIVERY, STORAGE, AND PROTECTION

- A. Comply with requirements of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Factory assemble entire unit. For shipping, disassemble into as large as practical sub-assemblies so that minimum amount of field work is required for re-assembly.

- C. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Minimum **[five]** <Insert number> years from date of Substantial Completion.
 - 2. Warranty to include coverage for **[dry cooler package]** **[motor]** **[labor only]** **[materials only]** **[labor and materials]**.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. Leibert.
 - 2. Young.
 - 3. <Insert manufacturer's name>.
 - 4. or approved equal.

2.2 MANUFACTURED UNITS

- A. Direct Drive Propeller Fan Dry coolers: Furnish and install air-cooled dry coolers, arranged for vertical airflow. Dry coolers shall be draw-through design and shall perform in accordance the scheduled requirements.
- B. General: Each dry cooler shall consist of casing, dry cooler coil, and propeller fans direct driven by individual fan motors, fan guards, and mounting legs. Fan motors shall be furnished for operation on power supply indicated on the drawings.

2.3 COIL

- A. The dry cooler coil shall be constructed using copper tubes on a staggered tube pattern. Tubes shall be expanded into continuous, rippled aluminum fins. The fins shall

have full-depth fin collars completely covering the copper tube.

- B. Copper tubes shall be connected to heavy wall type L headers, inlet coil connector tubes shall pass through relieved holes in the tube sheet, for maximum resistance to piping strain and vibration. Coils shall be factory leak-tested at 300 PSIG (minimum); dehydrated, evacuated and sealed.
- C. Coils shall be designed to deliver required performance with cooled liquid consisting of 50% propylene glycol/water solution.

2.4 CASING

- A. The dry cooler casing shall be constructed of bright aluminum sheet. Casing shall be divided into individual fan sections by full width baffles.
- B. Structural support members, including coil support frame, motor and drive support shall be galvanized steel for strength and corrosion resistance. Aluminum legs with rigging holes shall be provided for hoisting the unit into position.
- C. FANS
- D. Fans shall have zinc-plated steel or aluminum blades. Fan shall be secured to fan shaft by means of heavy-duty dual set screws. Fan diameter shall be 30 inches or less. Fans shall be factory-balanced and run before shipment.
- E. Fan guards shall be heavy gauge, close-meshed, steel wire, with corrosion resistant finish.
- F. FAN MOTORS
- G. Fan motors shall be equipped with rain slingers and permanently sealed ball bearings. Motors shall include built-in overload protection. Motors shall be rigidly mounted on die-formed galvanized steel supports.
- H. Quiet-Line Motors: Fan motors shall be 12-pole, 570 RPM, equipped with rain shields and permanently sealed ball bearings. Motors shall include built-in overload protection. Motors shall be rigidly mounted on die-formed galvanized steel supports.

2.5 ELECTRICAL CONTROL

- A. All electrical connections (and electrical low ambient control options) shall be provided in a weatherproof enclosure, integral with the dry cooler. Controls shall include combination magnetic motor controller for each motor.
- B. Constant Operation: The unit (Liebert model DNL or equivalent) shall provide magnetic contactor and control voltage for remote starting of the dry cooler. The dry cooler shall be provided with disconnect switch mounted and wired.
- C. Fan cycling model (Liebert model DNT or equivalent) shall be equipped to control

leaving fluid temperature by cycling fans in one or two steps. The 24 volt control system as furnished to consists of control transformer and fan temperature control(s).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that openings are ready to receive work.
- B. Verify field measurements are as shown on Drawings.
- C. Verify that required utilities are available, in proper location, and ready to use.
- D. Beginning of installation means installer accepts existing conditions.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install cooler on structural steel beams as instructed by manufacturer.
- C. Install cooler on vibration isolators. Refer to Section 230548.13 "Vibration Controls for HVAC".
- D. Connect cooler water piping with flanged connections to cooler. Refer to Section 232113 "Hydronic Piping".
- E. Connect make-up water piping with flanged or union connections to cooler. Pitch to cooler. Pipe drain, overflow drain, and bleed lint to nearest floor drain.

3.3 ELECTRICAL WIRING AND CONNECTIONS

- A. Provide for any field-installed electrical accessories and wiring required to yield a fully-wired assembly; refer to Part 2 above.

3.4 FIELD QUALITY CONTROL

- A. **Manufacturer's Field Service:** Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Prepare and start systems.
 - 2. Inspect cooler after installation and submit report prior to start-up, verifying

- installation is in accordance with specifications and manufacturer's recommendations.
3. Supervise rigging, hoisting, and installation; include **<Insert number>** eight-hour days per cooler.
 4. Allow **<Insert number>** eight-hour days per cooler for start-up and instructions for DEN Project Managers operating personnel.
 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 6. Verify bearing lubrication.
 7. Verify proper motor rotation.
 8. Test Reports: Prepare a written report to record the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- C. Dry type liquid coolers will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Adjust temperature controls and verify operation.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain dry type liquid coolers.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236533.16

SECTION 236600 - PRECONDITIONED AIR HYDRONIC AIR HANDLING UNITS - AVIATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes hydronic units, supplied with chilled water from a chiller system.
- B. Related Sections:
 - 1. Section 236611 "Preconditioned Air DX Air Handling Units - Aviation" for DX air handling units.
 - 2. Section 236613 "Preconditioned Air Ductwork and Accessories - Aviation" for ductwork and accessories.
 - 3. Section 236616 "Preconditioned Air Electric Control Systems - Aviation" for electric control systems.
 - 4. Section 236619 "Preconditioned Air Sequence of Operation - Aviation" for sequence of operation.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of hydronic air handling unit.
 - 1. Product data for selected models, including specialties, accessories, and the following:
 - a. Fan performance curves with system operating conditions indicated.
 - b. Motor ratings and electrical characteristics plus motor and fan accessories.
 - c. Materials thicknesses and finishes.
 - d. Dampers, including housings, linkages, and operators.
 - e. Submit air filter manufacturer's technical product data including dimensions, weights, required clearances and access, flow capacity including initial and final pressure drop at rated air flow, efficiency and test method, fire classification, and installation instructions.
 - 2. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: Shop drawings from manufacturer detailing equipment assemblies and indicating dimensions, weights, required clearances, components, and location and size of field connections.
- C. Wiring diagrams that detail power, signal, and control wiring.
 - 1. Differentiate between manufacturer installed wiring and field installed wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Product certificates, signed by manufacturers of air handling units, certifying that their products comply with specified requirements.
- B. Field quality-control reports.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For hydronic air handling units to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- B. ARI Compliance: Air filter equipment shall comply with ARI 850.
- C. NFPA Compliance: Comply with applicable portions of NFPA 70, for components and installation of air handling units.
- D. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.
- E. UL Compliance: Components shall be UL listed and labeled.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Lift and support units with the manufacturer's designated lifting or supporting points.
- B. Disassemble and reassemble units as required for movement into the final location

following manufacturer's written instructions.

- C. Deliver fan units as a factory assembled unit to the extent allowable by shipping limitations, with protective crating and covering.
- D. Store all equipment and material in suitable facilities until delivery and acceptance by the Owner.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace heat exchanger of hydronic air handling units that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Minimum **[two (2)] [five (5)] <Insert number>** years from date of Substantial Completion.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. Air Handling Units:
 - a. **Twist, Inc.**
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
 - 2. Air Filters:
 - a. American Air Filter Company.
 - b. Farr Company.
 - c. Research Products Corp.
 - d. **<Insert manufacturer's name>**
 - e. or approved equal.

2.2 FANS

- A. General: Provide fans that are factory fabricated and assembled, factory tested, and factory finished, with required capacities and characteristics.
- B. Fans and Shafts: Statically and dynamically balanced and designed for continuous operation at the maximum rated fan speed and motor horsepower.
 - 1. Fan Shaft: Turned, ground, and polished steel designed to operated at no more than 70 percent of the first critical speed at the top of the speed range of the fan's class.
- C. Shaft Bearings: Provide bearings having a median life "Rating Life" (ABMA L50) of 200,000, calculated in accordance with ABMA 9 for ball bearings or ABMA 11 for roller bearings.
- D. Factory Finish:
 - 1. Sheet Metal Parts: Prime coating prior to final assembly.
 - 2. Exterior Surfaces: Manufacturer's standard finish is acceptable.

2.3 AIR FILTERS

- A. Provide [**reusable**] [**throw away**] type air filters in the PCA air handling units.
 - 1. Cleanable (Washable) Panel Filters: Provide factory fabricated, flat panel type cleanable air filters with holding frames, with 25 mm thick cleanable filtering media constructed of galvanized woven and crimped steel screening, with 0.91 mm galvanized steel frame. Provide cleanable filters with rated face velocity of 2.5 M/sec, initial resistance not greater than 24.9 Pa, and average arrestance of 75 percent.
 - 2. Throw Away Air Filters: Provide factory fabricated, dual filter system, consisting of a 25 mm fiberglass media prefilter, and a 100 mm 30/30 woven cotton fabric main filter. Provide filters with rated face velocity of 2.5 M/sec, initial resistance not greater than 24.9 Pa, and average arrestance of 75 percent.

2.4 AIR HANDLING UNIT AND SUPPLY AIR SYSTEM

- A. The system and all components shall be designed and constructed in accordance with all codes, standards, local laws and regulations applicable to the design and construction of this type of equipment.
- B. Units shall be factory fabricated and factory tested, and all components shall be UL listed.
- C. Provide compact, lightweight, and low noise insulated air handling units that can be mounted on the passenger loading bridge, such that bridge movement is unrestricted on apron drives. Air handling unit shall be mounted underneath bridge at rotunda or

the cab. Unit shall be free of vibration transmission and installed with vibration isolators when necessary. The air handling unit at each gate shall contain cooling coils, blower, inlet vane damper (or inlet butterfly damper), auxiliary electric strip heater (for use when central plant(s) are still in the dedicated cooling season, minimal heating, only), and controls to provide the required cool air, heated air, or ventilation to maintain the aircraft cabin temperature specified. Maximum air handler weight shall not exceed 1360 Kg, including accessories, mounted at the rotunda or on the bridge behind the lift column.

1. The air handling unit(s) to be provided at each gate shall be of the "Type" as scheduled on the drawings. Per schedule listed above, AHU's shall have the capacity to sufficiently cool the largest designated aircraft parked at each bridge (see note below) as indicated on plan drawings, considering quantity of air to be delivered and static pressures as scheduled in following paragraphs of this Article. Units serving wide body gates shall also operate properly when serving a narrow body aircraft at the same gate. Units serving B 747 / A340 gates shall also operate properly when serving a wide body or narrow body aircraft. Submittals shall indicate the actual M 3/hr at the minimum and maximum static pressure conditions and list the kW input at each condition. (Note: Two wide body AHU's may be used to serve one B 747, A340 or B 777. Refer to plans for bridge and aircraft locations. Some narrow-body gates may have wide body AHU's for that purpose.)
2. Airflow shall be controlled with an inlet vane damper (or inlet butterfly damper) on the blower interfaced with a thermostat. Variable frequency drive, as a method of airflow control, is also acceptable. The blower shall be centrifugal type and sized for the appropriate variable volume airflow requirements. The unit size shall be selected so that the fan brake horsepower does not exceed the maximum required over the design operating range of the unit at the total static pressure.
3. External static pressure shall be defined as the static pressure at the outlet of the air handling unit. The Contractor shall present the external static pressure of each type air handling unit on the appropriate equipment data sheet. An estimate of static pressure available at the aircraft connection, on a per gate basis, shall also be presented with the submittal.
4. Horsepower shall be selected based on the Contractor's choice of equipment that affects the external resistance of the system. However, the minimum nominal motor rating requirement for a narrow body air handling unit shall be 11.19 kW (15 hp); a wide body air handling unit shall be 18.65 kW (25 hp); and for a B 747 / A340 air handling unit 37.3 kW (50 hp). Contractor shall furnish the fan motor and unit size adequate for static pressure and maximum brake horsepower requirements.
5. The AHU shall be provided with motor starter equipment.
6. Return air to the unit shall not be utilized.
7. The Contractor shall submit correspondence with the bridge manufacturer indicating coordination efforts to maintain structural integrity of the bridge.
8. The construction of the unit shall be of a material sufficient to provide adequate structural rigidity of frame and enclosure; of a noncorrosive nature; and provided with thermal insulation for conditions encountered in normal usage. Equipment exterior shall be primed and painted to match bridge color. Equipment interior shall be painted per manufacturer's standard color.

9. Provide and install hooks on any service and cable boxes (both sides) as required to meet OSHA standards and Owner's safety system. Provide maintenance instruction on the correct method of servicing all bridge mounted equipment.
 10. If the air handling unit is to be mounted underneath a fixed bridge, a minimum of four guard posts shall be mounted on the apron around the unit for protection.
 11. The maximum sound level for the air handling unit(s) at maximum cooling shall not exceed 85 dBA at a distance of 5 M from the unit. Sound power level radiated by the unit outlet and at the unit inlet when the unit is operated at the designated capacity shall be furnished with the submittal.
 12. Coil(s) shall be copper finned copper tube. The number of tubes and fin spacing shall be submitted on coil selections made. Coils shall be constructed and certified in accordance with ASHRAE 15 and ARI 410. Furnish drainable coils. Galvanized casing shall be the manufacturer's standard. Design coils for a working pressure of 862 kPa. Hydrostatically test at 2758 kPa and air test at 1379 kPa under water.
 13. Capacity control and defrost control shall be identified and explained in submittal.
 14. Provide access doors of the hinged and insulated type. Locate as required for proper access to the following:
 - a. Dampers.
 - b. Filters.
 - c. Coils.
- D. A drain pan shall be provided for each AHU. A condensate Pump shall be required in each AHU where the gate configuration does not allow for gravity drain to a potable water ramp drain. The condensate pump shall be lightweight, self priming, and capable of running dry without damage. Minimum pump rating shall be 0.2 L/sec, 13 M head, with suitable horsepower rating.
1. Position the drain pan under the coil section. Drain pan shall be stainless steel. Condensate pump shall be provided with a summer/winter switch or internal float switch actuated assembly.
- E. Controls shall include, but are not limited to a remote "start/stop" push button station accessible from the ground level for each AHU.
1. **[ModBus] [Wireless]** connection to LonWorks compatible building automation system to monitor, view, and control all points. Wiring, Conduit and interface shall be included with PC Air unit and coordinated with other components.
- F. A narrow body air handling unit shall be capable of delivering a minimum of 68 Kg/min of 1.7 degrees C air at 2488 Pa total pressure at the end of the aircraft air hose nozzle through 18 M of air hose at sea level. Provide a 20 kW auxiliary electric strip heater. The air handling unit provided in this contract shall be designed appropriately to compensate for operating conditions at installation altitude. The supply air pressure shall not exceed the aircraft manufacturer's maximum inlet pressure.
- G. A wide body air handling unit shall be capable of delivering a minimum of 110 Kg/min

of 0 degrees C air at 5473 Pa total pressure at the end of the aircraft hose nozzle through 18 M of air hose at sea level. Provide a 40 kW auxiliary electric strip heater. The air handling unit provided in this contract shall be designed appropriately to compensate for operating conditions at the installation altitude.

- H. A B 747 / A340 air handling unit shall be a single 190 Kg/min unit capable of delivering a minimum of 85 Kg/min of 0 degrees C air at 4975 Pa total pressure at the end of each of two aircraft air hose nozzles through 18 M of air hose at sea level. Provide a 53 kW auxiliary electric strip heater. The air handling unit provided in this contract shall be designed appropriately to compensate for operating conditions at the installation altitude.

2.5 MOTORS

- A. Provide motors in accordance with Division 26 sections.
- B. Starters, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 26.

2.6 CONTROL SYSTEMS

- A. Refer to Section [236619 "Preconditioned Air Electric Control Systems"] [236621 "Preconditioned Air Sequence of Operation"] for controls requirements.

PART 3 - EXECUTION

- A. FACTORY TEST OF AIR HANDLING UNITS
- B. Factory test each air handling unit prior to shipment. Test each unit in accordance with the following procedure and submit a record of the results of each test identifying the unit number of each data set.
- C. Apparatus: Static pressure, either external or total, shall be measured with a U tube manometer. The manometer must have graduations no larger than 5.0 Pa from zero to 500 Pa, and graduations no larger than 50 Pa from 500 Pa up.
1. Volume flowrate shall be measured by static pressure drop across ASME long radius nozzles. The nozzles shall be housed in a multiple nozzle airflow chamber, which is built and operated in accordance with AMCA Standard 210 85, "Laboratory Methods of Testing Fans for Rating". The manometer used to measure the pressure drop must have a demonstrated accuracy of 2.5 Pa.
 2. Air density shall be determined with wet and dry bulb thermometers and a mercury barometer, or the equivalent. An ammeter, voltmeter, and tachometer shall be employed.
- D. Procedure: The central station air handler will be connected to the flow chamber and sealed well. The fan unit will be started and allowed to run for at least five minutes. A

static pressure load shall be exerted on the fan by dampering or blocking the inlet or outlet. In the case of specified total pressure, the static taps should be placed on either side of the fan wall. In the case of specified external pressure, the static taps should be placed on the inlet and outlet of the cabinet.

1. Static pressure and hence flowrate shall be measured at least at three points. One at a static load near design, one slightly above, and one slightly below. This will yield a short curve intersecting the system curve.
2. Motor amperage draw, line voltage, and fan RPM shall be measured for each performance point.
3. Using the measured density, results shall be corrected to standard conditions or to conditions at job site. Results shall be plotted for comparison to specifications. A central station air handler is considered acceptable when the volume flowrate is at between 97.5 percent and 102.5 percent of design, when evaluated along the specified system curve and the motor amperage draw does not exceed nameplate amperes. Owner's Representative shall be notified five (5) days prior to test.

3.2 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of air handling units.
- B. Do not proceed until unsatisfactory conditions have been corrected.

3.3 INSTALLATION

- A. PCA air handling units shall be mounted underneath the bridge at the rotunda or the cab.
- B. Arrange installation of units to provide access space around air handling units for service and maintenance.
- C. Furnish all necessary supports, brackets, guard posts, safety hooks, etc., for properly installing all air handling units.
- D. All air handling units shall be properly aligned, adjusted and lubricated before final acceptance.
- E. Perform water and air system testing and balancing as specified in Section 230593 "Testing, adjusting, and Balancing for HVAC".

3.4 CONNECTIONS

- A. Duct installations and connections are specified in other Sections. Make final duct connections with flexible connections.

- B. Electrical Connections: The following requirements apply:
1. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
 2. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables" in compliance with the National Electrical Code.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Inspect the field assembly of components and installation of air handling units including ductwork and electrical connections.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 3. Test Reports: Prepare a written report to record the following:
 - a. Test procedures used.
 - b. Test results that comply with requirements.
 - c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- C. Hydronic air handling units will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain oil-fired unit heaters.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236600

SECTION 236611 - PRECONDITIONED AIR DX AIR HANDLING UNITS - AVIATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes the following types of direct expansion air handling units:
 - 1. Preconditioned air handling units for narrow-body aircraft; can be applied to wide-body aircraft under favorable conditions (45-60 tons).
- B. Related Requirements:
 - 1. Section 230548.13 "Vibration Controls for HVAC".
 - 2. Section 236600 "Preconditioned Air Hydronic Air Handling Units - Aviation" for hydronic air handling units.
 - 3. Section 236613 "Preconditioned Air Ductwork and Accessories - Aviation" for ductwork and accessories.
 - 4. Section 236616 "Preconditioned Air Electric Control Systems - Aviation" for electric control systems.
 - 5. Section 236619 "Preconditioned Air Sequence of Operation - Aviation" for sequence of operation.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- 1. Product Data: For each type of product. Submit manufacturer's technical product data, including rated capacities of selected model clearly indicated, dimensions, required clearances, weights, furnished specialties and accessories; and installation and start up instructions. Also include the following:
 - a. Fan performance curves with system operating conditions indicated.
 - b. Motor ratings and electrical characteristics plus motor and fan accessories.
 - c. Materials gauges and finishes.
 - d. Dampers, including housings, linkages, and operators.
 - e. Submit air filter manufacturer's technical product data including dimensions, weights, required clearances and access, flow capacity including initial and

- final pressure drop at rated air flow, efficiency and test method, fire classification, and installation instructions.
2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Shop drawings detailing fabrication and installation for metal supports and anchorage for air handling unit equipment.
1. Submit shop drawings detailing the manufacturer's electrical requirements for power supply wiring. Submit manufacturer's ladder type wiring diagrams for interlock and control wiring.
 - a. Clearly differentiate between portions of wiring that are factory installed and portions to be field installed.
- 1.4 INFORMATIONAL SUBMITTALS
- A. Welder certificates signed by Contractor certifying that welders comply with requirements specified under the Quality Assurance Article.
 - B. Field quality-control reports.
- 1.5 CLOSEOUT SUBMITTALS
- A. Operation and Maintenance Data: For preconditioned air DX air handling units to include in operation and maintenance manuals.
 1. Submit maintenance data and parts list for each air handling unit, including "troubleshooting" maintenance guide, servicing guide and preventative maintenance schedule and procedures. Include this data in the maintenance manual; in accordance with requirements of Section 230400 "Basic HVAC Requirements" and Division 1.
 - B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
- 1.6 MAINTENANCE SUBMITTALS
- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Filters: One (1) set of filters for each unit.

1.7 QUALITY ASSURANCE

- A. ARI Compliance: Coils shall comply with ARI 410; Air filter equipment shall comply with ARI 850.
- B. ASHRAE Compliance: Air filters shall comply with ASHRAE Standard 52 for method of testing, and for recording and calculating airflow rates; and Standard 15 Safety Code for Mechanical Refrigeration.
- C. NFPA Compliance: Comply with applicable portions of NFPA 70, for components and installation of air handling units.
- D. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.
- E. UL Compliance: Components shall be UL listed and labeled.
- F. Comply with the local building and fire codes as required by jurisdictional authorities.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Lift and support units with the manufacturer's designated lifting or supporting points.
- B. Disassemble and reassemble units as required for movement into the final location, following manufacturer's written instructions.
- C. Deliver fan units as factory assembled units to the extent allowable by shipping limitations, with protective crating and covering.
- D. Store all equipment and material in suitable facilities until delivery and acceptance by the DEN Project Manager.
- E. Each air handling unit shall be easily mounted and removed from the aircraft bridge without permanent damage to the bridge or its operation.

1.9 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements".

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Air Handling Units:
 - 1) Twist, Inc.
 - 2) **<Insert manufacturer's name>**.
 - 3) or approved equal.
 - b. Air Filters:
 - 1) American Air Filter Company.
 - 2) Farr Company.
 - 3) Research Products Corp.
 - 4) **<Insert manufacturer's name>**
 - 5) or approved equal.

2.2 GENERAL DESCRIPTION

- A. The pre-conditioned air unit shall be an all electric, self-contained, automatically controlled air conditioning unit that provides ventilation, cooling, dehumidifying, filtering, and heating of air supplied to parked aircraft. The unit shall use direct expansion, vapor cycle technology. The pre-conditioned air unit shall be designed to provide comfortable cabin temperatures for passengers and crew during pre-flight, turn-around, overnight parking and maintenance operations.
- B. Provide a compact, minimum weight, and low noise insulated DX air handling unit that can be mounted on equipment stands or passenger loading bridges, such that the operational characteristics of the bridge are unrestricted and the bridge's structural integrity is not compromised.
 1. 45-60 Ton Stand-Mounted: The DX units shall be stand mounted on the apron. All stands shall be designed and manufactured by the pre-conditioned air unit manufacturer. Any proposed apron-mounted air handling unit shall require a telescoping duct across the bridge. It is unacceptable to use flexible air duct (hose) from the rotunda out to the bogie. Location for mounting the air handling unit underneath the bridge shall be behind the bogie wheels and as indicated on the contract drawings.
 2. 45, 60, and 90 Tons Bridge-Mounted: The DX units shall be mounted to the underside of the passenger boarding bridges on the "C" Tunnel, as far back from drive column as possible. All support brackets and accessories shall be designed and provided and by the pre-conditioned air unit manufacturer.

- C. Unit shall be free of vibration transmission and installed with vibration isolators when necessary.
- D. The air handling unit at each gate shall contain evaporator coils, evaporator blower, compressors, condenser coils, condenser fan, refrigeration and temperature controls, smoke detector, electric resistance heaters, filters, complete motor starting equipment (including disconnect switch), condensate drain pan, and condensate discharge pump (where gravity drain to potable water drain cannot be accomplished) to provide the required cooled, ventilated or heated air to maintain the aircraft cabin temperature specified.
- E. The air handling unit(s) shall have the capacity required to sufficiently cool the largest designated aircraft parked at a gate, considering quantity of air to be delivered and static pressures.
 - 1. Units serving wide-body gates shall also operate properly when serving narrow-body aircraft at the same gate.
 - 2. Units service B-747 gates shall also operate properly when serving a wide-body or narrow-body aircraft at the same gate.
- F. The blower shall be sized for the appropriate variable volume airflow requirements. The unit size shall be selected so that the fan brake horsepower does not exceed the maximum required over the design operating range of the unit at the total static pressure.
- G. Unit external static pressure shall be defined as the gauge pressure measured at the outlet of the air handling unit.
 - 1. The Contractor shall submit data presenting the gauge pressure that the proposed air handling unit can produce at the outlet of the air handling unit and at the aircraft connection through 45 feet of hose and an aircraft adapter nozzle in the submittal.
- H. Horsepower shall be selected based on the Contractor's choice of equipment based on the external resistance of the system.
 - 1. Contractor shall furnish the fan motor and unit size adequate for final total static pressure and maximum brake horsepower requirements.
 - 2. Minimum horsepower requirement for narrow-body air handling units shall be 15; for wide-body air handling units, shall be 40; and for B-747/A340 air handling units shall be 50.
- I. Return air to the unit shall not be utilized.
- J. The Contractor shall submit evidence that coordination efforts have been made with the bridge manufacturer for bridge-mounted DX air handling units equipment weights, static and dynamic loading, location, and safety factors.
- K. The construction of the unit shall be as follows:

1. Of a material sufficient to provide adequate structural rigidity of frame and enclosure.
 2. Of a noncorrosive nature.
 3. Provided with thermal insulation for conditions encountered in normal usage.
- L. Where applicable, equipment exterior shall be primed and painted to match bridge color. Equipment interior shall be manufacturer's standard.
- M. The maximum sound level for the DX air handling units at maximum cooling shall not exceed 85 dBA at a distance of 15 feet from the unit. Sound power level radiated by the unit outlet and at the unit inlet when the unit is operated at the designated capacity shall be furnished with the submittal.
- N. No dirty filter indications will be required. However, Contractor shall include in the O&M manuals provisions for scheduled, routine filter cleaning or replacement.
- O. All apron mounted DX air handling units shall be installed with guard posts for protection from ramp activities.
1. Guard posts shall be 6 inches in diameter concrete filled steel pipes embedded 2' 0" minimum in an 18 inch square concrete foundation and projecting 3' 6" above grade.
 2. Guard posts shall be located at all corners of equipment and spaced no more than 4' 0" apart.
 3. All posts shall be painted to match existing posts.
 4. Post locations shall not inhibit access to PCA service areas.
- P. Capacity control and defrost control shall be identified and explained in submittal.
- Q. Provide access doors of the hinge type or removable panels. Locate as required for proper access to the following:
1. Compressors.
 2. Blower/damper.
 3. Filters.
 4. Coils.
- R. Controls panel shall include, but are not limited to:
1. A remote "start/stop" push button station shall be provided, accessible from the ground level for each AHU.
 2. "ON" light.
 3. "Ready" light (lighted pushbutton).
 4. Stop/Reset Pushbutton (red light for fault)
 5. WB/NB pushbutton or B 747/WB/NB pushbutton as applicable.
 6. Wireless connection to LonWorks compatible building automation system to monitor, view and control all points. Wiring, conduit and interface shall be included with PC Air unit and coordinated with other components.
- S. Internal ductwork of air handler shall be stainless steel or aluminum construction.

- T. The unit shall have a variable frequency drive (VFD) to modulate and provide a soft start for airflow. The VFD shall gradually ramp up when the unit is activated to minimize hose snap.

2.3 SCHEDULE 2 - 45, 60 AND 90 TON UNITS

- A. PRODUCT DATA SHEET 1 - The unit design shall consist of three refrigeration systems to provide multiple stages of control.

1. Refrigeration Circuit Configuration: The refrigeration circuit configuration will consist of a Pre-Cool System, a Primary System and a Secondary System.
- a. Refrigeration Circuit Configuration: The refrigeration circuit configuration will consist of a Primary System, a Middle System, and a Secondary System.

- 1) Primary System: The Primary System to be comprised of basic refrigeration circuits consisting of an evaporator coil, compressor, condenser coils, necessary piping, and a means of controlling the flow of refrigerant. The Primary System takes air from the outside, through the air filters, through the blower where it picks up the heat of compression from the blower, and cools the air. This stage takes a large amount of moisture out of the air. The air is then directed to the Middle System.
- 2) Middle System: The Middle System to be comprised of basic refrigeration circuits consisting of an evaporator coil, compressor, condenser coil, necessary piping, and a means of controlling the flow of refrigerant. The Middle System intakes air from the Primary System, where it was cooled, further cools it, and discharges it to the Secondary System.
- 3) Secondary System: The Secondary Systems to be comprised of basic refrigeration circuits consisting of an evaporator coil, compressor, condenser coil, necessary piping, and a means of controlling the flow of refrigerant. The Secondary System intakes air from the Middle System, where it was cooled, further cools it, and discharges it to the aircraft.
- 4) Control Stages from low ambient to high temperatures:

Stage:	System:	Mode of Operation:
1	Three (3) Stages of heat	Heat
2	Two (2) Stages of heat	Heat
3	One (1) Stage of heat	Heat.
4	Blowers only	Ventilate
5	Secondary System	Cool
6	Primary and Secondary Systems.	Cool
7	Pre-Cool, Primary, Secondary	Cool

- 5) The unit shall be designed to use one blower system. The airflow shall be reduced with the VFD for narrow-body mode and heating

modes.

- 6) The condensers shall use one or two condenser fans and motors.
- 7) The air shall be filtered with 2" thick aluminum washable type filters.

2. Air Conditioning Components:

- a. Refrigerant Compressor: The refrigerant compressors shall be hermetic scroll type, 2-pole motor, unidirectional compressor with a solidly mounted compressor base assembly and with oil Sight glass and oil charging valve.
- b. Condenser Coil: the condenser coil shall be copper-tube / aluminum fin heat exchanger. Copper tubes shall be rifled and aluminum fins raised lanced to intensify heat transfer.
- c. Filter-Drier: A replaceable sealed-type filter-drier, installed in the liquid line, to remove moisture and contamination from the refrigerant. The filter-drier shall contain a 100-mesh screen and a molded blend of desiccants for acid and water removal.
- d. Sight Glass: A combination moisture and liquid indicator shall be installed in the liquid line to monitor the flow and moisture content of the refrigerant. The sight glass color indicator is to be protected by a pad and screen and changes color on the basis of relative moisture in the refrigerant.
- e. Expansion Valve: A thermostatic expansion valve to automatically meter the refrigerant flow to the evaporator coil by sensing evaporating pressure and temperature of the vapor leaving the evaporator coil.
- f. Evaporator Coil: The evaporator coil shall be copper tube / aluminum fin heat exchanger with rifled copper tubing and raised lanced aluminum fins to intensify the heat transfer process.
- g. Electronic Discharge Bypass Valve: An electronic discharge bypass valve shall be installed in the Secondary System circuit to prevent the coil from dropping below freezing and to control the capacity of this coil.
- h. Pressure Transducers: Located as appropriate according to sound engineering practices, the transducers shall be fully encapsulated, non-adjustable, direct mount controls for use with non-corrosive refrigerants. These controls shall be fitted with a 1/4 inch SAE female flare fitting with an internal depressor for the Schrader valves located in the piping to prevent refrigerant loss during replacement.
- i. Access (Schrader) Valves: 1/4 inch SAE male valves designed for flare connection used as ports for pressure switch connections and access to the system.
- j. A 3/8 SAE flare charging valve shall be installed in the suction and discharge lines for evacuating and charging the system.

3. Air moving Components:

- a. Supply air blower:
 - 1) 2-pole motor, direct driver, radial wheel turbo pressure type blower with anti-spark and corrosion wheel.
 - 2) Blower motors shall be totally enclosed fan cooled, Direct-connected to blower impeller and of NEMA design B, Class F insulation, 1.15

service factor.

- b. Cooling Air Fan: Axial type, 4-pole or 6-pole motor driven fan with spark and corrosion proof fan blades. The motor is fan-cooled, totally enclosed of NEMA Design B, Class F insulation, 1.15 Service Factor.
 - c. Air Filter: Used to filter intake ambient air, the air filter shall be the cleanable, viscous impingement type
 - d. Control of the unit shall be by means of three or four push buttons. Two or three buttons for Start, one button for Stop/Reset of the unit. These modes, and all of the components shall be controlled by a solid state Direct Digital Controller (DDC) with communication capability. This capability can be linked to monitor the performance of the unit.
4. Safety Provisions and Components:
- a. Circuit Protection: The following systems and / or components will be protected against short-circuit currents or grounds by means of properly selected circuit breakers or fuses:
 - 1) Main Power.
 - 2) Blower motor.
 - 3) Fan motors.
 - 4) Compressor motors.
 - 5) Heater stages.
 - 6) Transformer primary winding (2-pole).
 - 7) Transformer secondary winding, 24 volt (1-pole).
 - b. Overload Protection: Each motor shall be protected from damaging overload currents as follows:
 - 1) Compressor motors: With solid-state built-in protection.
 - 2) Blower Motor: Overload protection provided by the VFD.
 - 3) Fan Motors: With relays of the manual reset type and adjustable setting range type.
 - c. Refrigerant Extreme Pressure Protection: High and low-pressure limit transducers shall protect each refrigeration system. High and low limit pressure transducers shall be used on all refrigeration systems.
 - d. Compressor Short Cycling Protection: Each refrigerant compressor motor shall be protected against short cycling (multiple starts and stops over a short period) by a run-limit timer. The timer shall be programmed in the controller; wired to the motor control circuit to provide a minimum 3-minute delay on re-energizing the compressor motors after each stop.
5. Performance and Capabilities: The following are the design criteria that have been established for the 45 Ton pre-conditioned air units (basic unit performance and configuration are shown in schedules on the drawings):
- a. Outdoor Design Temperatures:

- 1) Summer:
 - a) 92°F db/59°F wb
 - b) 95°F db/63°F wb – Air Cooled Condensing Temperature
 - 2) Winter:
 - a) -5°F db
 - b. Performance Outputs: When operating in the Cooling Mode at design ambient conditions and at the nominal airflow rates, the unit shall deliver 34°F (1°C) air at the unit. When operating in the Heating Mode the unit shall deliver air temperatures between 100°F (38°C) and 160°F (71°C) at the unit.
 - c. Nominal airflow has been shown in the drawing schedules; however, the unit shall be capable of operating at increased airflow rates with a coincident decrease in static pressure. The unit shall be capable of delivering up to 15 percent greater airflow with a concomitant increase in cooling-duty supply air temperature of approximately 5°F.
 - d. Blowers must be adjusted for site altitude of 5,400 ft.
6. Miscellaneous Equipment:
- a. Supply Air Duct: The length of duct going from the pre-conditioned air unit to the aircraft shall be 60 feet.
 - b. Mode Selector: The controls shall be three or four push buttons mounted on the passenger loading bridge.
 - c. Hose Trolley: steel construction with safety yellow finish, toe brakes, capacity of 80 feet of 14" PCA duct.
 - d. Supply Hose Reducer: The PC air unit shall be supplied with a fabric duct that attaches into the 14-inch duct and reduces it to 8-inch duct.
 - e. Provide 2" tall reflective black and yellow, angle-striped, reflective safety tape on the bottom edges of all loading bridge mounted units.

2.4 AIR HANDLING UNIT SUPPORT

- A. All air handling units shall be supported on a factory furnished stand. Stands shall be constructed of steel shapes complying with ASTM A 36, ASTM A 572 grade 50. Stands shall be coated with a baked enamel finish with the color matching the unit or safety yellow.
- B. Field Welding: Comply with AWS D1.1 Structural Welding Code - Steel, as referenced in Part 1.
- C. Supports for all loading bridge mounted units shall be provided by the air handling unit supplier.

2.5 CONTROL SYSTEMS

- A. Refer to Section [236619 "Preconditioned Air Electric Control Systems"] [236621 "Preconditioned Air Sequence of Operation"] for controls requirements.

2.6 EQUIPMENT SCHEDULES

45- TON PRECONDITIONED AIR UNITS:

Tons Nominal (Actual Compressor Tonnage)	45
Unit Weight (lbs)	4500
Refrigerant	R-410A
Power Voltage/Hertz/Phase	480-60-3
Rated Amps	150
Compressors, Scroll @ 60 Hz Rating	15, 15, 15 Ton
Blower H.P.	25
Design Airflow lb/min (kgs)	275 (2.08)
Static at Aircraft in. Wc (kPa)	25 (6.25)
Cooling Discharge Temperature degrees F/C	32 (0.6) - 36 (3.3)
Heating Discharge Temperature degrees F/C	100 (38) - 160 (71)

NOTE: Blowers shall be corrected for site altitude of 5,400 ft. above sea level.

60- TON PRECONDITIONED AIR UNITS:

Tons Nominal (Actual Compressor Tonnage)	60
Unit Weight (lbs)	4850
Refrigerant	R-410A
Power Voltage/Hertz/Phase	480-60-3
Rated Amps	200
Compressors, Scroll @ 60Hz Rating	20, 20, 20 Ton
Blower H.P.	40
Design Airflow lb/min (kgs)	325 (2.45)
Static at Aircraft in Wc (kPa)	30 (7.5)
Cooling Discharge Temperature degrees F/C	32 (0.6) - 38 (3.3)
Heating discharge Temperature degrees F/C	100 (38) - 160 (71)

NOTE: Blowers shall be corrected for site altitude of 5,400 ft. above sea level.

90- TON PRECONDITIONED AIR UNITS:

Tons Nominal (Actual Compressor Tonnage)	90
Unit Weight (lbs)	7950
Refrigerant	R-410A
Power Voltage/Hertz/Phase	480-60-3
Rated Amps	300
Compressors, Scroll @ 60Hz Rating	25, 25, (2)20 Ton
Blower H.P.	60
Design Airflow lb/min (kgs)	500 (3.78)

Cooling Discharge Temperature F/C	32 (0.6) - 38 (3.3)
Heating Discharge Temperature F/C	100 (38) - 160 (71)
Outlet Ducts	Two (2) 14-inch Diameter

NOTE: Blowers shall be corrected for site altitude of 5,400 ft. above sea level.

PART 1 - EXECUTION

2.7 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of air handling units.
- B. Do not proceed until unsatisfactory conditions have been corrected.

2.8 INSTALLATION, GENERAL

- A. PCA air handling units shall be mounted underneath and on the bridge. Units may be apron mounted due to weight considerations, with DEN Project Manager's approval.
- B. Arrange installation of units to provide access space around air handling units for service and maintenance.
- C. Furnish all necessary supports, brackets, guard posts, safety hooks, etc., for properly installing all air handling units.
- D. All air handling units shall be properly aligned, adjusted and lubricated before final acceptance.
- E. Perform system testing and balancing as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC".

2.9 CONNECTIONS

- A. Duct installations and connections are specified in other Division 23 Sections. Make final duct connections with flexible connections.
- B. Electrical Connections: The following requirements apply:
 - 1. Electrical power wiring is specified in Division 26.
 - 2. Temperature control wiring and interlock wiring as specified in Section 236619 "Preconditioned Air Electrical Control Systems".
 - 3. Grounding: Connect unit components to ground in accordance with the National Electrical Code.

2.10 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:
 - 1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
 - 2. Inspect the field assembly of components and installation of DX air handling units including ductwork and electrical connections.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Prepare test and inspection reports.

2.11 DEMONSTRATION

- A. Startup Services:
 - 1. Provide the services of a factory authorized service representative to start up PCA DX air handling units, in accordance with manufacturer's written start up instructions.
 - 2. Test controls and demonstrate compliance with requirements.
 - 3. Replace damaged or malfunctioning controls and equipment.
- B. Operating and maintenance training for Owner's Representative is described in Section 230593 "Testing, Adjusting and Balancing for HVAC".
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

2.12 ADJUSTING, CLEANING, AND PROTECTING

- A. Clean unit cabinet interiors to remove foreign material and construction dirt and dust. Vacuum clean fan wheel and cabinet.

PART 3 - MEASUREMENT

3.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 4 - PAYMENT

4.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236611

SECTION 236614 - PRECONDITIONED AIR DUCTWORK AND ACCESSORIES - AVIATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes telescoping ductwork, glycol over the bridge devices, aircraft adapter nozzles, baskets, flexible aircraft duct (hose), miscellaneous hard ductwork and fittings, and flexible connections.
- B. Related Sections:
 - 1. Section 236600 "Preconditioned Air Hydronic Air Handling Units - Aviation" for preconditioned air hydronic air handling units.
 - 2. Section 236611 "Preconditioned Air DX Air Handling Units - Aviation" for DX air handling units.
 - 3. Section 236616 "Preconditioned Air Electric Control Systems - Aviation" for electric control systems.
 - 4. Section 236619 "Preconditioned Air Sequence of Operation - Aviation" for sequence of operation.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Submit manufacturer's technical product data for each type of ductwork, glycol over the bridge device, fitting, flexible connection, aircraft adapter nozzle, and basket, including dimensions, capacities, and materials of construction; and installation instructions.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Submit manufacturer's assembly-type shop drawings for each type of product data required, showing interfacing requirements with equipment, method of fastening or support, and methods of assembly of components.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Submit manufacturer's maintenance data including parts list for each type of product data required. Include these data, product data, and shop drawings in maintenance manual in accordance with requirements of Division 1.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 QUALITY ASSURANCE

- A. Manufacturer's Qualifications: Firms regularly engaged in manufacture of ductwork and accessories, of types and sizes required, whose products have been in satisfactory use in similar service for not less than three (3) years.
- B. Codes and Standards:
 - 1. SMACNA Compliance: Comply with applicable portions of SMACNA HVAC Duct Construction Standards, 1985 edition.
 - 2. Industry Standards: Comply with ASHRAE recommendations pertaining to construction of ductwork accessories, except as otherwise required.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver and store flexible aircraft duct (hose), aircraft adapter nozzle, basket, glycol over the bridge device and telescoping duct to the jobsite in original unopened containers with labels indicating manufacturer, product name, and related data.
- B. Examine all items for concealed damage or flaws and report any damage.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. **Flexible Aircraft Duct (Hose):**

- a. Air-A-Plane Corporation.
 - b. AmCraft.
 - c. J&B Aviation.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
2. Aircraft Adapter Nozzle:
- a. Air-A-Plane Corporation.
 - b. J&B Aviation.
 - c. Devtec Corporation.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
3. Basket:
- a. J&B Aviation.
 - b. **<Insert manufacturer's name>**.
 - c. or approved equal.
4. Hose Reels:
- a. Air-A-Plane Corporation.
 - b. J&B Aviation.
 - c. Reelcraft Industries, Inc.
 - d. **<Insert manufacturer's name>**.
 - e. or approved equal.
5. Telescoping Air Duct:
- a. Cavotec INET US Inc.
 - b. Twist Inc.
 - c. **<Insert manufacturer>**
 - d. or approved equal.
6. Hose Trolley:
- a. Metroplex Conveyor
 - b. **<Insert manufacturer>**
 - c. or approved equal.

2.2 SHEET METAL MATERIALS

- A. Sheet Metal, General: Provide sheet metal in thicknesses required, packaged, and marked as specified in ASTM A 700.
- B. Galvanized Sheet Steel: Lock-forming quality, ASTM A 527, Coating Designation G90. Provide mill phosphatized finish for exposed surfaces of ducts exposed to view.

2.3 SEALING MATERIALS

- A. The Contractor shall insure that ductwork (hard and flexible) on the bridge is free from excessive air leaks. Contractor shall use sealants as recommended by the manufacturer for the application of preconditioned air ductwork.

2.4 HANGERS AND SUPPORTS

- A. Hangers: Furnish hangers and supporting systems in accordance with Section II of SMACNA and suitable for outdoor installation.
- B. Where galvanized steel ducts are installed, provide hot-dipped galvanized steel shapes and plates.
- C. Straps and Rod Sizes: Conform with Table 5-1 in SMACNA HVAC Duct Construction Standards, 2005 edition, for sheet steel width and gauge, and rod diameters. All materials must be suitable for outdoor installation.
- D. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials, and suitable for outdoor installation.

2.5 ROUND DUCT FABRICATION

- A. Round Ducts: Fabricate round supply ducts with spiral lockseam construction. Comply with SMACNA HVAC Duct Construction Standards, Table 3-2 for galvanized steel gauges.

2.6 ROUND SUPPLY FITTINGS FABRICATION

- A. Ninety Degree Tees and Laterals and Conical Tees: Fabricate to conform to SMACNA HVAC Duct Construction Standards, 1985 edition, Figures 3-4 and 3-5, and with metal thicknesses specified for longitudinal and straight duct.
- B. Elbows: Fabricated in die-formed, gored, pleated, or mitered construction. Fabricate the bend radius of die-formed, gored, and pleated elbows 1.5 times the elbow diameter. Provide elbows meeting the following requirements:
 - 1. Mitered Elbows: Fabricate mitered elbows with welded construction in metal thicknesses specified below.
 - a. Mitered Elbows Radius and Number of Pieces: Construct elbow to comply with SMACNA HVAC Duct Construction Standards, Table 3-1.
 - 2. Round Elbows: Larger than 350 mm: Gored elbows, except where space restrictions require a mitered elbow.
- C. PVC-Coated Elbows and Fittings: Fabricate elbows and fittings as follows:

1. Round Elbows 225 to 650 mm: Standing seam construction.
2. Other Fittings: Riveted and bonded joints.
3. Couplings: Slip-joint construction with a minimum of a 50 mm insertion length.

2.7 SCHEDULE 2 - TELESCOPING AIR DUCTS

- A. PRODUCT DATA SHEET 1 - General: The telescoping air duct shall be a complete assembly of rigid insulated tubing sections, air seals or gaskets, guide bearings, brackets and other mounting and alignment devices. It shall be designed to extend and retract during the full range of motion of a telescoping passenger loading bridge to which it is attached.
- B. PRODUCT DATA SHEET 2 - Materials and Construction: Telescoping air duct shall be rigid cross-bridge, shall be foam core fiberglass with minimum 1/8" inner and outer fiberglass layer for rigid construction. Polyurethane insulation core shall be flame retardant, fireproof and smoke proof, as tested and demonstrated according to approved NFPA procedures. Telescoping section shall have Teflon bearings and foam seals to minimize air leaks. Seals shall be provided as necessary to limit air leakage during operation to less than 1% under the above rated air pressure conditions. Telescoping air duct to be designed to maximize airflow and minimize heat gains when utilizing subfreezing airflow. The number of telescoping sections shall match the number of tunnels of the passenger loading bridge at each gate. Provide no hindrance or resistance to bridge retraction or extension in excess of 110 lbs of force opposing the bridge motion.
- C. PRODUCT DATA SHEET 3 - Ratings: The TAD shall be rated to carry pressurized air at up to 40 inches water column at temperatures between -20°F and +130°F. In order to accommodate the required airflows within acceptable pressure drop limits, the inner diameter of the smallest section of duct shall be at least 14 inches.
- D. PRODUCT DATA SHEET 4 - Mounting: Furnish telescoping duct with all brackets and supports as recommended by the manufacturer's installation requirements.
- E. PRODUCT DATA SHEET 5 - Quality: The construction shall allow extension and retraction of the duct assembly while mounted on the bridge for a minimum of 50,000 full cycles or ten (10) years without requiring inspection or any scheduled maintenance. This shall be proven in practice by a minimum of 100 previously-installed units in continuous service on passenger boarding bridges. Minimum overlap between duct sections is 12" regardless of duct diameter.
- F. PRODUCT DATA SHEET 6 - Safety: Provide reflective 6" tall, black and yellow, angled-stripe, reflective safety tape on the bottom edges of ductwork.

2.8 SCHEDULE 3 - FLEXIBLE AIRCRAFT DUCT (HOSE)

- A. PRODUCT DATA SHEET 1 - Flat Duct Characteristics – Outer Surface:
 1. Orange colored outer cover shall be constructed of 1000 denier Nylon, tight

- weave construction, with polyurethane laminated backing. The finished material thread is nylon type thread 66. Vinyl outside surface is not acceptable.
2. The minimal grab tensile strength shall be:
 3. Warp 600 lbs.
 4. Fill 500 lbs.
 5. The minimal Torque tear strength shall be:
 6. Warp 50 lbs.
 7. Fill 50 lbs.
 8. Material shall have fire resistance of 3 seconds maximum for flame out, 5 seconds maximum for glow, and 5 inches maximum for char length.
 9. The abrasion resistance at the end of 1000 wear cycles the fabric coating shall not be worn to such an extent that the basic fabric is torn by the abraser wheel. (H-22 Abraser wheel under 1000).
 10. The material shall not exceed 10% thickness, 15% weight, and 20% volume increase if soaked for 48 hrs. in 91 octane gasoline, SAE No. 10 oil and water.
 11. No scorching or other harmful effects to be resulted following hot air flowing inside at 170 degrees F for two hrs. No harmful effects due to flexing and exposure to -65 degrees F for 24 hrs. Operating temperature range -46 degrees F to +200 degrees F intermittent to +170 degrees Fahrenheit.
 12. There shall be no visual evidence of deterioration or fungus growth per MIL-STD-810, Method 508.1, Procedure II.
 13. All stitching shall be nylon thread.
 14. 2-ply cuffs shall be at each end of each section of flat duct hose. Each section of hose shall have Velcro connections for means of attaching and securing additional sections.

B. PRODUCT DATA SHEET 2 - Flat Duct Characteristics - Inner Liner:

1. Inner liner shall be constructed of tear resistant woven nylon material. Vinyl inner liner is not acceptable.
2. The minimum grab tensile strength in lbs. shall be 600 lbs warp and 500 lbs fill.
3. The minimum Tongue Tear shall be 50 lbs warp and 50 lbs fill.
4. Material shall have fire resistance for 5 seconds maximum on flame out, 8 seconds maximum for glow, and 5 inches for char length.
5. The inner liner shall be moisture resistant and cold resistant to -65 degrees F.

C. PRODUCT DATA SHEET 3 - Flat Duct Characteristics - Insulation:

1. Insulation shall have the following characteristics:
2. Thickness: 0.05" nominal
3. Weight: 0.02 lbs/sq. ft.
4. Contact Temperature Range -60°F to 180°F
5. Flame spread: 25 in accordance with ASTM E 84
6. Smoke Development: 35
7. Linear shrinkage: none
8. Puncture Resistance: 47 lbs./psi
9. Fire rating NFPA Class A/UBC Class 1
10. Emittance 0.03-0.04
11. Reflectivity 0.96-0.97 in accordance with ASTM C 1371

12. Aluminum foil sheet, bonded to woven polyethylene film, fungi resistant.
13. Thermal Values, R-Value of 3.25 or greater.
14. Insulation (between the inner liner and the outside cover) shall not retain moisture nor create a wicking effect should the insulation come in contact with water or any fluids.

D. PRODUCT DATA SHEET 4 - Spiral-Reinforced Duct Characteristics - Outer Surface:

1. Yellow colored outer surface shall be comprised of 3-ply high strength PVC fabric and black wearstrip. Finished material thickness shall be 0.029 inches.
2. Spiral reinforcement shall be hard-drawn steel with 4" or 6" standard pitch.
3. Temperature Rating: -20 degrees F to 180 degrees F
4. 2-ply cuffs shall be at each end of each section of flat duct hose. Each section of hose shall have Velcro connections for means of attaching and securing additional sections.

E. PRODUCT DATA SHEET 5 - Spiral-Reinforced Duct Characteristics - Inner Liner:

1. 3-ply PVC fabric designed to eliminate delamination commonly found in inner liners
2. Finished material thickness shall be 0.017 inches.

F. PRODUCT DATA SHEET 6 - Spiral-Reinforced Duct Characteristics - Insulation:

1. Stitch-bonded polyester insulation similar to high performance material found in cold weather clothing and camping products.
2. Insulation shall not retain moisture nor create a wicking effect should the insulation come in contact with water or any fluids.

G. PRODUCT DATA SHEET 7 - Pantograph:

1. Contractor shall provide a pantograph for the cables over the bridge service. Pantograph shall be four-piece with 3 looped hinges and have two cable conduits. One (1) conduit shall remain as spare. Pantographs supports shall be by the manufacturer. Proposed device must have satisfactory service in other PCA systems for a minimum of two (2) years.

H. PRODUCT DATA SHEET 8 - Hose Trolley:

1. A three-wheel type metal hose trolley shall be provided to store the flexible supply ducts and aircraft adapter nozzles at each gate. The hose trolley shall be stainless steel and free of sharp edges. Trolleys connected to apron drive bridges shall be constructed such that the trolley can be readily removed and reconnected. All hinges shall be stainless steel. Wheels shall be composite urethane with stainless steel bearings and bushings. No plastic internals shall be used. Trolley design and location shall be approved by the DEN Project Manager.

2.9 FLEXIBLE CONNECTIONS

- A. General: Provide flexible duct connections wherever ductwork connects to vibration isolated equipment. Construct flexible connections of neoprene-coated flameproof fabric with dual clamps at the flexible duct connection to the AHU collar for ease of maintenance. Flexible connector shall be suitable for outdoor installation and pressure classification of supply air. Make airtight joint. Provide adequate joint flexibility to allow for thermal, axial, transverse, and torsional movement, and also capable of absorbing vibrations of connected air handling unit.

2.10 MISCELLANEOUS

- A. Provide one or two flat, insulated, flexible aircraft ducts per gate as required by PCA service for extension of the hard ductwork, from the loading bridge to the aircraft connection(s) at each gate. The flexible ducts shall be provided in segments with a connecting device to allow easy replacement in the field without special tools. The flexible ducts shall be a minimum of 18 M in length, but in no case requiring a "taut" over-extension to the connection point.
- B. Contractor shall supply two aircraft adapter nozzles for each gate.

2.11 SCHEDULE 4 - AIRCRAFT ADAPTER NOZZLE:

- A. PRODUCT DATA SHEET 1 - Properties and characteristics:
1. The adapter shall be manufactured using a Nylon material using Nylon 66 impact modified Super Tough Heat Stabilized and lubricated material known as Hylon Select N1000STHL. The connector is of injection molded construction.
 2. The connector shall be designed to withstand an IZOD tested impact of 16ft/lbs. The method used to conduct this test is ASTM D 256 for scored material.
 3. The connector assembly shall be capable of operating under the following conditions with no deleterious effect on the connector:
 4. High Temperature range 250 degrees F.
 5. Low Temperature range -40 degrees F.
 6. The connector shall have integral means to prevent the stainless hose clamps from sliding off.
 7. The connector flange to remain rigid under all operational conditions to provide positive seal to aircraft connection point to reduce risk of air loss. The gasket material for the flange shall be 1/2" thick and consist of foam neoprene, medium density. This gasket shall be glued to the flange.
 8. The inlet shall be beveled to prevent damage to flat duct hose.
 9. PRODUCT DATA SHEET 2 - Latching Mechanism
 10. Connector latching mechanism shall be 100 percent slot filled and provide positive connection to mating aircraft flange preventing unintentional disengagement.
 11. Latching hooks shall be retractable to minimize risk of damage to hose in storage condition.
 12. Latching mechanism shall be removable to allow for easy access should repairs

or adjustments become necessary.

B. PRODUCT DATA SHEET 3 - Operating Levers:

1. Each operating lever shall have dimensions of not less than 7 inches long and 1 inch wide.
2. Each operating lever shall serve as a handle for the purpose of installing adapter to the aircraft.
3. Handle shall be constructed of not less than 3/16", 303 stainless steel.
4. The operators grip area shall be covered with resilient material not less than 4 inches in length for cold weather operation.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine areas and conditions under which ductwork and accessories will be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to installer.

3.2 DUCT INSTALLATION

- A. Duct System Pressure Class: Construct and install each duct system for the specific duct pressure classification required.
- B. Install ducts with the fewest possible joints.
- C. Use fabricated fittings for all changes in directions, changes in size and shape, and connections.
- D. Locate ducts, vertically and horizontally, parallel and perpendicular to passenger bridge lines; avoid diagonal runs. Install duct systems in shortest route that does not obstruct usable space or block access for servicing bridge and its equipment.
- E. Install ducts close to walls, overhead substrates, columns, and other structural and permanent enclosure elements of bridge.
- F. All rigid and flexible ductwork shall be insulated so as to maintain a 3 degree C maximum heat gain from leaving coil temperature to supply temperature at the aircraft.

3.3 INSTALLATION OF DUCTWORK ACCESSORIES

- A. Install ductwork accessories in accordance with manufacturer's installation instructions, with applicable portions of details of construction as shown in SMACNA standards, and in accordance with recognized industry practices to ensure that products serve intended function.

- B. Coordinate with other work, as necessary to interface installation of ductwork accessories properly with other work.

3.4 SEAM AND JOINT SEALING

- A. General: Seal duct seams and joints as follows:
 - 1. Pressure Classifications Greater than 750 Pa: All transverse joints and longitudinal seams.

3.5 HANGING AND SUPPORTING

- A. Install rigid round duct with support systems indicated in SMACNA HVAC Duct Construction Standards, Tables 4-1 through 4-3 and Figures 4-1 through 4-8.
- B. Support horizontal ducts within 600 mm of each elbow.
- C. Support vertical ducts at a maximum interval of 5 m.

3.6 CONNECTIONS

- A. Air Handling Unit Connection: Connect equipment with flexible connectors.
- B. Aircraft Connection: Aircraft connections shall be made with a mating nozzle; referred to in this document as an aircraft adapter nozzle.

3.7 FIELD QUALITY CONTROL

- A. Test for air leakage while system is operating. Remake leaking joints as necessary.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236614

SECTION 236616 - PRECONDITIONED AIR ELECTRIC CONTROL SYSTEMS - AVIATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
- B. Related Requirements:
 - 1. Section 230548.13 "Vibration Controls for HVAC".
 - 2. Section 236600 "Preconditioned Air Hydronic Air Handling Units - Aviation" for hydronic air handling units.
 - 3. Section 236611 "Preconditioned Air DX Air Handling Units - Aviation" for DX air handling units.
 - 4. Section 236613 "Preconditioned Air Ductwork and Accessories - Aviation" for ductwork and accessories.
 - 5. Section 236619 "Preconditioned Air Sequence of Operation - Aviation" for sequence of operation.
 - 6. Electrical work shall be as specified in Division 26.
 - 7. Control sequences are specified Section 236619 "Preconditioned Air Sequence of Operation - Aviation".
 - 8. Installation of instrument wells and valve bodies in mechanical systems: Other Division 23 Sections as applicable.
 - 9. For the following work: Division 26 Sections as applicable:
 - a. Power supply wiring for power source to power connection on controls and/or unit control panels. Include starters, disconnects, and required electrical devices, except where specified as furnished, or factory installed, by manufacturer.
 - b. Interlock wiring between electrically operated equipment units; and between equipment and field installed control devices. Interlock wiring specified as factory installed is work of this Section.
 - 10. Provide the following electrical work as work of this Section, complying with requirements of Division 26 Sections:
 - a. Control wiring between field installed controls, indicating devices, and unit control panels.

1.2 SUMMARY

- A. Section includes control panels and all related components, controls, and devices to complete the systems specified herein.

B. General:

1. Contractor shall furnish all design drawings and detailed submittal data corresponding to the complete control system included as part of the Preconditioned Air design. Drawings and specifications are to indicate general arrangement of the equipment, controls, and devices, types of control schemes, and the extent of remote controls as required to make the complete system meet the performance specifications.
2. Systems Included:
 - a. Preconditioned air central chiller plant(s) system.
 - b. Ramp air handling systems.
 - c. The direct digital control system.
3. Type of Control System: Electronic sensing electric or electronic positioning.

C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of preconditioned air electric control system.

1. Submit manufacturer's technical product data for each control device furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, and including installation instructions and start up instructions.
 - a. Furnish description or specification sheets on all control components.
 - b. Submit samples of all control system graphic maps to be created or modified with all points to be used.
2. Include data substantiating that materials comply with requirements.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For preconditioned air electric control systems to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 QUALITY ASSURANCE

- A. Manufacturer's Qualifications: Firms regularly engaged in manufacturer of electric control equipment, of types and sizes required, whose products have been in

satisfactory use in similar service for not less than five (5) **<Insert number>** years.

B. Codes and Standards:

1. Electrical Standards: Provide electrical products, which have been tested, listed and labeled by UL and comply with NEMA standards; except AHUs, which shall have, components listed and labeled by UL, or shall be Owner approved.
2. NEMA Compliance: Comply with NEMA standards pertaining to components and devices for electric control systems.
3. NFPA Compliance: Comply with NFPA 90A where applicable to controls and control sequences.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Provide factory shipping cartons for each piece of equipment, and control device. Maintain cartons through shipping, storage and handling as required to prevent equipment damage, and to eliminate dirt and moisture from equipment. Store equipment and materials inside and protected from weather.

1.7 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace preconditioned air electric control system that fails in materials or workmanship within specified warranty period.
1. Warranty Period: Minimum **[two (2)] [five (5)] <Insert number>** years from date of Substantial Completion.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Honeywell, Inc.
 2. Johnson Controls, Inc.
 3. Siemens Corp.
 4. **<Insert manufacturer's name>**.
 5. or approved equal.

2.2 MATERIALS AND EQUIPMENT

- A. General: Provide LonMark certified electric control products in sizes and capacities required, consisting of valves, dampers, thermostats, clocks, sensors, controllers, and other components as required for complete installation. Provide manufacturer's standard control system components as indicated by published product information, designed and constructed as recommended by manufacturer. Provide electric control systems with all specified functional and construction features. Devices shall communicate seamlessly with existing DEN LonWorks-based Honeywell Building Solutions Facility Management System (FMS).
- B. Control Valves: Provide factory fabricated electrical control valves of type, body material and pressure class as determined by manufacturer for installation requirements and pressure class, based on maximum pressure and temperature rating of piping system. Provide valves which mate and match material of connecting piping. Equip control valves with control valve motors, and with proper shutoff ratings for each individual application.
1. Water Service Valves: Equal percentage characteristics with rangeability of 50 to 1, and maximum full flow pressure drop of 35 kPa.
 2. Single Seated Valves: Cage type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.
 3. Double Seated Valves: Balanced plug type, with cage type trim providing seating and guiding surfaces for plugs on "top and bottom" guided plugs.
 4. Valve Trim and Stems: Polished stainless steel.
 5. Packing: Spring loaded Teflon, self adjusting.
 6. Air Handling Unit Control Valves: Provide control valves for control of air handling units that are of integral motor type. Provide 2 position or modulating type valves, electrically actuated by line voltage of 24 V.

2.3 SPACE TEMPERATURE CONTROL ASSEMBLY - BRIDGE SERVICE

- A. Furnish a temperature sensor (probe), which can be placed by gate agents in the aircraft interior. This probe shall sense the aircraft space temperature and control the aircraft space temperature automatically.

2.4 RELAYS

- A. Electrical relays shall be approved industrial type with NEMA 12 general purpose enclosures and multiple contacts as required.
- B. All relays shall be 220 volts or less.
- C. All relays shall have A600 contact rating.
- D. All relays shall have two spare contacts (1 N.O. and 1 N.C.)

2.5 ELECTRONIC - ELECTRIC PROPORTIONAL OPERATORS

- A. Operators shall have single phase 220 volt or 24 volt heavy duty motors and sealed oil immersed gear train.
- B. Operators shall modulate the controlled device without exceeding the torque rating of the motor.
- C. Furnish integral spring return to permit fail safe operation upon power interruption.
- D. Provide built in, adjustable, auxiliary switches where required.
- E. Furnish complete with mounting brackets, control arms, linkage, and cranks.

2.6 TEMPERATURE INDICATOR AND SELECTOR SWITCHES

- A. Control panel mounted electronic precision temperature indicators and selector switches may be used in lieu of control panel mounted dial temperature gauges.
- B. Sensing elements: Wire wound resistance temperature elements.
- C. Provide automatic compensation for ambient temperature variations.
- D. Minimum calibrated accuracy shall be 1 percent of full scale range.
- E. Minimum scale length shall be adequate to provide 1 degree division and a range of approximately -10 to 50 degrees C.
- F. Temperature indicator readings shall not be affected by a supply voltage variation of plus or minus 10 percent line voltage fluctuation.
- G. Maximum response time shall be 6 seconds for full scale deflection.
- H. Selector switches shall be panel mounted momentary contact push button type with approved type nameplates.

2.7 MOTORIZED VALVE ASSEMBLIES - INTERIOR EQUIPMENT AREAS

- A. Assemblies shall include the following:
 - 1. Electronic or electric operators as specified in this Section.
 - 2. Adjustable linkage.
 - 3. Position indicators.
- B. Valve bodies for up to 105 degrees C water service. Bodies shall be as follows:
 - 1. Have adequate flow coefficient Cv for the application and as indicated.
 - 2. Suitable for the temperatures and fluid handled.

3. Provide tight shutoff if single seated.
4. Bronze with screwed ends up to 65 mm.
5. 125 pound cast iron flanged in sizes over 65 mm, unless otherwise indicated due to higher pressures.

- C. Control valve operators shall be adequate to close valves completely against the maximum shutoff pressure of the system.

2.8 ELECTRICAL AND ELECTRONIC CONTROL DEVICES

- A. Switches, potentiometers, and other control components shall be rated at 220 volt service and have suitable dustproof enclosures equal to NEMA 12 general purpose. Provide indicating plates, and identifying nameplates unless otherwise specified.
- B. Transformers shall be furnished as required with enclosed terminals and adequate ratings for use with 220 volt ac primary supply voltage.
- C. Outdoor control devices shall have NEMA 4 weathertight enclosures. Electrical devices installed in hazardous AREAS shall have enclosures approved for the NEC classification.
- D. Water Flow Switches: Provide water flow switches of stainless steel or bronze paddle types. Where flow switches are used in chilled water applications, provide vapor proof type to prevent condensation of electrical switch. Provide pressure flow switches of bellows actuated mercury type or snap acting type, with appropriate scale range and differential adjustment for service indicated.
- E. Local Control Panels: Panels shall be manufacturer's standard, completely enclosed, wall mounted cubicle panels. Control arrangement shall be approved by the Construction Supervisor.
1. Fabricate panels of 1.9 mm furniture quality steel, or 6063 T5 extruded aluminum alloy, totally enclosed, with hinged doors and keyed lock, with manufacturer's standard shop painted finish and color. Provide UL listed cabinets for use with line voltage devices.
 2. Panel Mounted Equipment: Include temperature and humidity controllers, relays and automatic switches, except exclude low temperature protection thermostats, firestats, and other devices excluded in sequence of operation. Fasten devices with adjustments accessible through front of panels. Also include manual switches, including damper "minimum off" positioning switches, "summer-winter" switches, and "manual automatic" switches; and including dial thermometers.
 3. Nameplates: Furnish for all components located on the front of the panel. Nameplates shall be sizes, materials, and contain legends consistent with Contractor's standard practice.
 4. Terminal Block: Furnish for all electrical connections. Identify terminals.
 5. Control Panel Wiring: Wiring shall be as specified in Division 26. Control panels shall be prewired at the factory to terminal strips for field connections. Factory test all wiring. Wiring terminals shall be arranged for top rear control cable connections unless otherwise specified or required. Connect terminal blocks with

approved flexible panelboard wiring to electrical control switches and devices mounted on the hinged door. Wiring shall be neatly arranged and supported in plastic or plated steel brackets.

- F. Central (Master) Control Panels: Provide central control panels of fully enclosed steel cubicle type, with locking doors and/or locking removable backs. Match finish of panels and provide multi color graphic displays, schematically showing system being controlled.
- G. Central Plant Control System: Refer to Section [15495 Preconditioned Air Sequence of Operation for PCA System Computer Control] [15955 - Building Automation System (Honeywell EBI)].
- H. Provide battery backup for all memory devices.

2.9 UNITARY CONTROLLERS

- A. General: Unitary DDC controllers (UCs) shall be standalone, EEPROM-based, configured to perform the sequences specified, and I/O selected for the application. All unitary DDC controllers (UCs) shall be LonMark-approved products and shall support the LonMark Functional Profile for the given application. UC s shall be tested and listed under UL916 for computing devices. UC enclosures shall be flame retardant, compact plastic conforming to UL94-V5 for plenum mounting or plated steel. UCs shall be CE approved and meet FCC Part 15 class B requirements. UC s shall be configured for DIN rail mounting, using industry-standard clip-on adapters, or for direct panel mounting. Each ASC shall be capable of standalone operation and shall continue to provide control functions without being connected to the network. Each ASC will contain sufficient I/O capacity to control the target system.
- B. Communication: The unitary controller shall communicate with other devices on the internetwork using EIA standard 709.1, the LonTalk™ protocol, as the common communication protocol with a minimum transmission speed of 78Kbaud. A twisted-pair cable utilizing T-Taps, star, and mixed topologies on the same network shall support this network. The free topology transceiver (FTT) network shall not be polarity sensitive. Network media shall be Level IV, 22AWG, twisted-pair wire, and shall conform to UL Category 4 for high-speed networks. Cable shall be supplied in plenum and non-plenum-rated versions. Network length shall not exceed 1,640 ft without the addition of Echelon LonWorks repeater achieving an additional length of 3280 ft. For lengths in excess of 3,280 ft, a daisy chain wiring scheme can be employed; using a repeater, this length can be extended to 10,000 ft. Lengths in excess of 10,000 ft will not be allowed. Repeater bus topologies shall include bus segments of 60 nodes unless routers are utilized. Systems communicating at slower speeds shall not exceed 30 nodes per segment to ensure adequate global data and alarm response times.
 - 1. PRODUCT DATA SHEET 2 - Controller shall communicate to BAS remote server via wireless transceiver:
 - a. Lantronix Wireless Device Server.

b. Device Specifications:

- 1) 802.11b/g wireless interface.
- 2) Two DB9 DTE serial ports to support RS-232, RS-422 or RS-485 communication.
- 3) Wireless security with IEEE 802.11i-pSK, WPA-PSK, TKIP protection.
- 4) 256-bit AES, end-to-end encryption.
- 5) Complete with power supply.

C. Environment: The hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for ambient temperature operation at -40 degrees C to +65 degrees C (-40 degrees F to +150 degrees F) and ambient humidity of 5 to 95 percent RH noncondensing.
2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for ambient temperature operation at 0 degree C to +50 degrees C (32 degrees F to +122 degrees F) and humidity of 5 to 95 percent RH noncondensing.

D. Serviceability: Each UC shall be provided with face-mounted LED type annunciation to continually display its operational mode: power, normal, or in an alarm state. As an alternative to the face-mounted integral LED, the control contractor shall provide relay-driven pilot lights mounted at the UC location, which shall provide the specified annunciation. UCs shall be configured for DIN rail mounting, using industry-standard clip-on adapters, or for direct panel mounting. Each controller shall be designed with on-board jacks for quick commissioning and troubleshooting with a portable programming tool.

E. Immunity to power and noise: Controllers shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent. Operation shall be protected against electrical noise of 5-120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

F. Transformer: Power supply for the ASC shall be rated at a minimum of 125 percent of ASC power consumption and shall be of the fused or current-limiting type.

G. Provide a standalone Single Zone DDC controller featuring preprogrammed heating and cooling and economizer control algorithms configurable for either standard single zone rooftop unit applications or heat pumps. Controller shall use Echelon LonWorks communication technology for field bus and shall utilize the LonMark Rooftop Unit (RTU) functional profile 8030 for interoperability with third-party LonMark devices in network applications. For rooftop applications, the controller shall have an extended operating temperature rating from -40 degrees F to +150 degrees F so the controller can be mounted directly in the wiring cabinet of AHU. If controller provided does not have a -40 degree F to 150 degree F temperature range, then the device shall be mounted in a separate enclosure with suitable heating and cooling to meet the controller operating temperature range. Controller application software shall include

PID control, set-point resets for energy demand limit control, and economizer minimum position for IAQ control. Separate unoccupied heating and cooling set-points shall be provided. Provide an adaptive algorithm that continuously adjusts the discharge air setpoint as needed. A standby feature shall be provided to reset the occupied temperature set point back to a user-definable limit based on status from an auxiliary device, such as an occupancy sensor or window contact. The controller shall include a temperature wall module connection that may be used in applications where the wall module shall sense temperature, control set point temperature, control occupied and unoccupied, or control fan speed. In addition to internal I/O selected for the application, the controller shall support distributed I/O from the network.

- H. Provide a standalone DDC Fan Coil controller for common two pipe or four pipe fan coil units featuring preprogrammed heating and cooling control algorithms for single or up to three fan speed applications. Controllers shall use Echelon LonWorks communication technology for field bus and shall utilize the LonMark Fan Coil Unit (FCU) functional profile 8020 for interoperability with third-party LonMark devices in network applications. Controllers shall have integral transformers and fan speed relays directly wired to line voltage power 115Vac and 230Vac. Controller application software shall include a set point reset for energy demand limit control. Separate unoccupied heating and cooling set points shall be provided. A standby feature shall be provided to reset the occupied temperature set point back to a user-definable limit based on status from an auxiliary device, such as an occupancy sensor or window contact. The controller shall include a temperature wall module connection that may be used in any applications where the wall module shall sense temperature, control set point temperature, control occupied and unoccupied, or control fan speed. In addition to internal I/O selected for the application, the controller shall support distributed I/O from the network. The control contractor shall furnish and ship damper actuators and Unitary DDC controllers to the zone equipment manufacturer for factory installation. See section <Insert section> and plans for coordination details.
- I. Provide a distributed input and output module that connects sensors and actuators onto the Echelon field bus network for use with a LonWorks general purpose controllers (GPCs) and unitary DDC controllers (UC). LonWorks controllers shall be configured to read and command these points as required or specified. These distributed I/O modules shall use a Neuron® chip and an FTT-10A free topology transceiver for communication on a LonWorks bus, and comply with LonMark Application Layer Guidelines V3.2. I/O. The device shall have extended operating temperature rating from -40 degrees F to +150 degrees F, so it can be mounted directly in a wiring cabinet of monitored appliances. The I/O device shall include a temperature wall module connection that may be used in applications where the wall module shall sense temperature, control set point temperature, control occupied and unoccupied, or control fan speed.

2.10 HYDRONIC PC AIR UNIT POINTS LIST

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Softwar e Point
PC Air Unit	X						

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Softwar e Point
Supply Fan Start-Stop and Status		X					
Supply Fan Status			X				
Supply Fan Runtime							X
Outdoor Air Temp					X		
Discharge Air Temp					X		
Cabin Temp Cooling Setpoint				X	X		
Heating Setpoint				X			
Heating Stage 1	X						
Heating Stage 2	X						
Cooling Coil Control Valve Damper Position or VFD				X			
On/Off/Auto Mode			X				
Duct Smoke Detectors (as required)			X				
Plenum Overtemp Alarm		X				X	
Blower Overload (on dampered units only)			X			X	
Coil Entering Temp					X		
Coil Leaving Temp					X		
Coil Flow Defrost Mode		X			X		
400 Hz ON/OFF Status		X					
400 Hz Fault		X					

2.11 DC PC AIR UNIT POINTS LIST

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Softwar e Point
PC Air Unit	X						
Supply Fan		X	X			X	
Start-Stop and Status							
Outdoor Air Temp					X		
Discharge Air Temp					X		
Cabin Temp					X		
Heating Stage 1				X			
Heating Stage 2				X			
Compressor Status (each)						X	
Condenser Fan Status (each)						X	
Damper Position			X	X		X	
Duct Smoke Detectors (as req'd)			X				
Condenser Fan Satus (each)						X	
Aircraft Size (each)					X		
Alarm Heat 1 (as req'd)		X				X	
Maintenance Alarm		X				X	
400 Hz ON/OFF Status		X					
400 Hz Fault		X					

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine areas and conditions under which electric control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to Installer.

3.2 INSTALLATION (BRIDGE MOUNTED EQUIPMENT ONLY)

- A. General:

- 1. Field check for clearances and interferences before fabrication.
- 2. Furnish all labor, tools, rigging equipment, scaffolding, and all other materials necessary to make a complete installation of the material and equipment specified and indicated.
- 3. Prepare surfaces and spot apply primer and finishing paint on all equipment after installation where the shop paint has been damaged or flaked off.
- 4. Installation shall equal or exceed the minimum requirements of the applicable codes and these specifications; however, where local codes and ordinances are more stringent, they shall govern.
- 5. Include all material, labor, and changes occasioned by the Contractor's choice of equipment.
- 6. All equipment furnished shall be installed complete including necessary piping, electrical connections, wiring, mounting, etc.
- 7. Contractor shall coordinate his work and interface of his work with others as required, including coordination with the bridge manufacturer to prevent damage to the bridge due to installation of Contractor furnished equipment.

- B. Electrical Wiring and Installation:

- 1. Materials and equipment shall be in accordance with Division 26.
- 2. Install wiring in conduits and provide separate conduits for electronic control circuits. All control circuit wiring shall be 220 volts or less.

3.3 INSTALLATION OF ELECTRIC CONTROL SYSTEMS

- A. General: Install systems and materials in accordance with manufacturer's instructions. Install electrical components and use electrical products complying with requirements of applicable Division 26 Sections of these Specifications. Mount controllers at convenient locations and heights.
- B. Control Wiring: The term "control wiring" is defined to include providing of wire, conduit, and miscellaneous materials as required for mounting and connecting electric control devices.
- C. Wiring System: Install complete control wiring system for electric control systems.

Conceal wiring, except in mechanical rooms and AREAS where other conduit and piping are exposed. Provide multi conductor instrument harness (bundle) in place of single conductors where number of conductors can be run along common path. Fasten flexible conductors bridging cabinets and doors, neatly along hinge side, and protect against abrasion. Tie and support conductors neatly.

- D. Number code or color code conductors appropriately for future identification and servicing of control system. Coding shall match designations shown on the manufacturer's control diagrams.
- E. Unit Mounted Equipment: Where control devices are to be unit mounted, ship such devices to unit manufacturer for mounting and wiring at factory.
- F. Furnish all the necessary components so that the system performs as specified.
- G. Completely adjust and test the systems specified to ensure those control systems perform satisfactorily.
- H. Group control components together in a neat orderly fashion in control panels.
- I. Permanently identify all control components by adhesive embossed plastic label corresponding to the numbers shown on the control diagrams submitted for approval.
- J. Post control diagrams and operating sequences in a frame with glass or clear plastic lens adjacent to the main control station panel. The control diagrams and sequences in final form shall be submitted for approval.
- K. Electronic sensing systems may use local control panel mounted electronic precision temperature indicators and resistance temperature detectors with panel mounted separate pushbuttons for each point of temperature indication in lieu of panel mounted dial thermometers.

3.4 STARTUP

- A. Start up, test, and adjust electric control systems in presence of manufacturer's authorized representative. Demonstrate compliance with requirements. Replace damaged or malfunctioning controls and equipment.
- B. Prepare test and inspection reports.

3.5 ADJUSTING AND CLEANING

- A. Cleaning: Clean factory finished surfaces. Repair any marred or scratched surfaces with manufacturer's touch up paint.
- B. Final Adjustment: After completion of installation, adjust thermostats, control valves, motors and similar equipment provided as work of this Section.

1. Final adjustment shall be performed by specially trained personnel in direct employ of manufacturer of primacy temperature control system.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain systems.
 1. Provide services of manufacturer's technical representative for **[two (2)] <Insert number>** 8-hour days to instruct Owner's personnel in operation and maintenance of electrical control systems.
 2. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 236616

SECTION 236619 - PRECONDITIONED AIR SEQUENCE OF OPERATION - AVIATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes requirements for sequence of operation for preconditioned air. Sequence of operation is defined as the manner and method by which the control system (direct digital control) functions.
- B. Related Sections:
 - 1. Section 230548.13 "Vibration Controls for HVAC".
 - 2. Section 236600 "Preconditioned Air Hydronic Air Handling Units - Aviation" for hydronic air handling units.
 - 3. Section 236611 "Preconditioned Air DX Air Handling Units - Aviation" for DX air handling units.
 - 4. Section 236613 "Preconditioned Air Ductwork and Accessories" for ductwork and accessories.
 - 5. Section 236616 "Preconditioned Air Electric Control Systems" for electric control systems.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For preconditioned air sequence of operation.
 - 1. Submit sequence of operation description along with Piping and Instrumentation Diagram (P&ID) diagram indicating methods and equipment applied to achieve specified operation of PCA system.
 - 2. Include data substantiating that materials comply with requirements.

1.4 CLOSEOUT SUBMITTALS

- A. Operation Data: For preconditioned air sequence of operation to include in emergency, operation, and maintenance manuals.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 QUALITY ASSURANCE

- A. Applicable Standards:
 - 1. EIA 485: Standard for Electrical Characteristics of Generators and receivers for Use and Balanced Digital Multi Point Systems.
- B. Manufacturer's Qualifications: Firms regularly engaged in manufacturer of electric control equipment, of types and sizes required, whose products have been in satisfactory use in similar service for not less than five (5) years.

1.6 PRECONDITIONED AIR SYSTEM SEQUENCE OF OPERATION

- A. General: The preconditioned air system shall provide heated, cooled, or ventilated air to gates as indicated on the drawings. The control system shall be expandable to [50] <Insert number> gates per concourse for future build out.
- B. The PCA system shall be designed such that the aircraft parked at the gates shall maintain an interior space temperature of 75 degrees F in the cooling season and 70 degrees F in the heating season (tolerance of +/- 2 degrees F). A minimum ventilation rate of 10 cfm/seat for the cooling mode and 5 cfm/seat for the heating mode shall be required. Cooling shall be provided for outdoor air temperatures of 45 degrees F and above during the dedicated cooling season. The central plant shall heat aircraft at an outdoor air temperature of 40 degrees F and below during the dedicated heating season.
- C. The system shall be comprised of two (2) major components (on each concourse):
 - 1. The air handling units and associated equipment located on each passenger bridge.
 - 2. The direct digital control system.

1.7 SCHEDULE 2 - PRECONDITIONED AIR SYSTEM SEQUENCE OF OPERATION (DETAILED SEQUENCE)

- A. PRODUCT DATA SHEET 1 - Start / Stop Control:
 - 1. The system is started through a momentary "Start" push button. The system runs continuously unless stopped by the blower motor VFD, the smoke detector, the phase monitor, or pressing the "Stop" button.
 - 2. Upon depressing the "Start" push buttons, the appropriate control relay energizes. A normally open contact on the control relay closes and signals the PCA controller (PCAC) that the unit has been started. The PCAC then energizes

the VFD relay, which tells the VFD to start the blower motor. When the blower starts, the auxiliary contact on VFD opens and tells the PCAC that the blower is running. When the VFD relay is energized, the NO contact closes and power is provided to the rest of the control circuit. The PCAC will start the compressors or heaters as required.

3. On system start-up, the VFD slowly starts the blower motor. This prevents power surges and hose snap.

B. PRODUCT DATA SHEET 2 - Fault Shut-Down:

1. The unit will initiate a "FAULT" (the red light on the "Stop" button) and shut the unit down for the following "out of normal" conditions.
2. The power monitor has tripped due to a phase reversal, voltage unbalance, low voltage, or loss of a phase.
3. The blower motor VFD overload has tripped.
4. The smoke detector has tripped.
5. Pushing the "Stop" button will reset the fault. Other components can stop operating without stopping the unit. Reasons include:
6. The condenser fans will shut down and fail to restart when the condenser fan motor overload trips.
7. Any of the compressors will shut down and not restart when the compressor motor overload trips. The compressors will shut down and restart automatically when the low suction pressure sensor trips or the high discharge pressure sensor trips.
8. The high pressure switch is manual reset. Push the reset button on the pressure switch to reset.

C. PRODUCT DATA SHEET 3 - Control Software - Data Base

1. The PCA controller will automatically select the appropriate operational mode based on the ambient temperature.
2. The unit is controlled by the discharge temperature set point.
3. Several stages of cooling are provided. Modulation in cooling mode is obtained by cycling the compressors and controlled with hot gas by-pass.
4. If for any reason the discharge sensor becomes unreadable or unstable, the PCA controller will determine the sensor reading to be invalid and shutdown the unit. The unit will not restart until the sensor is repaired. The maintenance required light will turn on.
5. If the ambient sensor becomes unreadable or unstable, the PCA controller will determine the sensor reading to be invalid and it will default to 53 degrees F, (Vent mode) where the blower will run but no compressors or heaters will turn on.
6. If the aircraft cabin sensor becomes unreadable or unstable, the PCA controller will determine the sensor reading to be invalid and it will default to 90 degrees F in the cooling mode or 60 degrees F in the heating mode. The maintenance required light will turn on. This will allow the unit to operate normally but will be in the full cool or heat mode.

D. PRODUCT DATA SHEET 4 - Control Logic

1. The PCAC status changes to "On" when the start push button is energized. The program then provides a signal to the blower output point, the compressor output points, and the condenser fan output point.
2. There is a five-second delay between each component start-up to prevent high current in-rush.
3. The discharge air temperature sensor reduces the capacity when the discharge air temperature drops below 32 degrees F (0 degrees C).
4. The condenser fans runs whenever the unit is on. The second condenser fan will cycle on the high pressure. The fan will come on at 400 psig, and off at 300 psig.
5. The VFD starts the blower motor slowly to provide a soft start preventing hose snap and high power inrush.
6. The compressors have a three-minute off delay to prevent rapid cycling of the compressors.

1.8 SCHEDULE 3 - PRECONDITIONED AIR SYSTEM CONTROL

- A. PRODUCT DATA SHEET 1 - The PCA system shall be controlled by a LonMark Certified direct digital control system, which shall monitor and control the use of the PCA system and communicate directly with the BAS. Upon failure of the automatic control system described below, the PCA system shall be operable manually through a Manual/Automatic Switch and position switches located inside each gate control unit (defined below).
- B. PRODUCT DATA SHEET 2 - Provide a digital data acquisition network to interactively communicate with the gate PCA equipment, and a central DDC system. The Contractor shall be totally responsible for the detailed design, supply, delivery, installation, test, and training of personnel for the control system.
- C. PRODUCT DATA SHEET 3 - This network shall serve all aircraft gates at the concourse of installation and additionally serve the system as a whole. A concourse specific central control and display system shall be installed in each PCA concourse mechanical equipment room. The concourse specific central control and display system (computer) shall allow control for the respective concourse it serves only. A central monitoring and display system (computer) shall be located in the building/terminal central mechanical plant and shall have the capability to monitoring any of the individual concourse plants. Each concourse system shall be expandable up to 50 gates with no changes to the control system hardware.
- D. PRODUCT DATA SHEET 4 - The PCA control system shall consist of the following four major functional elements:
 1. A Gate Control Unit (GCU) installed at each passenger loading bridge. This unit shall provide all necessary interfaces between the ground handling personnel and the central control system. It shall also provide monitoring and selective control functions of gate ground support activity.
 2. A Data Acquisition System (DAS), which provides two way data/control transmission between all gate control units and the central control unit. It shall also provide one way data transmission (digital input) between the 400 Hz

- frequency converters, gate boxes, and the central control unit.
3. A Building Automation System (BAS), which receives all data from, and passes information/control to, the gates via the DAS. The BAS shall store all gate and other defined data. The BAS shall provide selected control or status signals to the gate control units as pre programmed or per manual input.
 4. Provide battery backup for all memory devices.
- E. PRODUCT DATA SHEET 5 - A GCU shall be installed at each gate. The GCU unit shall have as a minimum, the following functions and features:
1. Monitoring of Aircraft: Each GCU shall automatically sense parked aircraft status to its associated passenger loading bridge.
 2. Switch shall be located adjacent to AHU on/off control.
 3. The switch shall be interlocked with the bridge so that a status light in the console of the bridge indicates PCA use.
 4. Monitoring and stand-alone control of Preconditioned Air (PCA) System: Each GCU shall perform the automatic monitoring and control of the gate's PCA to the aircraft as described in the points lists at the end of this section. Refer to Section 15955 for additional unit controller requirements.
 5. The GCU shall contain a weatherproof control panel to be interfaced by the ground crew operator. The control panel shall have the following features and may be mounted on the AHU:
 6. Manual/Automatic switch (located inside GCU).
 7. Manual position switches for positioning of glycol valve and air damper (locate inside GCU).
 8. Lighted "PCA Disabled."
 9. Lighted "400 Hz Disabled."
 10. The GCU shall contain a wireless transceiver interface to the DAS and thus to the BAS to supply and receive data.
 11. The GCU shall contain in addition to the above defined interfaces and control panel, the required circuitry, power supplies, and other components necessary to perform the functional operation described below:
 12. The GCU shall continuously scan the status of the PCA status described above and light the summary fault light(s) on its control panel and pass the data on to the DAS. The GCU shall also scan the inputs from the DAS (originating in the BAS).
 13. The BAS shall accept data/control transmission from the DAS, associated with each 400 hertz frequency converter. Points are to be annunciated at the BAS screens.
- F. PRODUCT DATA SHEET 6 - The Data Acquisition System (DAS) shall provide two way data/control transmission between all GCU's and the BAS and shall accept digital inputs from the 400 hertz frequency converter's controls. Refer to other Division 23 Controls Sections for router requirements.
- G. PRODUCT DATA SHEET 7 - The major functional components of the Building Automation System (BAS) are defined in other Division 23 Controls Sections.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace preconditioned air sequence of operation system that fails in materials or workmanship within specified warranty period.
1. Warranty Period: Minimum **[two (2)] [five (5)] <Insert number>** years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Honeywell, Inc.
 2. Johnson Controls, Inc.
 3. Siemens Corp.
 4. **<Insert manufacturer's name>**.

2.2 EQUIPMENT

- A. Provide a fully programmable LonMark Certified microprocessor control system (direct digital control) inclusive of sensing and measuring devices for each concourse.
- B. Software shall be user configurable with a complete library of energy management, measuring, control, reporting, alarming, and color graphic programs.
- C. Each concourse shall operate independently; however, all concourses shall communicate directly with the building BAS. Refer to Section **<Insert section number and name>**

2.3 HYDRONIC PC AIR UNIT POINTS LIST

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Software Point
PC Air Unit	X						
Supply Fan Start-Stop and Status		X					
Supply Fan Status			X				
Supply Fan Runtime							X

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Software Point
Outdoor Air Temp					X		
Discharge Air Temp					X		
Cabin Temp					X		
Cooling Setpoint				X			
Heating Setpoint				X			
Heating Stage 1		X					
Heating Stage 2		X					
Cooling Coil				X			
Control Valve							
Damper Position or VFD				X			
On/Off/Auto Mode			X				
Duct Smoke Detectors (as required)			X				
Plenum		X				X	
Overtemp Alarm							
Blower Overload (on dampered units only)			X			X	
Coil Entering Temp					X		
Coil Leaving Temp					X		
Coil Flow					X		
Defrost Mode		X					
400 Hz ON/OFF Status		X					
400 Hz Fault		X					

2.4 DC PC AIR UNIT POINTS LIST

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Software Point
PC Air Unit	X						
Supply Fan Start-Stop and Status		X	X			X	
Outdoor Air Temp					X		
Discharge Air Temp					X		
Cabin Temp					X		

	System Graphic	Digital Output	Digital Input	Analog Output	Analog Input	Alarm Point	Software Point
Heating Stage 1				X			
Heating Stage 2				X			
Compressor Status (each)						X	
Condenser Fan Status (each)						X	
Damper Position			X	X		X	
Duct Smoke Detectors (as required)			X				
Condenser Fan Status (each)						X	
Aircraft Size (each)					X		
Alarm Heat 1 (as required)		X				X	
Maintenance Alarm		X				X	
400 Hz ON/OFF Status		X					
400 Hz Fault		X					

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine areas and conditions under which electric control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to Installer.

3.2 INSTALLATION GENERAL

- A. Field check for clearances and interferences before fabrication.
- B. Furnish all labor, tools, and all other materials necessary to make a complete installation of the material and equipment specified and indicated.
- C. Installation shall equal or exceed the minimum requirements of the applicable codes and these specifications; however, where local codes and ordinances are more stringent, they shall govern.
- D. Include all material, labor, and changes occasioned by the Contractor's choice of equipment.

3.3 INSTALLATION OF SYSTEMS

- A. General: Install systems and materials in accordance with manufacturer's instructions.
- B. Furnish all the necessary components so that the system performs as specified.
- C. Completely adjust and test the systems specified to ensure that they perform satisfactorily.

3.4 STARTUP AND DEMONSTRATION

- A. Start Up: Start up, test, and adjust systems in presence of Owner's Representative. Demonstrate compliance with requirements.
- B. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain systems.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **236619**

SECTION 237200 - AIR-TO-AIR ENERGY RECOVERY EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Heat wheels.
 - 2. Heat-pipe heat exchangers.
 - 3. Fixed-plate sensible heat exchangers.
 - 4. Fixed-plate total heat exchangers.
 - 5. Packaged energy recovery units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Seismic Performance: Air-to-air energy recovery equipment shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **and the unit will be fully operational after the seismic event**."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, furnished specialties, and accessories. Provide data with dimensions, locations, and size of tappings and performance data.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For air-to-air energy recovery equipment. Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring Diagrams: For power, signal, and control wiring.
 3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
 4. Test Reports: Indicate tube bundle pressure tests.
- D. Delegated-Design Submittal: For air-to-air energy recovery equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Detail fabrication and assembly of air-to-air energy recovery equipment.
 2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 3. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
1. Suspended ceiling components.
 2. Structural members to which equipment or suspension systems will be attached.
- B. Seismic Qualification Certificates: For air-to-air energy recovery equipment, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

C. Certificates: Certify that **[Products]** <Insert item> meet or exceed **[specified requirements.]**

D. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-to-air energy recovery equipment to include in maintenance manuals.

1. Include start up and shut down instructions, assembly drawings, and spare parts lists.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Filters: **[One (1)]** <Insert number> set(s) of each type of filter specified.
2. Fan Belts: **[One (1)]** <Insert number> set(s) of belts for each belt-driven fan in energy recovery units.
3. Wheel Belts: **[One (1)]** <Insert number> set(s) of belts for each heat wheel.

1.8 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ARI Compliance:

1. Capacity ratings for air-to-air energy recovery equipment shall comply with ARI 1060, "Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment."
2. Capacity ratings for air coils shall comply with ARI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils."

C. ASHRAE Compliance:

1. Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
2. Capacity ratings for air-to-air energy recovery equipment shall comply with ASHRAE 84, "Method of Testing Air-to-Air Heat Exchangers."

- D. NRCA Compliance: Roof curbs for roof-mounted equipment shall be constructed according to recommendations of NRCA.
- E. UL Compliance:
 - 1. Packaged heat recovery ventilators shall comply with requirements in UL 1812, "Ducted Heat Recovery Ventilators"; or UL 1815, "Nonducted Heat Recovery Ventilators."
 - 2. Electric coils shall comply with requirements in UL 1995, "Heating and Cooling Equipment."

1.9 COORDINATION

- A. Coordinate layout and installation of air-to-air energy recovery equipment and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Protect internals from entry of foreign material by temporary caps on flanged openings.

1.11 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air-to-air energy recovery equipment that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Packaged Energy Recovery Units: Minimum [**two (2)**] **<Insert number>** years.
 - 2. Warranty Period for Fixed-Plate Total Heat Exchangers: Minimum [**ten (10)**] **<Insert number>** years.
 - 3. **<Insert components requiring extended warranty>**.
- B. CONSTRUCTION WASTE MANAGEMENT
- C. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 HEAT WHEELS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Advanced Thermal Technologies.](#)
 2. [Airxchange Inc.](#)
 3. [American Energy Exchange, Inc.](#)
 4. [Loren Cook Company.](#)
 5. [SEMCO Incorporated.](#)
 6. [Trane; American Standard Companies, Inc.](#)
 7. **<Insert manufacturer's name>.**
 8. or approved equal.
- B. Casing:
1. Steel with standard factory-painted finish.
 2. Integral purge section limiting carryover of exhaust air to between **[0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg (0.05 percent at 400-Pa and 0.20 percent at 1000-Pa)] <Insert value>** differential pressure.
 3. Casing seals on periphery of rotor and on duct divider and purge section.
 4. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings[**or permanently lubricated bearings**]. Support horizontal rotors on tapered roller bearing.
- C. Rotor: Aluminum segmented wheel strengthened with radial spokes[, **with nontoxic, noncorrosive, silica-gel desiccant coating**].
1. Maximum Solid Size for Media to Pass: **[500] [800] [1200]** micrometer.
- D. Rotor: **[Glass-fiber] [Polymer]** segmented wheel strengthened with radial spokes impregnated with nonmigrating, water-selective, molecular-sieve desiccant coating.
1. Maximum Solid Size for Media to Pass: **[800] [1200]** micrometer.
- E. Drive: Fractional horsepower motor and gear reducer[, **with speed changed by variable frequency controller**] and self-adjusting multilink belt around outside of rotor.
1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- F. Controls:

1. Starting relay, factory mounted and wired, and manual motor starter for field wiring.
2. Variable frequency controller, factory mounted and wired, permitting input of field connected 4-20 mA or 1-10-V control signal.
3. Variable frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
4. Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain[**exhaust temperature above freezing and**] air differential temperature above set point. Rotor speed shall increase to maximum when exhaust-air temperature is less than outdoor-air temperature.
5. Pilot-Light Indicator: Display rotor rotation and speed.
6. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.

G. Disposable Panel Filters:

1. Comply with NFPA 90A.
2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
3. Factory-fabricated, viscous-coated, flat-panel type.
4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
5. Dust-Holding Capacity: <Insert lb (kg)>.
6. Initial Resistance: <Insert inches wg (Pa)>.
7. Recommended Final Resistance: <Insert inches wg (Pa)>.
8. Minimum Arrestance: [80] <Insert value>, according to ASHRAE 52.1.
9. MERV: [5] <Insert value>, according to ASHRAE 52.2.
10. Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
11. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.

H. Extended-Surface, Disposable Panel Filters:

1. Comply with NFPA 90A.
2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
3. Factory-fabricated, dry, extended-surface type.
4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
5. Dust-Holding Capacity: <Insert lb (kg)>.
6. Initial Resistance: <Insert inches wg (Pa)>.
7. Recommended Final Resistance: <Insert inches wg (Pa)>.
8. Minimum Arrestance: [90] <Insert value>, according to ASHRAE 52.1.
9. MERV: [7] <Insert value>, according to ASHRAE 52.2.
10. Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
11. Media-Grid Frame: [Nonflammable cardboard] [Galvanized steel] [Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets].

12. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

I. Extended-Surface, Nonsupported-Media Filters:

1. Comply with NFPA 90A.
2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
3. Factory-fabricated, dry, extended-surface, self-supporting type.
4. Dust-Holding Capacity: <Insert lb (kg)>.
5. Initial Resistance: <Insert inches wg (Pa)>.
6. Recommended Final Resistance: <Insert inches wg (Pa)>.
7. Minimum Arrestance: **[95]** <Insert value>, according to ASHRAE 52.1.
8. MERV: **[13]** <Insert value>, according to ASHRAE 52.2.
9. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions[**and antimicrobial agent**].
10. Filter-Media Frame: **[Galvanized steel]** **[Hard polyurethane foam]**.
11. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks[**with space for prefilter**].

2.2 HEAT-PIPE HEAT EXCHANGERS

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Applied Air; Mestek Technology, Inc.](#)
2. [Des Champs Technologies.](#)
3. [Engineered Air.](#)
4. [Gaylord Industries, Inc.](#)
5. [Heat Pipe Technology, Inc.](#)
6. <Insert manufacturer's name>.
7. or approved equal.

B. Casing: Galvanized-steel flanged casing, with airtight partition between airstreams.

C. Refrigerant: ASHRAE 15, Group 1. <Insert requirements>.

D. Tubes: **[5/8-inch- (16-mm-)]** **[1-inch- (25-mm-)]** diameter, **[aluminum]** **[copper]** <Insert material>.

E. Fins: **[Aluminum]** **[Integral aluminum]** **[Copper]**.

1. Fin Spacing: **[0.125 inch (3.18 mm)]** **[0.091 inch (2.31 mm)]** **[0.071 inch (1.80 mm)]** **[0.067 inch (1.70 mm)]** **[0.056 inch (1.42 mm)]** **[0.0075 inch (0.19 mm)]** <Insert fins per inch (mm)>.
2. Fin and Tube Joint: **[Mechanical bond]** **[Silver brazed]**.

- F. Coating: **[Thermoplastic vinyl] [Epoxy] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] <Insert coating>**; apply to supply and exhaust.
- G. Control: Integral plenum containing heat-pipe coil and gasketed, face-and-bypass, opposed-blade dampers with rods extended outside casing for damper operator and linkage.
- H. Control: Pivot center of bottom of heat-pipe coil on shaft and bearings to tilt coil. Include tilt controls with electronic controller, electric actuator and linkage, thermostats, sensors, and polyester fabric with PVC-coated flexible connector for automatic supply temperature regulation, summer/winter changeover, and frost protection.

2.3 FIXED-PLATE SENSIBLE HEAT EXCHANGERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [American Energy Exchange, Inc.](#)
 - 2. [Des Champs Technologies.](#)
 - 3. [Eclipse Innovative Thermal Technologies.](#)
 - 4. [Nutech Brands Inc.](#)
 - 5. [RenewAire LLC.](#)
 - 6. [UAS, Inc.: a CLARCOR company.](#)
 - 7. **<Insert manufacturer's name>**.
 - 8. or approved equal.
- B. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- C. Casing: **[Aluminum] [Galvanized steel] [Enameled steel, with galvanized-steel liner] [Enameled steel]** with duct collars.
- D. Casing Insulation: **[1/2-inch- (13-mm-) thick, foil-faced glass fiber] [1-inch- (25-mm-) thick, foil-faced glass fiber] [1 inch (25 mm) thick, ASTM C 1071 with coated surface] [1 inch (25 mm) thick, fiber free]**.
- E. Drain Pan: **[Same material as casing, with drain connections on exhaust and supply side] [Molded ABS covering bottom of case, with drain connections on exhaust and supply side]**.
 - 1. Comply with requirements in ASHRAE 62.1.
- F. Plates: Evenly spaced and sealed and arranged for counter airflow.
 - 1. Plate Material: **[Embossed aluminum] [Stainless steel] [Polypropylene copolymer (high-density plastic)]**.
 - 2. Plate Coating: **[Epoxy] [Air-dried phenolic]**.

- G. Bypass Plenum: Within casing, with gasketed face-and-bypass dampers having operating rods extended outside casing.
- H. Water Wash: Automatic system, with spray manifold to individual spray tubes or traversing type with stainless-steel-screw operating mechanism and electric motor drive; activated by time clock[, **with detergent injection**].
- I. Disposable Panel Filters:
1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, viscous-coated, flat-panel type.
 4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
 5. Initial Resistance: <Insert inches wg (Pa)>.
 6. Recommended Final Resistance: <Insert inches wg (Pa)>.
 7. Minimum Arrestance: [80] <Insert value>, according to ASHRAE 52.1.
 8. MERV: [5] <Insert value>, according to ASHRAE 52.2.
 9. Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
 10. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.
- J. Extended-Surface, Disposable Panel Filters:
1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, dry, extended-surface type.
 4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
 5. Initial Resistance: <Insert inches wg (Pa)>.
 6. Recommended Final Resistance: <Insert inches wg (Pa)>.
 7. Minimum Arrestance: [90] <Insert value>, according to ASHRAE 52.1.
 8. MERV: [7] <Insert value>, according to ASHRAE 52.2.
 9. Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
 10. Media-Grid Frame: [Nonflammable cardboard] [Galvanized steel] [Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets].
 11. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.
- K. Extended-Surface, Nonsupported-Media Filters:
1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, dry, extended-surface, self-supporting type.

4. Initial Resistance: <Insert inches wg (Pa)>.
5. Recommended Final Resistance: <Insert inches wg (Pa)>.
6. Minimum Arrestance: [95] <Insert value>, according to ASHRAE 52.1.
7. MERV: [13] <Insert value>, according to ASHRAE 52.2.
8. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions[**and antimicrobial agent**].
9. Filter-Media Frame: [Galvanized steel] [Hard polyurethane foam].
10. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks[**with space for prefilter**].

2.4 FIXED-PLATE TOTAL HEAT EXCHANGERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Mitsubishi Electric Sales Canada Inc.](#)
 2. [RenewAire LLC.](#)
 3. <Insert manufacturer's name>.
 4. or approved equal.
- B. Casing: Galvanized steel.
- C. Plates: Evenly spaced and sealed and arranged for counter airflow.
1. Plate Material: Chemically treated paper with selective hydroscopicity and moisture permeability, and gas barrier properties.
- D. Bypass Plenum: Within casing, with gasketed face-and-bypass dampers having operating rods extended outside casing.
- E. Disposable Panel Filters:
1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, viscous-coated, flat-panel type.
 4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
 5. Initial Resistance: <Insert inches wg (Pa)>.
 6. Recommended Final Resistance: <Insert inches wg (Pa)>.
 7. Minimum Arrestance: [80] <Insert value>, according to ASHRAE 52.1.
 8. MERV: [5] <Insert value>, according to ASHRAE 52.2.
 9. Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
 10. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.
- F. Extended-Surface, Disposable Panel Filters:

1. Comply with NFPA 90A.
2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
3. Factory-fabricated, dry, extended-surface type.
4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
5. Initial Resistance: <Insert inches wg (Pa)>.
6. Recommended Final Resistance: <Insert inches wg (Pa)>.
7. Minimum Arrestance: [90] <Insert value>, according to ASHRAE 52.1.
8. MERV: [7] <Insert value>, according to ASHRAE 52.2.
9. Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
10. Media-Grid Frame: [**Nonflammable cardboard**] [**Galvanized steel**] [**Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets**].
11. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

2.5 PACKAGED ENERGY RECOVERY UNITS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Advanced Thermal Technologies.](#)
2. [American Energy Exchange, Inc.](#)
3. [Applied Air; Mestek Technology, Inc.](#)
4. [Carnes Company.](#)
5. [Des Champs Technologies.](#)
6. [Engineered Air.](#)
7. [Fairchild Industrial Products Company.](#)
8. [Gaylord Industries, Inc.](#)
9. [Greenheck Fan Corporation.](#)
10. [Loren Cook Company.](#)
11. [Mitsubishi Electric & Electronics USA, Inc.](#)
12. [Mitsubishi Electric Sales Canada Inc.](#)
13. [RenewAire LLC.](#)
14. [SEMCO Incorporated.](#)
15. [Trane; American Standard Companies, Inc.](#)
16. [Venmar CES Inc.](#)
17. [Wing, L. J.; Mestek Technology, Inc.](#)
18. <Insert manufacturer's name>.
19. or approved equal.

- B. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

- C. Housing: Manufacturer's standard construction with corrosion-protection coating and exterior finish, [**gasketed and calked weathertight,**] [**hinged access doors**] [**removable panels**] with neoprene gaskets for inspection and access to internal parts, minimum [1-inch- (25-mm-)] [2-inch- (50-mm-)] <Insert thickness> thick thermal

insulation, knockouts for electrical and piping connections, exterior drain connection, and lifting lugs.

1. Inlet: Weatherproof **[hood]** **[louver]**, with damper for exhaust and supply.
 - a. Exhaust: **[Gravity backdraft damper]** **[Spring-return, two-position, motor-operated damper]**.
 - b. Supply: **[Gravity backdraft damper]** **[Spring-return, two-position, motor-operated damper]**.
 2. Roof Curb: Refer to Section 077200 "Roof Accessories" for roof curbs and equipment supports.
- D. Heat Recovery Device: **[Heat wheel]** **[Heat-pipe heat exchanger]** **[Fixed-plate heat exchanger]**.
- E. Supply and Exhaust Fans: **[Forward-curved, centrifugal]** **[Propeller]** **[Backward-inclined, SWSI centrifugal]** **[Backward-inclined, plenum centrifugal]** fan with **[spring isolators]** **[restrained, spring isolators]** **[spring hangers]** **[spring hangers with vertical-limit stops]** **[and]** **[insulated]** flexible duct connections.- 1. Motor and Drive: **[Direct driven]** **[Belt driven with adjustable sheaves, motor mounted on adjustable base]** **[Drive type indicated on Drawings]**.
- 2. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- 3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- 4. Spring isolators on each fan having **[1-inch (25-mm)]** **<Insert deflection>** static deflection.

F. Disposable Panel Filters:

 1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, viscous-coated, flat-panel type.
 4. Thickness: **[1 inch (25 mm)]** **[2 inches (50 mm)]**.
 5. Initial Resistance: **<Insert inches wg (Pa)>**.
 6. Recommended Final Resistance: **<Insert inches wg (Pa)>**.
 7. Minimum Arrestance: **[80]** **<Insert value>**, according to ASHRAE 52.1.
 8. MERV: **[5]** **<Insert value>**, according to ASHRAE 52.2.
 9. Media: Interlaced glass fibers sprayed with nonflammable adhesive **[and antimicrobial agent]**.
 10. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.

G. Extended-Surface, Disposable Panel Filters:

1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, dry, extended-surface type.
 4. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
 5. Initial Resistance: <Insert inches wg (Pa)>.
 6. Recommended Final Resistance: <Insert inches wg (Pa)>.
 7. Minimum Arrestance: [90] <Insert value>, according to ASHRAE 52.1.
 8. MERV: [7] <Insert value>, according to ASHRAE 52.2.
 9. Media: Fibrous material formed into deep-V-shaped pleats[with antimicrobial agent] and held by self-supporting wire grid.
 10. Media-Grid Frame: [Nonflammable cardboard] [Galvanized steel] [Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets].
 11. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.
- H. Extended-Surface, Nonsupported-Media Filters:
1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, dry, extended-surface, self-supporting type.
 4. Initial Resistance: <Insert inches wg (Pa)>.
 5. Recommended Final Resistance: <Insert inches wg (Pa)>.
 6. Minimum Arrestance: [95] <Insert value>, according to ASHRAE 52.1.
 7. MERV: [13] <Insert value>, according to ASHRAE 52.2.
 8. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions[and antimicrobial agent].
 9. Filter-Media Frame: [Galvanized steel] [Hard polyurethane foam].
 10. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks[with space for prefilter].
- I. Cooling Coils: Rated according to ARI 410 and ASHRAE 33[, and bearing the ARI label].
1. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service and maintenance of coil(s).
 2. Casing: [Manufacturer's standard material] [Aluminum] [Galvanized steel] [Stainless steel] <Insert material>.
 3. Tubes: [Copper] <Insert material>.
 4. Tube Headers: [Manufacturer's standard material] [Copper] [Carbon steel] [Red brass] <Insert material>.
 5. Fins: [Aluminum] [Copper] <Insert material>.
 6. Fin and Tube Joint: Mechanical bond.
 7. Leak Test: Coils shall be leak tested with air under water.
 8. Refrigerant Coils:

- a. Capacity Reduction: Circuit coils for **[face] [row] [interleaved]** control.
 - b. Suction and Distributor: Seamless copper tube with brazed joints.
9. Coating: Phenolic epoxy corrosion-protection coating after assembly.
- J. Cooling-Coil Condensate Drain Pans:
1. Fabricated from **[galvanized] [stainless]**-steel sheet and sloped in multiple planes to collect and drain condensate from cooling coils, coil piping connections, coil headers, and return bends.
 2. Complying with requirements in ASHRAE 62.1.
 3. Drain Connections: At low point of pan with minimum **<Insert size>** threaded nipple.
 4. Units with stacked coils shall have an intermediate drain pan to collect and drain condensate from top coil.
- K. Hot-Water Coils: Rated according to ARI 410 and ASHRAE 33[, **and bearing the ARI label**].
1. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service and maintenance of coil(s).
 2. Casing: **[Manufacturer's standard material] [Aluminum] [Galvanized steel] [Stainless steel] <Insert material>**.
 3. Tubes: **[Copper] <Insert material>**.
 4. Tube Headers: **[Manufacturer's standard material] [Copper] [Carbon steel] [Red brass] <Insert material>**.
 5. Fins: **[Aluminum] [Copper] <Insert material>**.
 6. Fin and Tube Joint: Mechanical bond.
 7. Leak Test: Coils shall be leak tested with air under water.
 8. Coating: Phenolic epoxy corrosion-protection coating after assembly.
- L. **[Nonfreeze Type]** Steam Coils: Rated according to ARI 410 and ASHRAE 33[, **and bearing the ARI label**].
1. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service and maintenance of coil(s).
 2. Casing: **[Manufacturer's standard material] [Aluminum] [Galvanized steel] [Stainless steel] <Insert material>**.
 3. Tubes: **[Copper] <Insert material>**.
 4. Tube Headers: **[Manufacturer's standard material] [Copper] [Carbon steel] [Red brass] <Insert material>**.
 5. Fins: **[Aluminum] [Copper] <Insert material>**.
 6. Fin and Tube Joint: Mechanical bond.
 7. Leak Test: Coils shall be leak tested with air under water.
 8. Coating: Phenolic epoxy corrosion-protection coating after assembly.
- M. Electrical Coils, Controls, and Accessories: Comply with UL 1995.
1. Casing Assembly: **[Slip-in] [Flanged]** type with galvanized-steel frame.

2. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service.
3. Sheathed Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
4. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
5. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
6. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
7. Control Panel: **[Unit]** **[Remote]** mounted with disconnecting means and overcurrent protection.
 - a. **[Magnetic]** **[Mercury]** contactor.
 - b. Solid-state, stepless pulse controller.
 - c. Toggle switches, one per step.
 - d. Step controller.
 - e. Time-delay relay.
 - f. Pilot lights, one per step.
 - g. Airflow proving switch.

N. Indirect-Fired Gas Furnaces:

1. Description: Factory assembled, piped, and wired; complying with NFPA 54, "National Fuel Gas Code," and ANSI Z21.47, "Gas-Fired Central Furnaces."
 - a. AGA Approval: Furnace shall bear label of AGA.
2. Burners: **[Aluminized steel with stainless-steel inserts]** **[Stainless steel]**.
 - a. Ignition: Electronically controlled electric spark with flame sensor.
 - b. High-Altitude **[Model]** **[Kit]**: For Project at elevations more than 2000 feet (610 m) above sea level.
3. Heat-Exchanger Drain Pan: Stainless steel.
4. Venting: Gravity vented.
5. Power Vent: Integral, motorized centrifugal fan interlocked with gas valve.
6. Gas Control Valve: **[Single stage]** **[Two stage]** **[Electronic modulating]**.
7. Gas Train: Single-body, regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff. Control devices and control sequence shall comply with requirements of **[FMG]** **[IRI]** **<Insert agency>**.
8. Access: Fabricate section to allow removal and replacement of furnace and to allow in-place access for service.

- O. Piping and Wiring: Fabricate units with space within housing for piping and electrical conduits. Wire motors and controls so only external connections are required during installation.
1. Indoor Enclosure: NEMA 250, Type 12 enclosure contains relays, starters, and terminal strip.
 2. Outdoor Enclosure: NEMA 250, Type 3R enclosure contains relays, starters, and terminal strip.
 3. Include **[fused]** **[nonfused]** disconnect switches.
 4. Variable-speed controller to vary fan capacity from 100 to approximately **[50]** **<Insert number>** percent.
- P. Accessories:
1. Roof Curb: **[Steel]** **[Galvanized steel]** **[Aluminum]** with gasketing, and factory-installed wood nailer; complying with NRCA standards; minimum height of **[14 inches (350 mm)]** **[24 inches (600 mm)]** **<Insert height>**.
 2. Intake weather hood with **2-inch-** (50-mm-) thick filters.
 3. Louvered intake weather hood with **2-inch-** (50-mm-) thick filters in V-bank configuration.
 4. Exhaust weather hood with birdscreen.
 5. Low-Leakage, Isolation Dampers: Double-skin, airfoil-blade, **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** dampers with compressible jamb seals and extruded-vinyl blade edge seals, in **[opposed]** **[parallel]**-blade arrangement with **[cadmium-plated]** steel operating rods rotating in **[stainless-steel sleeve]** **[sintered bronze or nylon]** bearings mounted in a single **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** frame, with operating rods connected with a common linkage, and electric damper operator factory wired. Leakage rate shall not exceed **5 cfm/sq. ft.** (0.22 L/s per sq. m) at **1-inch wg** (250 Pa) and **9 cfm/sq. ft.** (0.4 L/s per sq. m) at **4-inch wg** (1.0 MPa).
 6. Isolation Dampers: Opposed-blade, **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** dampers with **[cadmium-plated]** steel operating rods rotating in sintered bronze or nylon bearings mounted in a single **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** frame with operating rods connected with a common linkage, and electric damper operator factory wired. Blades shall have gaskets and edge seals, and shall be mechanically fastened to operating rod.
 7. Duct flanges.
 8. Rubber-in-shear isolators for ceiling-mounted units.
 9. Hinged access doors with quarter-turn latches.
 10. Drain pans for condensate removal **[complying with ASHRAE 62.1]**.
 11. Automatic, in-place, spray-wash system.
 12. Weatherproofing for tilt-control system.

2.6 CONTROLS

- A. Time Clock: Solid-state, programmable, microprocessor-based unit for **[wall mounting]** **[mounting in outdoor NEMA 250, Type 3R enclosure]** with up to eight

on/off cycles per day and battery backup protection of program settings against power failure to energize unit.

- B. Motion (Occupancy) Sensor: Passive infrared sensor for **[wall]** **[ceiling]** mounting with adjustable time-off delay of up to 30 minutes to energize unit.
- C. Carbon Monoxide Sensor: Adjustable control from 600 to 2000 ppm for **[wall]** **[duct]** mounting with digital display and computer/building management system interface to energize unit.
- D. Humidistat: Adjustable, wall-mounted instrument to energize unit when space relative humidity exceeds **[50 percent]** **<Insert relative humidity>**.
- E. Chilled-Water-Cooling-Coils Controls:
1. **[Factory-mounted sensor in unit discharge]** **[Remote-mounted sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to modulate factory-**[mounted]** **[furnished]** coil-control valve to maintain temperature.
 2. Wall-mounted, space-temperature sensor with **[temperature adjustment]** **[unit-mounted temperature adjustment]** **[adjustment on remote-control panel]** to modulate factory-**[mounted]** **[furnished]** coil-control valve to maintain temperature.
- F. Refrigerant-Cooling-Coils Controls:
1. **[Factory-mounted sensor in unit discharge]** **[Remote-mounted sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to control remote condensing unit to maintain temperature.
 2. Wall-mounted, space-temperature sensor with **[temperature adjustment]** **[unit-mounted temperature adjustment]** **[adjustment on remote-control panel]** controls remote condensing unit to maintain temperature.
 3. Cooling Capacity Control: **[On/off]** **[Multiple steps]** **<Insert type>**.
- G. **[Hot-Water-]** **[and]** **[Steam-]**Coils Controls:
1. **[Factory-mounted sensor in unit discharge]** **[Remote-mounted sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to modulate factory-**[mounted]** **[furnished]** coil-control valve to maintain temperature.
 2. Wall-mounted, space-temperature sensor with **[temperature adjustment]** **[unit-mounted temperature adjustment]** **[adjustment on remote-control panel]** to modulate factory-**[mounted]** **[furnished]** coil-control valve to maintain temperature.
- H. Electric-Coils Controls:
1. **[Factory-mounted sensor in unit discharge]** **[Remote-mounted sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to control electric coil to maintain temperature.

2. Wall-mounted, space-temperature sensor with **[temperature adjustment]** **[unit-mounted temperature adjustment]** **[adjustment on remote-control panel]** to control electric coil to maintain temperature.
3. Coil Controls: **[On/off]** **[Multiple steps]** **[Modulating SCR]** **<Insert type>**.

I. Indirect-Fired-Gas-Furnaces Controls:

1. **[Factory-mounted sensor in unit discharge]** **[Remote-mounted sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to control gas furnace burner to maintain temperature.
2. Wall-mounted, space-temperature sensor with **[temperature adjustment]** **[unit-mounted temperature adjustment]** **[adjustment on remote-control panel]** to control gas furnace burner to maintain temperature.
3. Burner Controls: **[On/off]** **[Multiple steps]** **[Modulating]** **<Insert type>**.

2.7 CAPACITIES AND CHARACTERISTICS

A. Exhaust Air:

1. Airflow: **<Insert cfm (L/s)>**.
2. Face Velocity: **<Insert fpm (m/s)>**.
3. Summer:
 - a. Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - b. Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - c. Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - d. Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
4. Winter:
 - a. Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - b. Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - c. Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - d. Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
5. Air Pressure Drop: **<Insert inches wg (Pa)>**.
6. Fan Motor Size: **<Insert horsepower>**.
7. Fan Motor Electrical Characteristics:
 - a. Volts: **[120] [208] [230] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.

B. Supply Air:

1. Airflow: **<Insert cfm (L/s)>**.
2. Face Velocity: **<Insert fpm (m/s)>**.
3. Summer:
 - a. Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.

- b. Entering-Air Temperature, Wet Bulb: <Insert deg F (deg C)>.
 - c. Leaving-Air Temperature, Dry Bulb: <Insert deg F (deg C)>.
 - d. Leaving-Air Temperature, Wet Bulb: <Insert deg F (deg C)>.
 4. Winter:
 - a. Entering-Air Temperature, Dry Bulb: <Insert deg F (deg C)>.
 - b. Entering-Air Temperature, Wet Bulb: <Insert deg F (deg C)>.
 - c. Leaving-Air Temperature, Dry Bulb: <Insert deg F (deg C)>.
 - d. Leaving-Air Temperature, Wet Bulb: <Insert deg F (deg C)>.
 5. Air Pressure Drop: <Insert inches wg (Pa)>.
 6. Fan Motor Size: <Insert horsepower>.
 7. Fan Motor Electrical Characteristics:
 - a. Volts: [120] [208] [230] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
- C. Wheel Drive:
 1. Motor Size: <Insert horsepower>.
 2. Motor Electrical Characteristics:
 - a. Volts: [120] [208] [230] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
- D. Effectiveness: <Insert percent>.
- E. Cooling Coil:
 1. Fluid: [Chilled water] [Refrigerant] <Insert fluid>.
 2. Sensible Heat-Transfer Rate: <Insert Btu/h (kW)>.
 3. Total Heat-Transfer Rate: <Insert Btu/h (kW)>.
 4. Entering-Air, Dry-Bulb Temperature: <Insert deg F (deg C)>.
 5. Entering-Air, Wet-Bulb Temperature: <Insert deg F (deg C)>.
 6. Leaving-Air, Dry-Bulb Temperature: <Insert deg F (deg C)>.
 7. Leaving-Air, Wet-Bulb Temperature: <Insert deg F (deg C)>.
 8. Face Area: <Insert sq. ft. (sq. m)>.
 9. Maximum Face Velocity: <Insert fpm (m/s)>.
 10. Maximum Air-Side, Static-Pressure Drop: <Insert inches wg (Pa)>.
 11. Coil Type: [Continuous circuit] [Self-draining] [Cleanable].
 12. Piping Connections: [Threaded] [Flanged], [same end] [opposite ends] of coil.
 13. Tube Thickness: <Insert inches (mm)>.
 14. Fin Spacing: <Insert fins per inch (cm)>.
 15. Fin Thickness: <Insert inches (mm)>.
 16. Number of Rows: <Insert number>.
 17. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.

18. Fluid:

- a. Fluid Flow: <Insert gpm (L/s)>.
- b. Maximum Fluid Pressure Drop: <Insert feet of head (kPa)>.
- c. Entering-Fluid Temperature: <Insert deg F (deg C)>.
- d. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
- e. Tube velocity: <Insert fpm (L/s)>.

F. [Hot-Water] [Steam] Coils:

1. Heat-Transfer Rate: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Face Area: <Insert sq. ft. (sq. m)>.
5. Maximum Face Velocity: <Insert fpm (m/s)>.
6. Maximum Air-Side, Static-Pressure Drop: <Insert inches wg (Pa)>.
7. Coil Type: [Continuous circuit] [Self-draining] [Cleanable].
8. Piping Connections: [Threaded] [Flanged], [same end] [opposite ends] of coil.
9. Tube Thickness: <Insert inches (mm)>.
10. Fin Spacing: <Insert fins per inch (cm)>.
11. Fin Thickness: <Insert inches (mm)>.
12. Number of Rows: <Insert number>.
13. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.
14. Fluid:
 - a. Fluid Flow: <Insert gpm (L/s)>.
 - b. Maximum Fluid Pressure Drop: <Insert feet of head (kPa)>.
 - c. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - d. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 - e. Tube velocity: <Insert fpm (L/s)>.

15. Steam Coils:

- a. Heat-Transfer Rate: <Insert Btu/h (kW)>.
- b. Steam Flow: <Insert lb/h (g/s)>.
- c. Inlet Steam Pressure: <Insert psig (kPa)>.
- d. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.

G. Electric Heating Coils:

1. Heat-Transfer Rate: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Power Input: <Insert kilowatts>.
5. Volts: [208] [230] [480] <Insert value>.
6. Phase: [Single] [Three].
7. Hertz: 60.
8. Full-Load Amperes: <Insert value>.

9. Maximum Overcurrent Protection: **<Insert amperage>**.
10. Capacity Control Number of Steps: **<Insert number>**.

H. Indirect-Fired Gas Furnace:

1. Heat-Transfer Rate: **<Insert Btu/h (kW)>**.
2. Entering-Air Temperature: **<Insert deg F (deg C)>**.
3. Leaving-Air Temperature: **<Insert deg F (deg C)>**.
4. Efficiency: **[80] <Insert number>** percent.
5. Fuel: **[Natural] [Propane]** gas.
6. Gas Heating Value: **<Insert Btu/cu. ft. (kJ/L)>**.
7. Gas Input: **<Insert cfh (mL/s)>**.
8. Power Input: **<Insert kilowatts>**.
9. Volts: **[120] [208] [230] [480] <Insert value>**.
10. Phase: **[Single] [Three]**.
11. Hertz: 60.
12. Full-Load Amperes: **<Insert value>**.
13. Minimum Circuit Ampacity: **<Insert value>**.
14. Maximum Overcurrent Protection: **<Insert amperage>**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine casing insulation materials and filter media before air-to-air energy recovery equipment installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for electrical services to verify actual locations of connections before installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Install to permit removal of components with minimum disturbance to installed equipment and piping.
- C. Install heat wheels so supply and exhaust airstreams flow in opposite directions and rotation is away from exhaust side to purge section to supply side.
 1. Install access doors in both supply and exhaust ducts, both upstream and downstream, for access to wheel surfaces, drive motor, and seals.

2. Install removable panels or access doors between supply and exhaust ducts on building side for bypass during startup.
 3. Access doors and panels are specified in Section 233300 "Air Duct Accessories."
- D. Install heat-pipe heat exchangers so supply and exhaust airstreams flow in opposite directions. Install flexible connectors on ducts to enable tilt control; make connections airtight and with slack to compensate for full tilt.
1. Install heat exchanger with clearance space for heat-pipe coil removal.
 2. Install duct access doors in both supply and exhaust ducts, both upstream and downstream, for access to both sides of heat-pipe coil. Access doors and panels are specified in Section 233300 "Air Duct Accessories."
 3. Install tilt-control components, including electronic controller, electric actuator and linkage, thermostats, and sensors.
- E. Install fixed-plate heat exchangers so supply and exhaust airstreams flow in opposite directions.
1. Install duct access doors in both supply and exhaust ducts, both upstream and downstream, for access to heat exchanger. Access doors and panels are specified in Section 233300 "Air Duct Accessories."
- F. Install gas-fired furnaces according to NFPA 54, "National Fuel Gas Code."
- G. Install floor-mounted units on **4-inch- (100-mm-)** high concrete base[**designed to withstand, without damage to equipment, seismic force required by code**].
- H. Equipment Mounting:
1. Install air-to-air energy recovery equipment on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete.]"** **[Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
- I. Roof Curb: Install on roof structure or concrete base, level and secure, according to **[The NRCA "Roofing and Waterproofing Manual - Volume 4: Construction Details - Low-Slope Roofing," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts.]"** **[ARI Guideline B.]** Install air-to-air energy recovery equipment on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 077200 "Roof Accessories." Secure air-to-air energy recovery equipment to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.
- J. Unit Support: Install unit level on structural **[curbs]** **[pilings]**. Coordinate wall penetrations and flashing with wall construction. Secure air-to-air energy recovery equipment to structural support with anchor bolts.
- K. Install wind and seismic restraints according to manufacturers' written instructions.**[Wind and seismically restrained vibration isolation roof-curb rails are specified in Section 230548 "Vibration and Seismic Controls for HVAC."]**

- L. Suspended Units: Suspend[**and brace**] units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- M. Install units with clearances for service and maintenance.
- N. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.
- O. Pipe drains from drain pans to nearest floor drain; use [ASTM B 88, Type L](#) ([ASTM B 88M, Type B](#)), drawn-temper copper water tubing with soldered joints, same size as condensate drain connection.
- P. Pipe drains from drain pans to nearest floor drain; use ASTM D 1785, Schedule 40 PVC pipe and solvent-welded fittings, same size as condensate drain connection.
 - 1. Requirements for Low-Emitting Materials:
 - a. PVC solvent cement shall have a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - b. Adhesive primer shall have a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 2. Requirements for Low-Emitting Materials: Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

3.3 CONNECTIONS

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to unit to allow service and maintenance.
- C. Connect piping to units mounted on vibration isolators with flexible connectors.
- D. Connect cooling condensate drain pans with air seal trap at connection to drain pan and install cleanouts at changes in pipe direction.
- E. **[Chilled] [and] [Hot]** Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.
- F. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and

Condensate Piping Specialties." Install shutoff valve at steam coil connections, float and thermostatic trap, and union or flange at each coil return connection.

- G. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping."
- H. Gas Piping: Comply with requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Connect gas piping with shutoff valve and union and with sufficient clearance for burner removal and service. Make connection with AGA-approved flexible connectors.
- I. Comply with requirements for ductwork specified in Section 233113 "Metal Ducts."
- J. Indirect-Fired Furnace Vent Connections: Comply with Section 235123 "Gas Vents."
- K. Install electrical devices furnished with units but not factory mounted.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to and inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 2. Adjust seals and purge.
 - 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 4. Set initial temperature and humidity set points.
 - 5. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Air-to-air energy recovery equipment will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 CLEANING

- A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.6 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train] [Train]** Owner's maintenance personnel to adjust, operate, and maintain air-to-air energy recovery units.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237200

SECTION 237313 - MODULAR INDOOR CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Constant-air-volume, single-zone air-handling units.
 - 2. Constant-air-volume, multizone air-handling units.
 - 3. Constant-air-volume, dual-duct air-handling units.
 - 4. Variable-air-volume, single-zone air-handling units.
 - 5. Variable-air-volume, dual-duct air-handling units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Structural Performance: Casing panels shall be self-supporting and capable of withstanding 133 percent of internal static pressures indicated, without panel joints exceeding a deflection of [L/200] [L/100] <Insert value> where "L" is the unsupported span length within completed casings.
- C. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

1.4 ACTION SUBMITTALS

- A. Product Data: For each air-handling unit indicated.

1. Unit dimensions and weight.
2. Cabinet material, metal thickness, finishes, insulation, and accessories.
3. Fans:
 - a. Certified fan-performance curves with system operating conditions indicated.
 - b. Certified fan-sound power ratings.
 - c. Fan construction and accessories.
 - d. Motor ratings, electrical characteristics, and motor accessories.
4. Certified coil-performance ratings with system operating conditions indicated.
5. Dampers, including housings, linkages, and operators.
6. Filters with performance characteristics.
7. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Delegated-Design Submittal: For vibration isolation[**and seismic restraints**] indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.
2. Support location, type, and weight.
3. Field measurements.

B. Seismic Qualification Certificates: For air-handling units, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- C. Source quality-control reports.
- D. Field quality-control reports.
- E. Copy of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: **[One (1)]** <Insert number> set(s) for each air-handling unit.
 - 2. Gaskets: **[One (1)]** <Insert number> set(s) for each access door.
 - 3. Fan Belts: **[One (1)]** <Insert number> set(s) for each air-handling unit fan.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
- C. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.
- D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- F. Comply with NFPA 70.

1.9 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.10 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of modular indoor central-station air-handling units that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures including all major operational components.
 - b. Faulty operation of controls.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal use.
 - 2. Warranty Periods: From date of Substantial Completion.
 - a. AHUs: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.
 - b. Other Components: Minimum **[one (1)] <Insert number>** year(s).

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [Air Enterprises, Inc.](#)
 - 2. [Airtherm; a Mestek company.](#)
 - 3. [Buffalo Air Handling.](#)
 - 4. [Carrier Corporation; a member of the United Technologies Corporation Family.](#)
 - 5. [Coil Company, LLC.](#)
 - 6. [Dunham-Bush, Inc.](#)
 - 7. [Engineered Air.](#)

8. [Mammoth Inc.](#)
9. [McQuay International](#)
10. [Scott Springfield Mfg. Inc.](#)
11. [Trane; American Standard Inc.](#)
12. [USA Coil & Air.](#)
13. [YORK International Corporation.](#)
14. <Insert manufacturer's name>.
15. or approved equal.

2.2 UNIT CASINGS

A. General Fabrication Requirements for Casings:

1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
2. Casing Joints: Sheet metal screws or pop rivets.
3. Sealing: Seal all joints with water-resistant sealant.
4. Factory Finish for [**Steel**] [**and**] [**Galvanized-Steel**] Casings: Apply manufacturer's standard primer immediately after cleaning and pretreating.
5. Factory Finish for [**Steel**] [**and**] [**Galvanized-Steel**] Casings: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked-on enamel finish, consisting of prime coat and thermosetting topcoat.
6. Casing Coating: [**Thermoplastic vinyl**] [**Epoxy**] [**Zinc**] [**Synthetic resin**] [**Phenolic**] [**Polytetrafluoroethylene**] [**Vinyl ester**] [**Hot-dip galvanized**] [**Powder-baked enamel**] <Insert special coating>.
7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Casing Insulation and Adhesive:

1. Materials: ASTM C 1071, [**Type I**] [**Type II**].
2. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the cooling-coil section.
 - a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service-air velocity.
3. Location and Application: Encased between outside and inside casing.

C. Inspection and Access Panels and Access Doors:

1. Panel and Door Fabrication: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.

2. Inspection and Access Panels:
 - a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.
 3. Access Doors:
 - a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Fabricate windows in **[fan section]** doors of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.
 - d. Size: At least **[18 inches (450 mm)] [24 inches (600 mm)] <Insert width>** wide by full height of unit casing up to a maximum height of **[60 inches (1500 mm)] [72 inches (1800 mm)] <Insert height>**.
 4. Locations and Applications:
 - a. Fan Section: **[Inspection and access panels] [Doors] [Doors and inspection and access panels]**.
 - b. Access Section: Doors.
 - c. Coil Section: Inspection and access panel.
 - d. Damper Section: **[Inspection and access panels] [Doors]**.
 - e. Filter Section: **[Inspection and access panels] [Doors]** large enough to allow periodic removal and installation of filters.
 - f. Mixing Section: Doors.
 - g. Humidifier Section: Doors.
 5. Service Light: 100-W vaporproof fixture with switched junction box located **[outside] [inside]** adjacent to door.
 - a. Locations: **[Each section accessed with door] [Fan section] <Insert location>**.
- D. Condensate Drain Pans:
1. Fabricated with **[one] [two]** percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.
 - a. Length: Extend drain pan downstream from leaving face **[to comply with ASHRAE 62.1] <Insert distance>**.
 - b. Depth: A minimum of **[2 inches (50 mm)] <Insert depth>** deep.

2. **[Formed sections] [Integral part of floor plating].**
 3. Single-wall, **[galvanized] [stainless]**-steel sheet.
 4. Double-wall, **[galvanized] [stainless]**-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
 5. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on **[one end] [both ends]** of pan.
 - a. Minimum Connection Size: **[NPS 1 (DN 25)] [NPS 2 (DN 50)] <Insert size>**.
 6. Pan-Top Surface Coating: Asphaltic waterproofing compound.
 7. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
- E. Service Platform: **[Steel] [Galvanized steel] [Aluminum]**, **[42 inches (1070 mm)] <Insert width>** wide running entire length of unit and located on service access side, with angle side rails, **4-inch (100-mm)** kick plates, and expanded metal floor. Provide platform with a fixed ladder that extends from the top of the side rail to the floor.
- F. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.
1. Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when air-handling unit frame is anchored to building structure.

2.3 FAN, DRIVE, AND MOTOR SECTION

- A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.
1. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.
 - a. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
 - b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
- B. Centrifugal Fan Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.
1. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.
 2. Horizontal-Flanged, Split Housing: Bolted construction.
 3. Housing for Supply Fan: Attach housing to fan-section casing with metal-edged flexible duct connector.

4. Flexible Connector: Factory fabricated with a fabric strip [3-1/2 inches (89 mm)] [5-3/4 inches (146 mm)] wide attached to 2 strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized-steel sheet or 0.032-inch- (0.8-mm-) thick aluminum sheets; select metal compatible with casing.
 - a. Flexible Connector Fabric: Glass fabric, double coated with neoprene. Fabrics, coatings, and adhesives shall comply with UL 181, Class 1.
 - 1) Fabric Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).
 - 2) Fabric Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.
 - 3) Fabric Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).
- C. Plenum Fan Housings: Steel frame and panel; fabricated without fan scroll and volute housing.
- D. Backward-Inclined, Centrifugal Fan Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.
- E. Forward-Curved, Centrifugal Fan Wheels: Inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically fastened to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.
- F. Airfoil, Centrifugal Fan Wheels: Smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.
- G. Axial Fans: Fan wheel and housing, straightening-vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.
 1. Variable-Pitch Fans: Internally mounted [pneumatic] [electric] [electronic] actuator, externally mounted positive positioner, and mechanical-blade-pitch indicator.
 2. Housings: [Steel] [Galvanized steel] [Aluminum].
 - a. Inlet and Outlet Connections: Flanges.
 - b. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
- H. Fan Shaft Bearings:
 1. Prelubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with a rated life of [50,000] [120,000] <Insert number> hours according to ABMA 9.
 2. Grease-Lubricated, Tapered-Roller Bearings: Self-aligning, pillow-block type with double-locking collars and 2-piece, cast-iron housing [with grease lines]

- extended to outside unit]** and a rated life of **[50,000] [120,000] <Insert number>** hours according to ABMA 11.
3. Grease-Lubricated Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing[**with grease lines extended to outside unit**].
- I. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with **[1.5] [1.4] [1.3] [1.2]** service factor based on fan motor.
 1. Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
 2. Motor Pulleys: Adjustable pitch for use with **[5] <Insert number>**-hp motors and smaller; fixed pitch for use with motors larger than **[5] <Insert number>** hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
 3. Belts: Oil resistant, nonsparking, and nonstatic; in matched sets for multiple-belt drives.
 4. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; **0.1046-inch (2.7-mm-)** thick, **3/4-inch (20-mm)** diamond-mesh wire screen, welded to steel angle frame; prime coated.
 - J. Variable-Inlet Vanes: Steel, with blades supported at both ends with permanently lubricated bearings. Variable mechanism terminating in single lever for connection to control actuator with connecting shaft for second set of variable inlet vanes on double-width fans.
 - K. Discharge Dampers: Heavy-duty steel assembly with channel frame and sealed ball bearings, and **[opposed] [parallel]** blades constructed of two plates formed around and welded to shaft, with blades linked out of air stream to single control lever.
 - L. Internal Vibration Isolation[**and Seismic Control**]: Fans shall be factory mounted with manufacturer's standard[**restrained**] vibration isolation mounting devices having a minimum static deflection of **[1 inch (25 mm)] [2 inches (50 mm)] <Insert value>**.
 1. Seismic Fabrication Requirements: Fabricate fan section, internal mounting frame and attachment to fans, fan housings, motors, casings, accessories, and other fan section components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when fan-mounting frame and air-handling-unit mounting frame are anchored to building structure.
 - M. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 1. Enclosure Type: Totally enclosed, fan cooled.
 2. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
 3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. Mount unit-mounted disconnect switches on **[exterior]** **[interior]** of unit.
6. **<Insert unique motor characteristics>**.

N. Variable Frequency Controllers:

1. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
2. Output Rating: 3-phase; 6 to **[60 Hz, with voltage proportional to frequency throughout voltage range]** **[66 Hz, with torque constant as speed changes]** **[120 Hz, with horsepower constant throughout speed range]**.
3. Unit Operating Requirements:
 - a. Input ac voltage tolerance of **[208 V, plus or minus 5]** **[380 to 500 V, plus or minus 10]** **[525 to 575 V, plus or minus 10]** percent.
 - b. Input frequency tolerance of 06/11 Hz, plus or minus 6 percent.
 - c. Minimum Efficiency: 96 percent at 60 Hz, full load.
 - d. Minimum Displacement Primary-Side Power Factor: 96 percent.
 - e. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
 - f. Starting Torque: 100 percent of rated torque or as indicated.
 - g. Speed Regulation: Plus or minus 1 percent.
4. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
5. Internal Adjustability Capabilities:
 - a. Minimum Speed: 5 to 25 percent of maximum rpm.
 - b. Maximum Speed: 80 to 100 percent of maximum rpm.
 - c. Acceleration: 2 to a minimum of 22 seconds.
 - d. Deceleration: 2 to a minimum of 22 seconds.
 - e. Current Limit: 50 to a minimum of 110 percent of maximum rating.
6. Self-Protection and Reliability Features:
 - a. Input transient protection by means of surge suppressors.
 - b. Undervoltage and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
 - c. Adjustable motor overload relays capable of NEMA ICS 2, **[Class 10]** **[Class 20]** **[Class 30]** performance.
 - d. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
 - e. Instantaneous line-to-line and line-to-ground overcurrent trips.
 - f. Loss-of-phase protection.
 - g. Reverse-phase protection.
 - h. Short-circuit protection.
 - i. Motor overtemperature fault.

7. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.
8. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped.
9. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
10. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
11. Door-mounted LED status lights shall indicate the following conditions:
 - a. Power on.
 - b. Run.
 - c. Overvoltage.
 - d. Line fault.
 - e. Overcurrent.
 - f. External fault.
12. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual-speed-control potentiometer and elapsed time meter.
13. Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
 - a. Output frequency (Hertz).
 - b. Motor speed (rpm).
 - c. Motor status (running, stop, fault).
 - d. Motor current (amperes).
 - e. Motor torque (percent).
 - f. Fault or alarming status (code).
 - g. Proportional-integral-derivative (PID) feedback signal (percent).
 - h. DC-link voltage (volts direct current).
 - i. Set-point frequency (Hertz).
 - j. Motor output voltage (volts).
14. Control Signal Interface:
 - a. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
 - b. Remote signal inputs capable of accepting any of the following speed-setting input signals from the control system:
 - 1) 0 to 10-V dc.
 - 2) 0-20 or 4-20 mA.
 - 3) Potentiometer using up/down digital inputs.
 - 4) Fixed frequencies using digital inputs.

- 5) RS485.
 - 6) Keypad display for local hand operation.
- c. Output signal interface with a minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
- 1) Output frequency (Hertz).
 - 2) Output current (load).
 - 3) DC-link voltage (volts direct current).
 - 4) Motor torque (percent).
 - 5) Motor speed (rpm).
 - 6) Set-point frequency (Hertz).
- d. Remote indication interface with a minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
- 1) Motor running.
 - 2) Set-point speed reached.
 - 3) Fault and warning indication (overtemperature or overcurrent).
 - 4) High- or low-speed limits reached.
15. Communications: RS485 interface allows VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.
16. Integral Disconnecting Means: **[NEMA AB 1, instantaneous-trip circuit breaker] [NEMA AB 1, molded-case switch] [NEMA KS 1, nonfusible switch] [NEMA KS 1, fusible switch]** with lockable handle.
17. Accessories:
- a. Devices shall be factory installed in controller enclosure unless otherwise indicated.
 - b. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
 - c. Standard Displays:
 - 1) Output frequency (Hertz).
 - 2) Set-point frequency (Hertz).
 - 3) Motor current (amperes).
 - 4) DC-link voltage (volts direct current).
 - 5) Motor torque (percent).
 - 6) Motor speed (rpm).
 - 7) Motor output voltage (volts).

2.4 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with ARI 410.

2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. For multizone units, provide air deflectors and air baffles to balance airflow across coils.
4. Coils shall not act as structural component of unit.
5. Seismic Fabrication Requirements: Fabricate coil section, internal mounting frame and attachment to coils, and other coil section components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when coil-mounting frame and air-handling-unit mounting frame are anchored to building structure.

B. Electrical Heating Coils, Controls, and Accessories: Comply with UL 1995.

1. Casing Assembly: **[Slip-in] [Flanged]** type with galvanized-steel frame.
2. Sheathed Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
3. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
4. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
5. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
6. Control Panel: **[Unit] [Remote]** mounted with disconnecting means and overcurrent protection.
 - a. **[Magnetic] [Mercury]** contactor.
 - b. Solid-state, stepless pulse controller.
 - c. Toggle switches, one per step.
 - d. Step controller.
 - e. Time-delay relay.
 - f. Pilot lights, one per step.
 - g. Airflow proving switch.

2.5 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section:

1. Comply with NFPA 90A.
2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
3. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

B. Disposable Panel Filters:

1. Factory-fabricated, viscous-coated, flat-panel type.
2. Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
3. Dust-Holding Capacity: <Insert lb (kg)>.
4. Initial Resistance: <Insert inches wg (Pa)>.
5. Recommended Final Resistance: <Insert inches wg (Pa)>.
6. Arrestance (ASHRAE 52.1): [80] <Insert value>.
7. Merv (ASHRAE 52.2): [5] <Insert value>.
8. Media: Interlaced glass fibers sprayed with nonflammable adhesive[and antimicrobial agent].
9. Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.

C. Extended-Surface, Disposable Panel Filters:

1. Factory-fabricated, dry, extended-surface type.
2. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
3. Dust-Holding Capacity: <Insert lb (kg)>.
4. Initial Resistance: <Insert inches wg (Pa)>.
5. Recommended Final Resistance: <Insert inches wg (Pa)>.
6. Arrestance (ASHRAE 52.1): [90] <Insert value>.
7. Merv (ASHRAE 52.2): [7] <Insert value>.
8. Media: Fibrous material formed into deep-V-shaped pleats[with antimicrobial agent] and held by self-supporting wire grid.
9. Media-Grid Frame: [Nonflammable cardboard] [Galvanized steel] [Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets].
10. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks.

D. Extended-Surface, Nonsupported-Media Filters:

1. Factory-fabricated, dry, extended-surface, self-supporting type.
2. Dust-Holding Capacity: <Insert lb (kg)>.
3. Initial Resistance: <Insert inches wg (Pa)>.
4. Recommended Final Resistance: <Insert inches wg (Pa)>.
5. Arrestance (ASHRAE 52.1): [95] <Insert value>.
6. Merv (ASHRAE 52.2): [13] <Insert value>.
7. Media: Fibrous material [with antimicrobial agent] constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.
8. Filter-Media Frame: [Galvanized steel] [Hard polyurethane foam].
9. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks[with space for prefilter].

E. Automatic Roll Filters:

1. Factory-fabricated, automatic, motor-driven, roll type.
2. Arrangement: [Horizontal] [Vertical].

3. Dust-Holding Capacity: <Insert lb (kg)>.
4. Initial Resistance: <Insert inches wg (Pa)>.
5. Recommended Final Resistance: <Insert inches wg (Pa)>.
6. Arrestance (ASHRAE 52.1): [80] <Insert value>.
7. Merv (ASHRAE 52.2): [5] <Insert value>.
8. Media: Compressed and rolled, fibrous-glass material viscous coated[, and with antimicrobial agent].
9. Holding Frame: Galvanized steel, with enclosed, clean media roll arranged to allow upstream replacement of filter media.
10. Auxiliary Frame: Locate on downstream side of unit with [downstream] [side] access.
11. Final Filter: Extended-surface, [retained-media] [nonsupported-media] [HEPA] filters.
12. Control and Drive:
 - a. Mechanism: Electric, gear-reducer, motor-driven, feed control equipped with manual media advance and runout switches for stopping media movement of filter bank and operating remote warning signal lights.
 - b. Manual Control: Manual switch to advance media and wired to override automatic controls.
 - c. Automatic Control: Prewired control package to advance media [when filter resistance exceeds adjustable high limit] [after adjustable operating time].

F. Activated-Carbon Panel Filters:

1. Factory-fabricated unit with activated-carbon media.
2. Flat-Panel Media: Multilayer filter with inlet layer of polyester fibers, layer of activated-carbon granules bonded to fibers, layer of polyurethane foam, and housed in cardboard frame.
3. Pleated Media: Multilayer filter with inlet layer of cotton and synthetic fibers and layer of activated-carbon granules bonded to synthetic fibers, formed into deep-V-shaped pleats and held by self-wire grid, and housed in nonflammable cardboard frame.
4. Mounting Frames: Welded galvanized steel, with polyurethane gaskets and fasteners, capable of holding media and media frame in place and suitable for bolting together into built-up filter banks.

G. Activated-Carbon Filters:

1. Factory-fabricated unit in deep-V arrangement with disposable panel prefilter.
2. Media: Activated carbon mounted in removable carbon-cell trays of epoxy-coated steel.
3. Activated-Carbon Capacity: [12 lb (5.4 kg) of activated carbon per 500 cfm (236 L/s)] [8.8 lb (4.0 kg) of activated carbon per 2000 cfm (944 L/s)] of airflow.
4. Housing: 0.064-inch- (1.6-mm-) thick, galvanized steel, for side servicing through gasketed access doors on both sides. Equip housings with metal slide channel tracks to hold activated-carbon trays.

H. HEPA Filters:

1. Factory-fabricated unit.
2. Dust-Holding Capacity: <Insert lb (kg)>.
3. Initial Resistance: <Insert inches wg (Pa)>.
4. Recommended Final Resistance: <Insert inches wg (Pa)>.
5. Arrestance (ASHRAE 52.1): [95 percent on 0.3-micrometer D.O.P. particles] [99.97 percent on 0.3-micrometer D.O.P. particles] [99.9995 percent on 0.1- and 0.2-micrometer D.O.P. particles] [99.99995 percent on 0.1- and 0.2-micrometer D.O.P. particles] <Insert value>.
6. Media: UL 586, fibrous glass, constructed of continuous sheets with closely spaced pleats with [aluminum separators] [vinyl-coated aluminum separators] [separators of ribbons of filter media].
7. Frame Material: [3/4-inch- (19-mm-) thick, fire-retardant plywood] [3/4-inch- (19-mm-) thick, fire-retardant particleboard] [3/4-inch- (19-mm-) thick plywood] [3/4-inch- (19-mm-) thick particleboard] [Galvanized steel] [Aluminized steel] [Cadmium-plated steel] [Stainless steel] [Aluminum].
8. Media to Frame Side Bond: [Polyurethane foam] [Silicone] [Neoprene adhesive] [Fiberglass-mat packing] [Thermosetting sealant] [Knife edge in fluid-filled channel].
9. Face Gasket: [Neoprene expanded rubber] [Ceramic fiber] [Silicone].
10. Mounting Frames: Downstream corners of holding device shall have cushion pads to protect media. Bolted filter-sealing mechanism shall mount and continuously seal each individual filter.

I. Filter Gage:

1. [3-1/2-inch- (90-mm-)] [2-inch- (50-mm-)] diameter, diaphragm-actuated dial in metal case.
2. Vent valves.
3. Black figures on white background.
4. Front recalibration adjustment.
5. [2] [3] percent of full-scale accuracy.
6. Range: [0- to 0.5-inch wg (0 to 125 Pa)] [0- to 1.0-inch wg (0 to 250 Pa)] [0- to 2.0-inch wg (0 to 500 Pa)] [0- to 3.0-inch wg (0 to 750 Pa)] [0- to 4.0-inch wg (0 to 1000 Pa)].
7. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch (6-mm) [aluminum] [plastic] tubing, and 2- or 3-way vent valves.

2.6 DAMPERS

- A. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed [2] <Insert number> percent of air quantity at [2000-fpm (10-m/s)] <Insert value> face velocity through damper and [4-inch wg (1000-Pa)] <Insert value> pressure differential.
- B. Damper Operators: Comply with requirements in Section 230923.12 "Control Dampers."

C. Electronic Damper Operators:

1. Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
2. Electronic damper position indicator shall have visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
3. Operator Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
 - c. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
4. Nonspring-Return Motors for Dampers Larger Than **25 Sq. Ft. (2.3 sq. m)**: Size for running torque of **150 in. x lbf (16.9 N x m)** and breakaway torque of **300 in. x lbf (33.9 N x m)**.
5. Spring-Return Motors for Dampers Larger Than **25 Sq. Ft. (2.3 sq. m)**: Size for running and breakaway torque of **150 in. x lbf (16.9 N x m)**.
6. Size dampers for running torque calculated as follows:
 - a. Parallel-Blade Damper with Edge Seals: **7 inch-lb/sq. ft. (86.8 kg-cm/sq. m)** of damper.
 - b. Opposed-Blade Damper with Edge Seals: **5 inch-lb/sq. ft. (62 kg-cm/sq. m)** of damper.
 - c. Parallel-Blade Damper without Edge Seals: **4 inch-lb/sq. ft. (49.6 kg-cm/sq. m)** of damper.
 - d. Opposed-Blade Damper without Edge Seals: **3 inch-lb/sq. ft. (37.2 kg-cm/sq. m)** of damper.
 - e. Dampers with **2- to 3-Inch wg (500 to 750 Pa)** of Pressure Drop or Face Velocities of **1000 to 2500 fpm (5 to 13 m/s)**: Increase running torque by 1.5.
 - f. Dampers with **3- to 4-Inch wg (750 to 1000 Pa)** of Pressure Drop or Face Velocities of **2500 to 3000 fpm (13 to 15 m/s)**: Increase running torque by 2.0.
7. Coupling: V-bolt and V-shaped, toothed cradle.
8. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
9. Fail-Safe Operation: Mechanical, spring-return mechanism with external, manual gear release on nonspring-return actuators.
10. Power Requirements (Two-Position Spring Return): **[24] [120] [230]-V ac**.
11. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
12. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.

13. Temperature Rating: [Minus 22 to plus 122 deg F (Minus 30 to plus 50 deg C)] [40 to 104 deg F (5 to 40 deg C)].
14. Run Time: [12 seconds open, 5 seconds closed] [30 seconds] [60 seconds] [120 seconds].

D. Pneumatic Damper Operators:

1. Rolling-diaphragm piston type with adjustable stops and spring return, sized to operate with sufficient reserve power to provide smooth modulating action or two-position action. Where actuators operate in sequence, provide pilot positioners.
2. Pneumatic Damper Position Indicator: Potentiometer mounted in enclosure with adjustable crank-arm assembly connected to damper to transmit 0 to 100 percent valve/damper travel.
3. Pilot Positioners:
 - a. Start Point: Adjustable from 2 to 12 psig (14 to 83 kPa).
 - b. Operating Span: Adjustable from 5 to 13 psig (35 to 90 kPa).
 - c. Linearity: Plus or minus 10 percent of output signal span.
 - d. Hysteresis: 3 percent of span.
 - e. Response: 0.25-psig (1723-Pa) input change.
 - f. Maximum Pilot Signal Pressure: 20 psig (140 kPa).
 - g. Maximum Control Air-Supply Pressure: 60 psig (410 kPa).
4. Actuator Housing: Molded or die-cast zinc or aluminum. [Terminal unit actuators may be high-impact plastic with ambient temperature rating of 50 to 140 deg F (10 to 60 deg C) unless located in return-air plenums.]
5. Inlet-Vane Operators: High pressure, with pilot positioners.

E. Zone Dampers: Two single-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers offset 90 degrees from each other on [cadmium-plated] steel operating rod rotating in sintered bronze or nylon bearings mounted in a single [galvanized-steel] [aluminum] [extruded-aluminum] frame. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

F. Face-and-Bypass Dampers: Opposed-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers with [cadmium-plated] steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [galvanized-steel] [aluminum] [extruded-aluminum] frame and with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

G. Outdoor- and Return-Air Mixing Dampers: Parallel-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers mechanically fastened to [cadmium-plated] steel operating rod in reinforced cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.

H. Outdoor- and Return-Air Dampers: Low-leakage, double-skin, airfoil-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers with compressible

jamb seals and extruded-vinyl blade edge seals in **[opposed]** **[parallel]**-blade arrangement with **[cadmium-plated]** steel operating rods rotating in **[stainless-steel sleeve]** **[sintered bronze or nylon]** bearings mounted in a single **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed **5 cfm/sq. ft.** (0.22 L/s per sq. m) at **1-inch wg** (250 Pa) and **9 cfm/sq. ft.** (0.4 L/s per sq. m) at **4-inch wg** (1.0 MPa).

- I. Mixing Section: Multiple-blade, air-mixer assembly located immediately downstream of mixing section.
- J. Combination Filter and Mixing Section:
 - 1. Cabinet support members shall hold **2-inch-** (50-mm-) thick, pleated, flat, permanent or throwaway filters.
 - 2. Multiple-blade, air-mixer assembly shall mix air to prevent stratification, located immediately downstream of mixing box.

2.7 HUMIDIFIERS

A. Steam Grid Humidifier:

- 1. Manifold:
 - a. ASTM A 666, Type 304 stainless steel.
 - b. Steam jacketed.
 - c. Insulated with **1/2-inch** (13-mm) fiberglass and stainless-steel jacket.
 - d. Manifold shall extend the full width of unit with mounting brackets at ends.
- 2. Steam Separator: **[Cast iron,]** **[ASTM A 666, Type 304 stainless steel,]** with **[separate]** humidifier control valve.
- 3. Humidifier Control Valve: Actuator: **[Pneumatic]** **[Electric]** modulating with spring return.
- 4. Humidifier Control Valve: Actuator: As specified in Section 230923.11 "Control Valves."
- 5. Steam Trap: Inverted-bucket type, sized for a minimum of three times the maximum rated condensate flow of humidifier at **1/2-psig** (3.4-kPa) inlet pressure.
- 6. Aquastat: For separate mounting on steam condensate, return piping to prevent cold operation of humidifier.
- 7. Strainer: In-line type.
- 8. Airflow Switch: To prevent humidifier operation in the absence of airflow.

B. Wet Glass Cell Washer Section:

- 1. **3-inch-** (75-mm-) deep cells with random packed, glass-fiber media in **[galvanized]** **[stainless]-**steel frames.
- 2. Access Door: Watertight with brass fittings[, **wire glass window,**] and locking handles.
- 3. Spray Tree Assembly: **[Brass]** **[Stainless-steel]** nozzles and **[galvanized]** **[stainless]-**steel piping.

4. Eliminator: [**Galvanized**] [**Stainless**]-steel plates.
5. Tank:
 - a. Welded[**stainless**] steel[, **with interior and exterior surfaces blasted and painted with zinc-chromate paint**].
 - b. Copper suction screen.
 - c. Drain, overflow, and suction connections.
 - d. Makeup connection with [**brass**]float valve, and with quick-fill connection.
6. Insulate exterior with duct insulation and mount on 2-inch (-(50-mm-)) thick, rigid insulation board.

C. Evaporative Humidifier Section:

1. Access Door: Watertight [**cast iron**]with brass fittings, wire glass window, and locking handles.
2. Spray Tree Assembly: Brass nozzles and galvanized piping, [**galvanized eliminator plates with flooding nozzles and header, and galvanized antisplash baffles**] [**cross-fluted cellulose media**].
3. Tank:
 - a. Welded steel tank with interior and exterior surfaces blasted and painted with zinc-chromate paint.
 - b. Copper suction screen, drain, overflow, and suction connections.
 - c. Makeup connection with [**brass**]float valve, and with quick-fill connection.
4. Insulation: Insulate with duct insulation on exterior and mount on 2-inch (-(50-mm-)) thick, rigid insulation board.

2.8 AIR-TO-AIR ENERGY RECOVERY

A. Heat Wheels:

1. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - a. [Airxchange](#).
 - b. [American Energy Exchange, Inc.](#)
 - c. [Loren Cook Company](#).
 - d. [SEMCO Incorporated](#).
 - e. [Trane; American Standard Inc.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.
2. Casing:
 - a. Steel, with manufacturer's standard paint coating.

- b. Integral purge section limiting carryover of exhaust air to between **0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg** (0.05 percent at 400-Pa and 0.20 percent at 1000-Pa) differential pressure.
 - c. Casing seals on periphery of rotor, on duct divider, and on purge section.
 - d. Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.
 3. Rotor: Aluminum, segmented wheel, strengthened with radial spokes[, **with nontoxic, noncorrosive, silica-gel desiccant coating**]. Construct media for passing maximum [500] [800] [1200]-micrometer solids.
 4. Rotor: [**Glass-fiber**] [**Polymer**] segmented wheel, strengthened with radial spokes impregnated with nonmigrating, water-selective, molecular-sieve desiccant coating. Construct media for passing maximum [800] [1200]-micrometer solids.
 5. Drive: Fractional horsepower motor and gear reducer[, **with speed changed by variable frequency controller,**] and self-adjusting multilink belt around outside of rotor.
 6. Controls:
 - a. Starting relay, factory mounted and wired, and manual motor starter for field wiring.
 - b. Variable frequency controller, factory mounted and wired, permitting input of field connected 4-20 mA or 1-10-V control signal.
 - c. Variable frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
 - d. Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain [**exhaust temperature above freezing and**] air differential temperature above set point. Provide maximum rotor speed when exhaust-air temperature is less than outdoor-air temperature.
 - e. Pilot-Light Indicator: Display rotor rotation and speed.
 - f. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.
- B. Fixed-Plate Sensible Heat Exchangers:
1. **Manufacturers:** Subject to compliance with requirements, [provide products by one of the following:
 - a. [American Energy Exchange, Inc.](#)
 - b. [Des Champs Technologies.](#)
 - c. [Exothermics Inc.; a brand of Eclipse, Inc.](#)
 - d. [Nutech Brands Inc.](#)
 - e. [RenewAire LLC.](#)
 - f. **<Insert manufacturer's name>**.
 - g. or approved equal.

2. Casing: **[Aluminum] [Galvanized steel] [Enameled steel, with galvanized-steel liner] [Enameled steel]**.
3. Plates: Evenly spaced and sealed and arranged for counter airflow.
4. Plate Material: **[Embossed aluminum] [Stainless steel] [Polypropylene copolymer (high-density plastic)]**.
 - a. Plate Coating: **[Epoxy] [Air-dried phenolic]**.
5. Bypass: Plenum within casing, with gasketed face-and-bypass dampers that have operating rods extended outside casing.
6. Water Wash: Automatic system, with spray manifold to individual spray tubes or traversing type with stainless-steel-screw operating mechanism and electric motor drive; activated by time clock, **with detergent injection**.
7. Heat-Exchanger Prefilters: **[1 inch (25 mm) thick, disposable] [2 inches (50 mm) thick, disposable] [Medium efficiency] [Electrostatic]**.

2.9 CAPACITIES AND CHARACTERISTICS

A. Casing:

1. Outside Casing: Galvanized steel, minimum **[0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] <Insert value>** thick.
2. Outside Casing: Aluminum, minimum **[0.050 inch (1.3 mm)] [0.063 inch (1.6 mm)] [0.080 inch (2.0 mm)] <Insert value>** thick.
3. Outside Casing: Stainless steel, minimum **[0.050 inch (1.3 mm)] [0.0625 inch (1.6 mm)] [0.0781 inch (2.0 mm)] <Insert value>** thick.
4. Inside Casing: Galvanized steel, **[solid] [perforated]**, minimum **[0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] <Insert value>** thick.
5. Inside Casing: Aluminum, **[solid] [perforated]**, minimum **[0.050 inch (1.3 mm)] [0.063 inch (1.6 mm)] [0.080 inch (2.0 mm)] <Insert value>** thick.
6. Inside Casing: Stainless steel, **[solid] [perforated]**, minimum **[0.050 inch (1.3 mm)] [0.0625 inch (1.6 mm)] [0.0781 inch (2.0 mm)] <Insert value>** thick.
7. Floor Plate: Galvanized steel, minimum **[0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] <Insert value>** thick.
8. Floor Plate: Aluminum, minimum **[0.040 inch (1.0 mm)] [0.050 inch (1.3 mm)] [0.063 inch (1.6 mm)] [0.080 inch (2.0 mm)] <Insert value>** thick.
9. Floor Plate: Stainless steel, minimum **[0.050 inch (1.3 mm)] [0.0625 inch (1.6 mm)] [0.0781 inch (2.0 mm)] <Insert value>** thick.
10. Insulation Thickness: **[1 inch (25 mm)] [1-1/2 inches (40 mm)] [2 inches (50 mm)] <Insert value>**.
11. Static-Pressure Classifications for Unit Sections before Fans: **[2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] [6-inch wg (1500 Pa)] [8-inch wg (2000 Pa)] [9-inch wg (2250 Pa)] [10-inch wg (2500 Pa)] <Insert value>**.
12. Static-Pressure Classifications for Unit Sections after Fans: **[2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] [6-inch wg (1500 Pa)] [8-inch wg (2000 Pa)] [9-inch wg (2250 Pa)] [10-inch wg (2500 Pa)] <Insert value>**.

B. Supply Fan:

1. **[Class I] [Class II] [Class III]:** AMCA 99-2408.
2. Drive: **[V-belt] [Direct]**.
3. Type: **[Steel, backward-inclined centrifugal] [Aluminum, backward-inclined centrifugal] [Black-steel, forward-curved centrifugal] [Galvanized-steel, forward-curved centrifugal] [Steel, airfoil centrifugal] [Aluminum, airfoil centrifugal] [Cast-aluminum axial]**.
4. Number of Fan Wheels: **<Insert number>**.
5. Fan Diameter : **<Insert inches (mm)>**.
6. Fan Housing and Wheel Coating: **[Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name; trade name>**.
7. Airflow: **<Insert cfm (L/s)>**.
8. Total Static Pressure: **<Insert inches wg (kPa)>**.
9. External Static Pressure: **<Insert inches wg (kPa)>**.
10. Speed: **<Insert rpm>**.
11. Maximum Outlet Velocity: **<Insert fpm (m/s)>**.
12. Inlet vane controls.
13. Motor Size: **<Insert horsepower>**.
14. Motor Speed: **<Insert rpm>**.
15. Electrical Characteristics:
 - a. Volts: **[120] [208] [230] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes: **<Insert value>**.
 - e. Minimum Circuit Ampacity: **<Insert value>**.
 - f. Maximum Overcurrent Protection: **<Insert amperage>**.
16. Fan Discharge Sound Power:
 - a. 1st Octave: **<Insert value>**.
 - b. 2nd Octave: **<Insert value>**.
 - c. 3rd Octave: **<Insert value>**.
 - d. 4th Octave: **<Insert value>**.
 - e. 5th Octave: **<Insert value>**.
 - f. 6th Octave: **<Insert value>**.
 - g. 7th Octave: **<Insert value>**.
 - h. 8th Octave: **<Insert value>**.

C. **[Exhaust] [Return] Fan:**

1. **[Class I] [Class II] [Class III]:** AMCA 99-2408.
2. Drive: **[V-belt] [Direct]**.
3. Type: **[Steel, backward-inclined centrifugal] [Aluminum, backward-inclined centrifugal] [Black-steel, forward-curved centrifugal] [Galvanized-steel, forward-curved centrifugal] [Steel, airfoil centrifugal] [Aluminum, airfoil centrifugal] [Cast-aluminum axial]**.
4. Number of Fan Wheels: **<Insert value>**.

5. Fan Diameter: <Insert inches (mm)>.
6. Fan Housing and Wheel Coating: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name; trade name>.
7. Airflow: <Insert cfm (L/s)>.
8. Total Static Pressure: <Insert inches wg (kPa)>.
9. External Static Pressure: <Insert inches wg (kPa)>.
10. Speed: <Insert rpm>.
11. Maximum Outlet Velocity : <Insert fpm (m/s)>.
12. Inlet vane controls.
13. Motor Size: <Insert horsepower>.
14. Motor Speed: <Insert rpm>.
15. Electrical Characteristics:
 - a. Volts: [120] [208] [230] <Insert value>.
 - b. Phase: [Single] [Three].
 - c. Hertz: 60.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

D. Preheat Coil:

1. Heat-Transfer Rate: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Face Area: <Insert sq. ft. (sq. m)>.
5. Maximum Face Velocity: <Insert fpm (m/s)>.
6. Maximum Air-Side, Static-Pressure Drop: <Insert inches wg (Pa)>.
7. Coil Type: [Continuous circuit] [Self-draining] [Cleanable].
8. Coil Type: [Steam distributed] [Single tube].
9. Piping Connections: [Threaded] [Flanged], [same end] [opposite ends] of coil.
10. Tube Material: [Copper] <Insert material>.
11. Tube Thickness: <Insert inches (mm)>.
12. Fin Type: [Plate] [Spiral].
13. Fin Material: [Aluminum] [Copper].
14. Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)] <Insert fins per inch (mm)>.
15. Fin Thickness: <Insert inches (mm)>.
16. Fin and Tube Joint: [Mechanical bond] [Silver brazed].
17. Headers:
 - a. Cast iron with[cleaning plugs and] drain and air vent tappings[extended to exterior of unit].
 - b. Seamless copper tube with brazed joints, prime coated.
 - c. Fabricated steel, with brazed joints, prime coated.
 - d. Provide insulated cover to conceal headers exposed outside casings.

18. Frames: Channel frame, [0.052-inch (- 1.3-mm-) **thick galvanized steel**] [0.064-inch- (1.6-mm-) **thick galvanized steel**] [0.079-inch (- 2.0-mm-) **thick galvanized steel**] [0.0625-inch (- 1.58-mm-) **thick galvanized steel**] [0.0625-inch (- 1.58-mm-) **thick stainless steel**].
19. Number of Rows: <Insert number>.
20. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.
21. Water:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Maximum Water Pressure Drop: <Insert feet of head (kPa)>.
 - c. Entering-Water Temperature: <Insert deg F (deg C)>.
 - d. Leaving-Water Temperature: <Insert deg F (deg C)>.
 - e. Tube Velocity: <Insert fpm (L/s)>.
22. Steam:
 - a. Steam Flow: <Insert lb/h (g/s)>.
 - b. Inlet Steam Pressure: <Insert psig (kPa)>.
 - c. Outer-Tube Diameter: <Insert inches (mm)>.
23. Coating: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name; trade name>.
24. Integral Face-and-Bypass Dampers: [Horizontal] [Vertical], opposed-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers with [cadmium-plated] steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [galvanized-steel] [aluminum] [extruded-aluminum] frame, with operating rods connected with a common linkage. Meeting edges of blades shall have gaskets and edge seals, and blades shall be mechanically fastened.

E. Heating Coil:

1. Heat-Transfer Rate: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Face Area: <Insert sq. ft. (sq. m)>.
5. Maximum Face Velocity: <Insert fpm (m/s)>.
6. Maximum Air-Side, Static-Pressure Drop: <Insert inches wg (Pa)>.
7. Coil Type: [Continuous circuit] [Self-draining] [Cleanable].
8. Coil Type: [Steam distributed] [Single tube].
9. Piping Connections: [Threaded] [Flanged], [same end] [opposite ends] of coil.
10. Tube Material: [Copper] <Insert material>.
11. Tube Thickness: <Insert inches (mm)>.
12. Fin Type: [Plate] [Spiral].
13. Fin Material: [Aluminum] [Copper].

14. Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)] <Insert fins per inch (mm)>.
 15. Fin Thickness: <Insert inches (mm)>.
 16. Fin and Tube Joint: [Mechanical bond] [Silver brazed].
 17. Headers:
 - a. Cast iron with [cleaning plugs and]drain and air vent tappings[extended to exterior of unit].
 - b. Seamless copper tube with brazed joints, prime coated.
 - c. Fabricated steel, with brazed joints, prime coated.
 - d. Provide insulated cover to conceal headers exposed outside casings.
 18. Frames: Channel frame, [0.052-inch (- 1.3-mm-) thick galvanized steel] [0.064-inch (- 1.6-mm-) thick galvanized steel] [0.079-inch (- 2.0-mm-) thick galvanized steel] [0.0625-inch (- 1.58-mm-) thick galvanized steel] [0.0625-inch (- 1.58-mm-) thick stainless steel].
 19. Number of Rows: <Insert number>.
 20. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.
 21. Water:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Maximum Water Pressure Drop: <Insert feet of head (kPa)>.
 - c. Entering-Water Temperature: <Insert deg F (deg C)>.
 - d. Leaving-Water Temperature: <Insert deg F (deg C)>.
 - e. Tube Velocity: <Insert fpm (L/s)>.
 22. Steam:
 - a. Steam Flow: <Insert lb/h (g/s)>.
 - b. Inlet Steam Pressure: <Insert psig (kPa)>.
 - c. Outer-Tube Diameter: <Insert inches (mm)>.
 23. Coating: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name; trade name>.
 24. Integral Face-and-Bypass Dampers: [Horizontal] [Vertical], opposed-blade, [galvanized-steel] [aluminum] [extruded-aluminum] dampers with [cadmium-plated]steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [galvanized-steel] [aluminum] [extruded-aluminum] frame, with operating rods connected with a common linkage. Meeting edges of blades shall have gaskets and edge seals, and blades shall be mechanically fastened.
- F. Electric Heating Coil:
1. Heat-Transfer Rate: <Insert Btu/h (kW)>.
 2. Input: <Insert kilowatts>.

3. Volts: [120] [208] [230] <Insert value>.
4. Phase: [Single] [Three].
5. Full-Load Amperes: <Insert value>.
6. Number of Steps: <Insert number>.

G. Cooling Coil:

1. Sensible Heat-Transfer Rate: <Insert Btu/h (kW)>.
2. Total Heat-Transfer Rate: <Insert Btu/h (kW)>.
3. Entering-Air, Dry-Bulb Temperature: <Insert deg F (deg C)>.
4. Entering-Air, Wet-Bulb Temperature: <Insert deg F (deg C)>.
5. Leaving-Air, Dry-Bulb Temperature: <Insert deg F (deg C)>.
6. Leaving-Air, Wet-Bulb Temperature: <Insert deg F (deg C)>.
7. Face Area: <Insert sq. ft. (sq. m)>.
8. Maximum Face Velocity: <Insert fpm (m/s)>.
9. Maximum Air-Side, Static-Pressure Drop: <Insert inches wg (Pa)>.
10. Coil Type: [Continuous circuit] [Self-draining] [Cleanable].
11. Piping Connections: [Threaded] [Flanged], [same end] [opposite ends] of coil.
12. Tube Material: [Copper] <Insert material>.
13. Tube Thickness: <Insert inches (mm)>.
14. Fin Type: [Plate] [Spiral].
15. Fin Material: [Aluminum] [Copper].
16. Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)] <Insert fins per inch (mm)>.
17. Fin Thickness: <Insert inches (mm)>.
18. Fin and Tube Joint: [Mechanical bond] [Silver brazed].
19. Headers:
 - a. Cast iron with [cleaning plugs and] drain and air vent tappings [extended to exterior of unit].
 - b. Seamless copper tube with brazed joints, prime coated.
 - c. Fabricated steel, with brazed joints, prime coated.
 - d. Provide insulated cover to conceal headers exposed outside casings.
20. Frames: Channel frame, [0.052-inch (- 1.3-mm-) thick galvanized steel] [0.064-inch- (1.6-mm-) thick galvanized steel] [0.079-inch (- 2.0-mm-) thick galvanized steel] [0.0625-inch (- 1.58-mm-) thick galvanized steel] [0.0625-inch (- 1.58-mm-) thick stainless steel].
21. Number of Rows: <Insert number>.
22. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.
23. Water:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Maximum Water Pressure Drop: <Insert feet of head (kPa)>.
 - c. Entering-Water Temperature: <Insert deg F (deg C)>.
 - d. Leaving-Water Temperature: <Insert deg F (deg C)>.
 - e. Tube Velocity: <Insert fpm (L/s)>.

24. Refrigerant Type: **<Insert type>**.
25. Coating: **[Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; <Insert manufacturer's name; trade name>**.

H. Prefilters:

1. Type: **<Insert type>**.
2. Face Area: **<Insert sq. ft. (sq. m)>**.
3. Surface Area: **<Insert sq. ft. (sq. m)>**.
4. Thickness or Depth: **<Insert inches (mm)>**.
5. Number of Filters: **<Insert number>**.
6. Access Location: **[Front] [Back] [Side]**.
7. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.

I. Filters:

1. Type: **<Insert type>**.
2. Face Area: **<Insert sq. ft. (sq. m)>**.
3. Surface Area: **<Insert sq. ft. (sq. m)>**.
4. Thickness or Depth: **<Insert inches (mm)>**.
5. Number of Filters: **<Insert number>**.
6. Access Location: **[Front] [Back] [Side]**.
7. Maximum or Rated Face Velocity: **<Insert fpm (m/s)>**.

J. Dampers: **[Zone] [Mixing dampers] [Face and bypass]**.

K. Steam Grid Humidifier:

1. Humidification Rate: **<Insert lb/h (g/s)>**.
2. Steam Supply Pressure: **<Insert psig (kPa)>**.
3. Dry-Bulb Air Temperature at Discharge: **<Insert deg F (deg C)>**.
4. Wet-Bulb Air Temperature at Discharge: **<Insert deg F (deg C)>**.
5. Maximum Absorption Distance: **<Insert inches (mm)>**.
6. Number of Manifolds: **<Insert number>**.

L. Wet Glass Cell Washer:

1. Rated Capacity: **<Insert lb/h (kg/h)>**.
2. Saturation Efficiency: **<Insert percent>**.

M. Evaporative Humidifier:

1. Rated Capacity: **<Insert lb/h (kg/h)>**.
2. Saturation Efficiency: **<Insert percent>**.

N. Air-to-Air Energy Recovery:

1. Exhaust Air:

- a. Airflow: **<Insert cfm (L/s)>**.
 - b. Face Velocity: **<Insert fpm (m/s)>**.
 - c. Summer:
 - 1) Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 2) Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - 3) Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 4) Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - d. Winter:
 - 1) Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 2) Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - 3) Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 4) Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - e. Air Pressure Drop: **<Insert inches wg (Pa)>**.
2. Supply Air:
- a. Airflow: **<Insert cfm (L/s)>**.
 - b. Face Velocity: **<Insert fpm (m/s)>**.
 - c. Summer:
 - 1) Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 2) Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - 3) Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 4) Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - d. Winter:
 - 1) Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 2) Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - 3) Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - 4) Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - e. Air Pressure Drop: **<Insert inches wg (Pa)>**.
3. Wheel Drive:
- a. Motor Size: **<Insert horsepower>**.
 - b. Motor Electrical Characteristics:
 - 1) Volts: **[120] [208] [230] <Insert value>**.
 - 2) Phase: **[Single] [Three]**.
 - 3) Hertz: 60.
4. Effectiveness: **<Insert percent>**.

2.10 SOURCE QUALITY CONTROL

- A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.
- B. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."
- C. Water Coils: Factory tested to **300 psig (2070 kPa)** according to ARI 410 and ASHRAE 33.
- D. Steam Coils: Factory tested to **300 psig (2070 kPa)** and to **200 psig (1380 kPa)** underwater according to ARI 410 and ASHRAE 33.
- E. Refrigerant Coils: Factory tested to **450 psig (3105 kPa)** according to ARI 410 and ASHRAE 33.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for steam, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 - 1. Install air-handling units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

- B. Suspended Units: Suspend[**and brace**] units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]
- C. Arrange installation of units to provide access space around air-handling units for service and maintenance.
- D. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.
- E. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

3.3 CONNECTIONS

- A. Comply with requirements for piping specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to air-handling unit to allow service and maintenance.
- C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.
- D. Connect condensate drain pans using [NPS 1-1/4 (DN 32)] **<Insert pipe size>**, ASTM B 88, Type M (ASTM B 88M, Type C) copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.
- E. Hot- and Chilled-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.
- F. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Install shutoff valve at steam supply connections, float and thermostatic trap, and union or flange at each coil return connection. Install gate valve and inlet strainer at supply connection of dry steam humidifiers, and inverted bucket steam trap to condensate return connection.
- G. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Install shutoff valve and union or flange at each supply and return connection.

- H. Connect duct to air-handling units with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 - 1. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
 - 2. Charge refrigerant coils with refrigerant and test for leaks.
 - 3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 4. Automatic-Roll-Filter Operational Test: Operate filters to demonstrate compliance with requirements. Test for leakage of unfiltered air while system is operating.
 - 5. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg (750 Pa) or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
 - 6. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg (750 Pa) or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter for air leaks according to ASME N510, pressure-decay method.
 - 7. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Verify that shipping, blocking, and bracing are removed.

3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that zone dampers fully open and close for each zone.
7. Verify that face-and-bypass dampers provide full face flow.
8. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
9. Comb coil fins for parallel orientation.
10. Verify that proper thermal-overload protection is installed for electric coils.
11. Install new, clean filters.
12. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. [**Replace fan and motor pulleys as required to achieve design conditions.**]
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.6 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237313

SECTION 237333.16 - INDOOR, INDIRECT, GAS-FIRED HEATING AND VENTILATING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes indirect, gas-fired heating and ventilating units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. DDC: Direct digital control.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and configuration of indoor, indirect, gas-fired heating and ventilating unit.
 - 1. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For each type and configuration of indoor, indirect, gas-fired heating and ventilating unit.
 - 1. Signed, sealed, and prepared by or under the supervision of a qualified professional engineer.
 - 2. Include plans, elevations, sections, and [mounting] [attachment] details.

3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail fabrication and assembly of gas-fired heating and ventilating units, as well as procedures and diagrams.
5. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
6. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
7. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Startup service reports.
- B. Sample Warranty: For manufacturer's special warranty.
- C. Seismic Qualification Certificates: For indoor, indirect, gas-fired heating and ventilating units, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For indirect-fired heating and ventilating units to include in emergency, operation, and maintenance manuals.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Filters: [**One (1)**] <Insert number> set(s) for each unit.
 2. Fan Belts: [**One (1)**] <Insert number> set(s) for each unit.

1.8 QUALITY ASSURANCE

- A. Comply with NFPA 70.
- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of indirect, gas-fired heating and ventilating units that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [AbsolutAire, Inc.](#)
 - 2. [Applied Air.](#)
 - 3. [ARES.](#)
 - 4. [Banza; Div. of Roberts-Gordon LLC.](#)
 - 5. [BessamAire, Inc.](#)
 - 6. [Cambridge Engineering, Inc.](#)
 - 7. [CaptiveAire Systems.](#)
 - 8. [CES Group.](#)
 - 9. [Des Champs Technologies.](#)
 - 10. [Energy Jet U.S.](#)
 - 11. [Engineered Air.](#)
 - 12. [Greenheck Fan Corporation.](#)
 - 13. [Hastings HVAC; Division of Eric, Inc.](#)
 - 14. [I.C.E. Manufacturing Ltd.; Industrial Commercial Equipment - I.C.E. \(US\), Inc.](#)

15. [Jackson & Church.](#)
16. [LCSystems.](#)
17. [Modine Manufacturing Company.](#)
18. [Powrmatic, Inc.](#)
19. [Rapid Engineering, Inc.](#)
20. [Reznor/Thomas & Betts Corporation.](#)
21. [Sterling HVAC Products.](#)
22. [Temprite.](#)
23. [Titan Air Incorporated.](#)
24. [Trane.](#)
25. [Weather-Rite, Inc.](#)
26. **<Insert manufacturer's name>.**
27. or approved equal.

2.2 SYSTEM DESCRIPTION

- A. Factory-assembled, prewired, self-contained unit consisting of cabinet, supply fan, controls, **[filters]**, and indirect-fired gas burner to be installed inside the building.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 UNIT CASINGS

- A. General Fabrication Requirements for Casings:
 1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
 2. Casing Joints: Sheet metal screws or pop rivets, factory sealed with water-resistant sealant.
 3. Factory Finish for **[Steel] [and] [Galvanized-Steel]** Casings: Apply manufacturer's standard primer immediately after cleaning and pretreating.
 4. Factory Finish for **[Steel] [and] [Galvanized-Steel]** Casings: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked-on enamel finish, consisting of prime coat and thermosetting topcoat.
 5. Casing Coating: **[Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel] <Insert special coating>.**
 6. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling-unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when air-handling-unit frame is anchored to building structure.

7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- B. Configuration: [**Horizontal**] [**Vertical**] unit with [**top**] [**horizontal**] [**bottom**] discharge for [**floor-mounted**] [**suspended**] installation.
- C. Cabinet: [**Galvanized-steel**] [**Aluminized- or galvanized-steel**] [**Aluminized-steel**] panels, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs. Duct flanges at inlet and outlet.
- D. Outer Casing: [**0.0598-inch- (1.519-mm-)**] [**0.0478-inch- (1.214-mm-)**] [**0.0359-inch- (0.912-mm-)**] thick steel with [**heat-resistant, baked-enamel**] [**enamel-painted**] [**baked-on, polyester-powder**] finish over corrosion-resistant-treated surface in color to match fan section.
- E. Outer Casing: [**0.0598-inch- (1.519-mm-)**] [**0.0478-inch- (1.214-mm-)**] [**0.0359-inch- (0.912-mm-)**] thick steel with unpainted finish
- F. Inner Casing:
1. Burner Section Inner Casing: **0.0299-inch ((0.759-mm))** steel.
 2. Double-wall casing with inner wall of [**perforated**] [**solid**] steel, for the following sections:
 - a. Blower section.
 - b. Filter section.
 - c. Mixing box.
 - d. Inlet plenum.
 - e. Discharge plenum.
 - f. Access [**Doors**] [**Panels**]: [**Lift out**] [**Piano hinged with cam-lock fasteners**] [**Hinged with handles**] for burner and fan motor assemblies on both sides of unit.
 3. Internal Insulation: Fibrous-glass duct lining, neoprene coated, comply with ASTM C 1071, Type II, applied on [**complete unit**] [**burner and fan sections only**].
 - a. Thickness: [**1 inch (25 mm)**] [**2 inches (50 mm)**].
 - b. Insulation Adhesive: Comply with ASTM C 916, Type I.
 - c. Density: [**1.5 lb/cu. ft. ((24.0 kg/cu. m))**] [**2.0 lb/cu. ft. ((32.0 kg/cu. m))**] [**3.0 lb/cu. ft. ((48.0 kg/cu. m))**].
 - d. Mechanical Fasteners: Galvanized steel suitable for adhesive, mechanical, or welding attachment to casing without damaging liner when applied as recommended by manufacturer and without causing air leakage.
- G. Discharge Section: [**Galvanized**] [**Aluminized**]-steel assembly with [**gravity**] [**individually adjustable, vaned,**] [**two-position, motorized,**] parallel-blade dampers with nylon bushings.
1. Pattern: [**Single**] [**Double**] deflection.

2. Leakage: **[Standard]** **[Low]** leakage.
- H. Discharge Section: Trapezoidal cowls with horizontal louvers.
- I. Discharge Section: Plenum with **[two]** **[four]** sides louvered.
- J. Discharge Section: Down-discharge plenum insulated with **1 inch** (25 mm), **1.5 lb/cu. ft.** (24.0 kg/cu. m) fibrous glass.
- K. Casing Internal Insulation and Adhesive:
 1. Materials: ASTM C 1071, **[Type I]** **[Type II]**.
 2. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the heating-coil section.
 - a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive, mechanical, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have airstream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric, depending on service-air velocity.
 3. Location and Application: Encased between outside and inside casing.
- L. Inspection and Access Panels and Access Doors:
 1. Panel and Door Fabrication: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.
 2. Inspection and Access Panels:
 - a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.
 3. Access Doors:
 - a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Fabricate windows in **[fan section]** doors of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.

- d. Size: At least [18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension> wide by full height of unit casing up to a maximum height of [60 inches (1500 mm)] [72 inches (1800 mm)] <Insert dimension>.
4. Locations and Applications:
 - a. Fan Section: [Inspection and access panels] [Doors] [Doors and inspection and access panels].
 - b. Access Section: Doors.
 - c. Coil Section: Inspection and access panels.
 - d. Damper Section: [Inspection and access panels] [Doors].
 - e. Filter Section: [Inspection and access panels] [Doors] large enough to allow periodic removal and installation of filters.
 - f. Mixing Section: Doors.
 - g. Humidifier Section: Doors.
 5. Service Light: 100-W vaporproof fixture with switched junction box located [outside] [inside] adjacent to door.
 - a. Locations: [Each section accessed with door] [Fan section] <Insert location>.
- M. Condensate Drain Pans:
1. Fabricated with [one] [two] percent slope in at least two planes to collect condensate from condensate-producing heat exchangers and from humidifiers and to direct water toward drain connection.
 - a. Length: Extend drain pan downstream from leaving face [to comply with ASHRAE 62.1] <Insert distance>.
 - b. Depth: A minimum of [2 inches (50 mm)] <Insert dimension> deep.
 2. [Formed sections] [Integral part of floor plating].
 3. Single-wall, [galvanized] [stainless]-steel sheet.
 4. Double-wall, [galvanized] [stainless]-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
 5. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on [one end] [both ends] of pan.
 - a. Minimum Connection Size: [NPS 1 (DN 25)] [NPS 2 (DN 50)] <Insert pipe size>.
 6. Pan-Top Surface Coating: Asphaltic waterproofing compound.
- ## 2.4 ACCESSORIES
- A. Service Platform: [Steel] [Galvanized steel] [Aluminum], [42 inches (1070 mm)] <Insert dimension> wide running entire length of unit and located on service access side, with angle side rails, 4-inch (100-mm) kick plates, and expanded metal floor.

Provide platform with a fixed ladder that extends from the top of the side rail to the floor.

2.5 SUPPLY-AIR FAN

- A. Fan Type: Centrifugal, rated according to AMCA 210; statically and dynamically balanced, galvanized steel; mounted on solid-steel shaft with heavy-duty[, **self-aligning, permanently lubricated ball bearings**][, **pillow-block bearings rated for L50 or 200,000 hours with external grease fittings**].
- B. Drive: V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly.
- C. Mounting: Fan wheel, motor, and drives shall be mounted in fan casing with [**restrained,**] [**elastomeric**] [**spring**] isolators.
- D. Fan-Shaft Lubrication Lines: Extended to a location outside the casing.

2.6 AIR FILTERS

- A. Comply with [**NFPA 90A**] [**NFPA 90B**].
- B. Cleanable Filters: Cleanable metal mesh.
 - 1. Thickness: [**1 inch (25 mm)**] [**2 inches (50 mm)**].
 - 2. Maximum Face Velocity: **<Insert fpm ((m/s))>**.
- C. Disposable Panel Filters: Factory-fabricated, flat-panel-type, disposable air filters with holding frames[, **with a MERV 6 according to ASHRAE 52.2**].
 - 1. Thickness: [**1 inch (25 mm)**] [**2 inches (50 mm)**].
 - 2. Media: Interlaced [**glass**] [**polyester**] fibers.
 - 3. Frame: Galvanized steel.
 - 4. Maximum Face Velocity: **<Insert fpm ((m/s))>**.

2.7 DAMPERS

- A. Outdoor-Air [**and Return-Air**] Damper: Galvanized-steel, opposed-blade dampers with vinyl blade seals and stainless-steel jamb seals, having a maximum leakage of **10 cfm/sq. ft. (51 L/s per sq. m)** of damper area, at a differential pressure of **2-inch wg (448 Pa)**.
- B. Damper Operator: Direct coupled, electronic with spring return or fully modulating as required by the control sequence.

2.8 INDIRECT-FIRED GAS BURNER

- A. Description: Factory assembled, piped, and wired; and complying with ANSI Z21.47, "Gas-Fired Central Furnaces," and with NFPA 54, "National Fuel Gas Code."
1. CSA Approval: Designed and certified by and bearing label of CSA.
 2. Burners: [**Aluminized steel with stainless-steel inserts**] [**Stainless steel**].
 - a. Gas Control Valve: [**Single stage**] [**Two stage**] [**Modulating**].
 - b. Fuel: [**Natural**] [**Propane**] gas.
 - c. Minimum Combustion Efficiency: [**80**] <Insert number> percent.
 - d. Ignition: Electronically controlled electric spark with flame sensor.
 - e. High-Altitude [**Model**] [**Kit**]: For Project elevation above sea level.
- B. Venting: Gravity vented.
- C. Venting: Power vented, with integral, motorized centrifugal fan interlocked with gas valve.
- D. Combustion-Air Intake: Separate combustion-air intake and vent terminal assembly.
- E. Heat Exchanger: [**Aluminized**] [**Stainless**] steel.
- F. Heat-Exchanger Drain Pan: Stainless steel.
- G. Safety Controls:
1. Vent Flow Verification: [**Differential pressure switch to verify open vent**] [**Flame rollout switch**].
 2. Control Transformer: 24-V ac.
 3. High Limit: Thermal switch or fuse to stop burner.
 4. Gas Train: Regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, [**hydraulic**] [**electronic**]-modulating temperature control valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
 5. Purge-period timer shall automatically delay burner ignition and bypass low-limit control.
 6. Gas Manifold: Safety switches and controls complying with ANSI standards [**and**] [**FM Global**] [**XL Insurance**].
 7. Airflow Proving Switch: Differential pressure switch senses correct airflow before energizing pilot.
 8. Automatic-Reset, High-Limit Control Device: Stops burner and closes main gas valve if high-limit temperature is exceeded.
 9. Safety Lockout Switch: Locks out ignition sequence if burner fails to light after three tries. Controls are reset manually by turning the unit off and on.

2.9 UNIT CONTROL PANEL

- A. Factory-wired, fuse-protected control transformer, connection for power supply and field-wired unit to remote control panel.

- B. Control Panel: **[Surface-mounted] [Recessed, with trim ring,]** remote panel, with engraved plastic cover, and the following lights and switches:
1. **[On-off] [On-off-auto]** fan switch.
 2. Heat-vent-off switch.
 3. Supply-fan operation indicating light.
 4. Heating operation indicating light.
 5. Thermostat.
 6. Damper position potentiometer.
 7. Dirty-filter indicating light operated by unit-mounted differential pressure switch.
 8. Safety-lockout indicating light.
 9. Enclosure: NEMA 250, **[Type 1] [Type 3R] [Type 4] [Explosion proof]**.

2.10 CONTROLS

- A. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for control equipment and sequence of operation.
- B. Control Devices:
1. Remote Thermostat: Adjustable room thermostat with temperature readout.
 2. Remote Setback Thermostat: Adjustable room thermostat without temperature readout.
 3. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
 4. Fire-Protection Thermostats: Fixed or adjustable settings to operate at not less than **75 deg F (24 deg C)** above normal maximum operating temperature.
 5. Timers: Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
 6. Timers: Solid-state, programmable time control with four separate programs; 24-hour battery carryover; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; and system fault alarm.
 7. Ionization-Type Smoke Detectors: 24-V dc, nominal; self-restoring; plug-in arrangement; integral visual-indicating light; sensitivity that can be tested and adjusted in place after installation; integral addressable module; remote controllability; responsive to both visible and invisible products of combustion; self-compensating for changes in environmental conditions.
 8. Smoke detectors, located in supply **[and return]** air, shall stop fans when the presence of smoke is detected.
- C. Fan Control: Interlock fan to start with exhaust fan(s) to which this heating and ventilating unit is associated for makeup air.

- D. Fan Control: Timer starts and stops indirect-fired heating and ventilating unit and exhaust fan(s).
1. Smoke detectors, located in supply[**and return**] air, shall stop fans when the presence of smoke is detected.
- E. Outdoor-Air Damper Control, 100 Percent Outdoor-Air Units: Outdoor-air damper shall open when supply fan starts, and close when fan stops.
- F. Mixed Outdoor- and Return-Air Damper Control: When fan is running, outdoor- and return-air dampers shall modulate to supply minimum outdoor air as follows:
1. Minimum **[30]** **<Insert number>** percent outdoor air.
 2. Outdoor-air quantity adjusted by potentiometer on control panel.
 3. Outdoor-air quantity to maintain minimum building static pressure.
- G. Temperature Control: Operates gas valve to maintain supply-air temperature.
1. Operates gas valve to maintain discharge-air temperature with factory-mounted sensor in blower outlet.
 2. Operates gas valve to maintain space temperature with wall-mounted, field-wired sensor[**with temperature adjustment,**] **[and unit-mounted control adjustment]** **[and adjustment on remote-control panel]**.
 3. Timer shall select remote setback thermostat to maintain space temperature at **[50 deg F (10 deg C)]** **<Insert temperature>**.
 4. Burner Control: Two or four steps of control using one or two burner sections in series.
 5. Burner Control: 20 to 100 percent modulation of the firing rate. 10 to 100 percent with dual burner units.
- H. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display status and alarms of heating and ventilating unit.
1. Hardwired Points:
 - a. Room temperature.
 - b. Discharge-air temperature.
 - c. Burner operating.
 2. **[ASHRAE 135.1 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol]** **<Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the heating and ventilating unit from an operator workstation. Control features and monitoring points displayed locally at heating and ventilating unit control panel shall be available through the DDC system for HVAC.

2.11 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 2. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 3. Motor Bearings: <Insert requirements>.
 4. Unusual Service Conditions:
 - a. Ambient Temperature: <Insert deg C>.
 - b. Altitude: <Insert feet (m)> above sea level.
 - c. High humidity.
 - d. <Insert conditions>.
 5. Efficiency: [**Premium efficient**] [**EPAct compliant**].
 6. NEMA Design: <Insert designation>.
 7. Service Factor: <Insert value>.

2.12 CAPACITIES AND CHARACTERISTICS

- A. Fan:
1. Discharge Configuration: [**Horizontal**] [**Vertical**].
 2. Airflow: <Insert cfm (L/s)>.
 3. External Static Pressure: <Insert inches wg (kPa)>.
 4. Maximum RPM: <Insert number>.
 5. Minimum Size: <Insert inches (mm)>.
 6. Altitude: <Insert feet ((m))>.
- B. Fan Motor:
1. Horsepower: <Insert value>.
 2. RPM: <Insert value>.
 3. Service Factor: <Insert value>.
 4. Speed: [**Single**] [**Two**].
- C. Single-Point Electrical Connection:
1. Volts: [**120**] [**240**] [**277**] [**480**] <Insert voltage>.
 2. Phase: [**Single**] [**Three**].
 3. Hertz: 60.
 4. Full-Load Amperes: <Insert value>.
 5. Minimum Circuit Ampacity: <Insert value>.
 6. Maximum Overcurrent Protection: <Insert amperage>.

- D. Indirect-Fired Gas Burner:
1. Minimum Combustion Efficiency: <Insert number> percent.
 2. Entering-Air Temperature: <Insert deg F (deg C)>.
 3. Leaving-Air Temperature: <Insert deg F (deg C)>.
 4. Airflow: <Insert cfm (L/s)>.
 5. Gas Input: <Insert MBh (kW)>.
 6. Burner Output: <Insert MBh (kW)>.
 7. Number of Stages: <Insert value>.
 8. Minimum Inlet Pressure: <Insert inches wg ((Pa))>.
 9. Maximum Inlet Pressure: <Insert inches wg ((Pa))>.
 10. Gas Piping Connection Size: <Insert NPS ((DN))>.
 11. Vent Diameter: <Insert inches ((mm))>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of indirect-fired heating and ventilating units.
- B. Examine roughing-in for piping, ducts, and electrical systems to verify actual locations of connections before equipment installation.
- C. Verify cleanliness of airflow path to include inner-casing surfaces, filters, coils, turning vanes, fan wheels, and other components.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 1. Install heating and ventilating units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete. "] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Unit Support: Install heating and ventilating unit level on structural **[curbs] [pilings]**. Coordinate wall penetrations and flashing with wall construction. **[Secure units to structural support with anchor bolts.]**

- C. Install gas-fired units according to NFPA 54, "National Fuel Gas Code."
- D. Install controls and equipment shipped by manufacturer for field installation with indirect-fired heating and ventilating units.

3.3 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.
 - 1. Gas Piping: Comply with requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Connect gas piping with shutoff valve and union and with sufficient clearance for burner removal and service. Make final connections of gas piping to unit with corrugated, stainless-steel tubing flexible connectors complying with ANSI LC 1/CSA 6.26 equipment connections.
- B. Drain: Comply with requirements in Section 221316 "Sanitary Waste and Vent Piping" for traps and accessories on piping connections to condensate drain pans under condensing heat exchangers.
- C. Where installing piping adjacent to heating and ventilating units, allow space for service and maintenance.
- D. Duct Connections: Connect supply[**and return**] ducts to indirect-fired heating and ventilating units with flexible duct connectors. Comply with requirements in Section 233300 "Air Duct Accessories" for flexible duct connectors.
- E. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- F. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].
- C. Units will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - a. Inspect for visible damage to burner combustion chamber.
 - b. Inspect casing insulation for integrity, moisture content, and adhesion.
 - c. Verify that clearances have been provided for servicing.
 - d. Verify that controls are connected and operable.
 - e. Verify that filters are installed.
 - f. Purge gas line.
 - g. Inspect and adjust vibration isolators[**and seismic restraints**].
 - h. Verify bearing lubrication.
 - i. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
 - j. Adjust fan belts to proper alignment and tension.
 - k. Start unit according to manufacturer's written instructions.
 2. Complete startup sheets and attach copy with Contractor's startup report.
 3. Inspect and record performance of interlocks and protective devices; verify sequences.
 4. Operate unit for run-in period recommended by manufacturer.
 5. Perform the following operations for both minimum and maximum firing and adjust burner for peak efficiency:
 - a. Measure gas pressure at manifold.
 - b. Measure combustion-air temperature at inlet to combustion chamber.
 - c. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
 6. Calibrate thermostats.
 7. Adjust and inspect high-temperature limits.
 8. Inspect dampers, if any, for proper stroke and interlock with return-air dampers.
 9. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.
 10. Measure and record airflow. Plot fan volumes on fan curve.
 11. Verify operation of remote panel, including pilot-operation and failure modes. Inspect the following:
 - a. High-limit heat.
 - b. Alarms.
 12. After startup and performance testing, change filters, verify bearing lubrication, and adjust belt tension.
 13. Verify drain-pan performance.
 14. Verify outdoor-air damper operation.

3.6 ADJUSTING

- A. Adjust initial temperature set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain heating and ventilating units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237333.16

SECTION 237339 - INDOOR, DIRECT-FIRED HEATING AND VENTILATING UNITS

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes indoor, direct-fired heating and ventilating units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type and configuration of indoor, direct-fired heating and ventilating unit.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For each type and configuration of indoor, direct-fired heating and ventilating unit.
 - 1. Include plans, elevations, sections, and **[mounting] [attachment]** details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.3 INFORMATIONAL SUBMITTALS

- A. Sample Warranty: For manufacturer's special warranty.
- B. Seismic Qualification Certificates: For indoor, direct-fired heating and ventilating units, accessories, and components, from manufacturer.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and maintenance data.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 QUALITY ASSURANCE

- A. Comply with NFPA 70.
- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.6 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of direct-fired heating and ventilating units that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [AbsolutAire, Inc.](#)
 - 2. [Applied Air.](#)
 - 3. [ARES.](#)
 - 4. [Banza; a division of Roberts-Gordon LLC.](#)
 - 5. [BessamAire, Inc.](#)
 - 6. [Cambridge Engineering, Inc.](#)
 - 7. [Captive-Air Systems, Inc.](#)
 - 8. [Energy Jet U.S.](#)
 - 9. [Engineered Air.](#)

10. [Greenheck Fan Corporation.](#)
11. [Hastings Industries.](#)
12. [I.C.E. Manufacturing Ltd.; Industrial Commercial Equipment - I.C.E. \(US\), Inc.](#)
13. [Jackson & Church.](#)
14. [LC Systems.](#)
15. [Modine Mfg. Co.](#)
16. [Powrmatic, Inc.](#)
17. [Rapid Engineering, Inc.](#)
18. [Reznor-Thomas & Betts Corporation.](#)
19. [Sterling HVAC Products; a Mestek company.](#)
20. [Temprite.](#)
21. [Titan Air Incorporated.](#)
22. [Trane Company \(The\).](#)
23. [Weather-Rite, Inc.](#)
24. **<Insert manufacturer's name>.**
25. or approved equal.

2.2 SYSTEM DESCRIPTION

- A. Factory-assembled, prewired, self-contained unit consisting of cabinet, supply fan, controls, [**filters**,]and direct-fired gas burner to be installed exterior to the building.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 UNIT CASINGS

- A. General Fabrication Requirements for Casings:
 1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
 2. Casing Joints: Sheet metal screws or pop rivets, factory sealed with water-resistant sealant.
 3. Factory Finish for [**Steel**] [**and**] [**Galvanized-Steel**] Casings: Apply manufacturer's standard primer immediately after cleaning and pretreating.
 4. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling-unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when air-handling-unit frame is anchored to building structure.
 5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

- B. Configuration: Horizontal unit with **[top]** **[horizontal]** **[bottom]** discharge for **[floor-mounting]** **[suspended]** installation.
- C. Cabinet: Galvanized-steel panels, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs. Duct flanges at inlet and outlet.
- D. Outer Casing: **[0.0598-inch (1.519-mm)]** **[0.0478-inch ((1.214-mm))]** **[0.0359-inch ((0.912-mm))]** thick steel with **[heat-resistant, baked-enamel]** **[enamel-painted]** **[baked-on, polyester-powder]** **[unpainted]** over-corrosion-resistant-treated surface in color to match fan section.
- E. Outer Casing: **[0.0598-inch (1.519-mm)]** **[0.0478-inch ((1.214-mm))]** **[0.0359-inch ((0.912-mm))]** thick steel with unpainted finish.
- F. Outer Casing: **0.0359-inch ((0.912-mm))** thick steel with heat-resistant, baked-enamel over-corrosion-resistant-treated surface in color to match fan section.
- G. Inner Casing:
1. Burner Section Inner Casing: **0.0299-inch- (0.759-mm-)** thick steel.
 2. Double-wall casing with inner wall of **[perforated]** **[solid]** steel[.][, **for the following sections:**]
 - a. Blower section.
 - b. Filter section.
 - c. Mixing box.
 - d. Inlet plenum.
 - e. Discharge plenum.
 - f. Access **[Doors]** **[Panels]:** **[Lift out]** **[Piano hinged with cam-lock fasteners]** **[Hinged with handles]** for burner and fan motor assemblies on both sides of unit.
 3. Internal Insulation: Fibrous-glass duct lining, neoprene coated, comply with ASTM C 1071, Type II, applied on **[complete unit]** **[burner and fan sections only]**.
 - a. Thickness: **[1 inch (25 mm)]** **[2 inches (50 mm)]**.
 - b. Insulation Adhesive: Comply with ASTM C 916, Type I.
 - c. Density: **[1.5 lb/cu. ft. ((24.0 kg/cu. m))]** **[2.0 lb/cu. ft. ((32.0 kg/cu. m))]** **[3.0 lb/cu. ft. ((48.0 kg/cu. m))]**.
 - d. Mechanical Fasteners: Galvanized steel suitable for adhesive, mechanical, or welding attachment to casing without damaging liner when applied as recommended by manufacturer and without causing air leakage.
- H. Discharge Section: **[Galvanized]** **[Aluminized]**-steel assembly with **[gravity]** **[individually adjustable, vaned,]** **[two-position, motorized,]** parallel-blade dampers with nylon bushings.
1. Pattern: **[Single]** **[Double]** deflection.

2. Leakage: **[Standard]** **[Low]** leakage.

- I. Discharge Section: Trapezoidal cowls with horizontal louvers.
- J. Discharge Section: Plenum with **[two]** **[four]** sides louvered.
- K. Discharge Section: Down-discharge plenum insulated with **1-inch** (25-mm), **1.5-lb/cu. ft.** (24.0-kg/cu. m) fibrous glass.
- L. Casing Insulation and Adhesive:
 - 1. Materials: ASTM C 1071, **[Type I]** **[Type II]**.
 - 2. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the heating-coil section.
- M. Inspection and Access Panels and Access Doors: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing and complying with ASHRAE 62.1.

2.4 ACCESSORIES

- A. Service Platform: **[Steel]** **[Galvanized steel]** **[Aluminum]**, **[42 inches** (1070 mm)**]** **<Insert dimension>** wide running entire length of unit and located on service access side, with angle side rails, **4-inch** (100-mm) kick plates, and expanded metal floor. Provide platform with a fixed ladder that extends from the top of the side rail to the floor.

2.5 SUPPLY-AIR FAN

- A. Fan Type: Centrifugal, rated according to AMCA 210; statically and dynamically balanced, galvanized steel; mounted on solid-steel shaft with heavy-duty[]], **self-aligning, permanently lubricated ball bearings]**, **pillow-block bearings]**. Bearing rating: **[L10 of 60,000 hours]** **[L10 of 120,000 hours]** **[L10 of 150,000 hours]** **<Insert value>**.
- B. Drive: V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly.
- C. Mounting: Fan wheel, motor, and drives shall be mounted in fan casing with **[restrained,]** **[elastomeric]** **[spring]** isolators.
- D. Fan-Shaft Lubrication Lines: Extended to a location outside the casing.

2.6 AIR FILTERS

- A. Comply with **[NFPA 90A]** **[NFPA 90B]**.

- B. Cleanable Filters: Cleanable metal mesh; [1 inch (25 mm)] [2 inches (50 mm)].
- C. Disposable Panel Filters: Factory-fabricated, flat-panel-type, disposable air filters; 1 inch (25 mm).

2.7 DAMPERS

- A. Outdoor-Air [**and Return-Air**] Damper: Galvanized-steel, opposed-blade dampers with vinyl blade seals and stainless-steel jamb seals, having a maximum leakage of 10 cfm/sq. ft. (51 L/s per sq. m) of damper area, at a differential pressure of 2-inch wg (448 Pa).
- B. Damper Operator: Direct coupled, electronic with spring return or fully modulating as required by the control sequence.

2.8 DIRECT-FIRED GAS BURNER

- A. Description: Factory assembled, piped, and wired; and complying with ANSI Z21.47, "Gas-Fired Central Furnaces," and with NFPA 54, "National Fuel Gas Code."
 - 1. CSA Approval: Designed and certified by and bearing label of CSA.
 - 2. Burners: [**Aluminized steel with stainless-steel inserts**] [**Stainless steel**].
 - a. Gas Control Valve: [**Single stage**] [**Two stage**] [**Modulating**].
 - b. Rated maximum turndown ratio of 30 to 1.
 - c. Fuel: [**Natural**] [**Propane**] gas.
 - d. Minimum Combustion Efficiency: [**95**] <Insert number> percent.
 - e. Ignition: Electronically controlled electric spark with flame sensor.
 - f. High-Altitude [**Model**] [**Kit**]: For Project elevation above sea level.
- B. Safety Controls:
 - 1. Vent Flow Verification: [**Differential pressure switch to verify open vent**] [**Flame rollout switch**].
 - 2. Control Transformer: 24-V ac.
 - 3. High Limit: Thermal switch or fuse to stop burner.
 - 4. Gas Train: Regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, [**hydraulic**] [**electronic**]-modulating temperature control valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
 - 5. Purge-period timer shall automatically delay burner ignition and bypass low-limit control.
 - 6. Gas Manifold: Safety switches and controls complying with ANSI standards [**and**] [**FM Global**] [**XL Insurance**].
 - 7. Airflow Proving Switch: Differential pressure switch senses correct airflow before energizing pilot.
 - 8. Automatic-Reset, High-Limit Control Device: Stops burner and closes main gas valve if high-limit temperature is exceeded.

9. Safety Lockout Switch: Locks out ignition sequence if burner fails to light after three tries. Controls are reset manually by turning the unit off and on.

2.9 UNIT CONTROL PANEL

- A. Factory-wired, fuse-protected control transformer, connection for power supply and field-wired unit to remote control panel.
- B. Control Panel: [**Surface-mounted**] [**Recessed, with trim ring,**] remote panel, with engraved plastic cover and the following lights and switches:
 1. [**On-off**] [**On-off-auto**] fan switch.
 2. Heat-vent-off switch.
 3. Supply-fan operation indicating light.
 4. Heating operation indicating light.
 5. Thermostat.
 6. Damper position potentiometer.
 7. Dirty-filter indicating light operated by unit-mounted differential pressure switch.
 8. Safety-lockout indicating light.
 9. Enclosure: NEMA 250, [**Type 1**] [**Type 3R**] [**Type 4**] [**Explosion proof**].

2.10 CONTROLS

- A. Control Devices:
 1. Remote Thermostat: Adjustable room thermostat with temperature readout.
 2. Remote Setback Thermostat: Adjustable room thermostat without temperature readout.
 3. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
 4. Fire-Protection Thermostats: Fixed or adjustable settings to operate at not less than **75 deg F (24 deg C)** above normal maximum operating temperature.
 5. Timers: Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
 6. Ionization-Type Smoke Detectors: 24-V dc, nominal; self-restoring; plug-in arrangement; integral visual-indicating light; sensitivity that can be tested and adjusted in place after installation; integral addressable module; remote controllability; responsive to both visible and invisible products of combustion; self-compensating for changes in environmental conditions.
- B. Fan Control: Interlock fan to start with exhaust fan(s) to which this heating and ventilating unit is associated for makeup air.
- C. Smoke detectors, located in supply[**and return**] air, shall stop fans when the presence of smoke is detected.

- D. Outdoor-Air Damper Control, 100 Percent Outdoor-Air Units: Outdoor-air damper shall open when supply fan starts, and close when fan stops.
- E. Mixed Outdoor- and Return-Air Damper Control: When fan is running, outdoor- and return-air dampers shall modulate to supply minimum outdoor air.
- F. Temperature Control: Operates gas valve to maintain supply-air temperature.
 - 1. Operates gas valve to maintain discharge-air temperature with factory-mounted sensor in blower outlet.
 - 2. Timer shall select remote setback thermostat to maintain space temperature at **[50 deg F (10 deg C)] <Insert temperature>**.
 - 3. Burner Control: Two or four steps of control using one or two burner sections in series.

2.11 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1. Enclosure: **[Open, dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over] [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine]**.
 - 2. Enclosure Materials: **[Cast iron] [Cast aluminum] [Rolled steel]**.
 - 3. Motor Bearings: **<Insert requirements>**.
 - 4. Unusual Service Conditions:
 - a. Ambient Temperature: **<Insert deg C>**.
 - b. Altitude: **<Insert feet (m)>** above sea level.
 - c. High humidity.
 - d. **<Insert conditions>**.
 - 5. Efficiency: **[Premium efficient] [EPA compliant]**.
 - 6. NEMA Design: **<Insert designation>**.
 - 7. Service Factor: **<Insert value>**.

2.12 CAPACITIES AND CHARACTERISTICS

- A. Fan:
 - 1. Discharge Configuration: **[Horizontal] [Vertical]**.
 - 2. Airflow in CFM (L/s): **<Insert quantity>**.
 - 3. External Static Pressure: **<Insert inches wg (kPa)>**.
 - 4. Maximum RPM: **<Insert number>**.
 - 5. Minimum Size: **<Insert inches (mm)>**.
 - 6. Altitude: **<Insert feet ((m))>**.

B. Fan Motor:

1. Horsepower: <Insert value>.
2. RPM: <Insert value>.
3. Service Factor: <Insert value>.
4. Speed: [Single] [Two].

C. Single-Point Electrical Connection:

1. Volts: [120] [240] [277] [480] <Insert value>.
2. Phase: [Single] [Three].
3. Hertz: 60.
4. Full-Load Amperes: <Insert value>.
5. Minimum Circuit Ampacity: <Insert value>.
6. Maximum Overcurrent Protection: <Insert amperage>.

D. Direct-Fired Gas Burner:

1. Minimum Combustion Efficiency: <Insert number> percent.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Airflow: <Insert cfm (L/s)>.
5. Gas Input: <Insert MBh (kW)>.
6. Burner Output: <Insert MBh (kW)>.
7. Number of Stages: <Insert value>.
8. Minimum Inlet Pressure: <Insert inches wg ((Pa))>.
9. Maximum Inlet Pressure: <Insert inches wg ((Pa))>.
10. Gas Piping Connection Size: <Insert NPS ((DN))>.
11. Vent Diameter: <Insert inches ((mm))>.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Equipment Mounting:

1. Install heating and ventilating units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

B. Unit Support: Install heating and ventilating unit level on structural [curbs] [pilings]. Coordinate wall penetrations and flashing with wall construction.[Secure units to structural support with anchor bolts.]

- C. Install gas-fired units according to NFPA 54, "National Fuel Gas Code."
- D. Install controls and equipment shipped by manufacturer for field installation with direct-fired heating and ventilating units.
- E. Install seismic restraints according to manufacturer's written instructions.

3.2 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.
 - 1. Gas Piping: Comply with requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Connect gas piping with shutoff valve and union, and with sufficient clearance for burner removal and service. Make final connections of gas piping to unit with corrugated, stainless-steel tubing flexible connectors complying with ANSI LC 1/CSA 6.26 equipment connections.
- B. Duct Connections: Connect supply[**and return**] ducts to direct-fired heating and ventilating units with flexible duct connectors. Comply with requirements in Section 233300 "Air Duct Accessories" for flexible duct connectors.
- C. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

- A. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].
- B. Units will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.4 ADJUSTING

- A. Adjust initial temperature set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain heating and ventilating units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237339

SECTION 237413 - PACKAGED, OUTDOOR, CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes packaged, outdoor, central-station air-handling units (rooftop units) with the following components and accessories:
 - 1. Direct-expansion cooling.
 - 2. Heat-pump refrigeration components.
 - 3. Hot-gas reheat.
 - 4. Electric-heating coils.
 - 5. Gas furnace.
 - 6. Economizer outdoor- and return-air damper section.
 - 7. Integral, space temperature controls.
 - 8. Roof curbs.
- B. Related Sections include the following:
 - 1. Section 237333.16 "Indoor, Indirect, Gas-Fired Heating and Ventilating Units" for outdoor units providing 100 percent tempered outdoor air with heat exchangers.
 - 2. Section 237339 "Indoor, Direct-Fired Heating and Ventilating Units" for outdoor units providing 100 percent tempered outdoor air without heat exchangers.
 - 3. Section 237433 "Dedicated Outdoor-Air Units" for outdoor equipment air conditioning 100 percent outdoor air to replace air exhausted from a building.
- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. DDC: Direct-digital controls.
- B. ECM: Electrically commutated motor.
- C. Outdoor-Air Refrigerant Coil: Refrigerant coil in the outdoor-air stream to reject heat during cooling operations and to absorb heat during heating operations. "Outdoor air"

is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

- D. Outdoor-Air Refrigerant-Coil Fan: The outdoor-air refrigerant-coil fan in RTUs. "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.
- E. RTU: Rooftop unit. As used in this Section, this abbreviation means packaged, outdoor, central-station air-handling units. This abbreviation is used regardless of whether the unit is mounted on the roof or on a concrete base on ground.
- F. Supply-Air Fan: The fan providing supply air to conditioned space. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.
- G. Supply-Air Refrigerant Coil: Refrigerant coil in the supply-air stream to absorb heat (provide cooling) during cooling operations and to reject heat (provide heating) during heating operations. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.
- H. VVT: Variable-air volume and temperature.

1.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design RTU supports to comply with **[wind] [and] [seismic]** performance requirements, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Wind-Restraint Performance:
 - 1. Basic Wind Speed: **<Insert value>**.
 - 2. Building Classification Category: **[I] [II] [III] [IV]**.
 - 3. Minimum **10 lb/sq. ft (48.8 kg/sq. m)** multiplied by the maximum area of the mechanical component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.
- C. Seismic Performance: RTUs shall withstand the effects of earthquake motions determined according to **[SEI/ASCE 7] <Insert requirement>**.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

1.5 ACTION SUBMITTALS

- A. Product Data: Include manufacturer's technical data for each RTU, including rated capacities, dimensions, required clearances, characteristics, weights, fan performance,

gages, and finishes of materials, electrical characteristics, connection requirements, furnished specialties, and accessories.

1. Provide data for filter media, filter performance data, filter assembly, and filter frames.
2. Provide fan curves with specified operating point clearly plotted.
3. Submit sound power level data for both fan outlet and casing radiation at rated capacity.
4. Submit electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
5. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
2. Wiring Diagrams: Power, signal, and control wiring.

D. Delegated-Design Submittal: For RTU supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
2. Detail mounting, securing, and flashing of roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
3. **[Wind-] [and] [Seismic-]**Restraint Details: Detail fabrication and attachment of wind and seismic restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Structural members to which RTUs will be attached.
 2. Roof openings
 3. Roof curbs and flashing.
- B. Manufacturer Wind Loading Qualification Certification: Submit certification that specified equipment shall withstand wind forces identified in "Performance Requirements" Article and in Section 230548 "Vibration and Seismic Controls for HVAC."
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculations.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of wind force and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Manufacturer Seismic Qualification Certification: Submit certification that RTUs, accessories, and components will withstand seismic forces defined in "Performance Requirements" Article and in Section 230548 "Vibration and Seismic Controls for HVAC."
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Field quality-control test reports.
- E. Warranty: Special warranty specified in this Section.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For RTUs to include in emergency, operation, and maintenance manuals.
1. Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fan Belts: **[One (1) set]** [**<Insert number> sets**] for each belt-driven fan.
 2. Filters: **[One (1) set]** [**<Insert number> sets**] of filters for each unit.

1.9 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this Section with minimum three (3) years documented experience, who issues complete catalog data on total product.
- B. ARI Compliance:
1. Comply with ARI 203/110 and ARI 303/110 for testing and rating energy efficiencies for RTUs.
 2. Comply with ARI 270 for testing and rating sound performance for RTUs.
- C. ASHRAE Compliance:
1. Comply with ASHRAE 15 for refrigeration system safety.
 2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.
 3. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- E. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.
- F. UL Compliance: Comply with UL 1995.
- G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.10 ENVIRONMENTAL REQUIREMENTS

- A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.
- B. Do not operate units for temporary heating or cooling prior to substantial completion without approval by DEN Project Manager.

1.11 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Accept products on site in factory-fabricated protective containers, with factory-installed shipping skids and lifting lugs. Inspect for damage.
- C. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.

1.12 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components of RTUs that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Compressors: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.
 - 2. Warranty Period for Gas Furnace Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] [ten (10)] [fifteen (15)] [twenty (20)] <Insert number>** years from date of Substantial Completion.
 - 3. Warranty Period for Solid-State Ignition Modules: Manufacturer's standard, but not less than **[three (3)] <Insert number>** years from date of Substantial Completion.
 - 4. Warranty Period for Control Boards: Manufacturer's standard, but not less than **[three (3)] <Insert number>** years from date of Substantial Completion.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. [AAON, Inc.](#)
 - 2. [Addison Products Company.](#)
 - 3. [Carrier Corporation.](#)
 - 4. [Engineered Air.](#)
 - 5. [Lennox Industries Inc.](#)

6. [McQuay International](#).
7. [Trane; American Standard Companies, Inc.](#)
8. [YORK International Corporation](#).
9. <Insert manufacturer's name>.
10. or approved equal.

2.2 CASING

- A. General Fabrication Requirements for Casings: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.
1. Fabricate on channel base, welded frame construction and drain pan of welded steel coated externally with manufacturers standard paint finish. Assemble sections with gaskets and bolts. Casing/frame assembly shall be capable of withstanding 30 lb. per square foot snow load and 100 MPH winds.
- B. Exterior Casing Material: G-90 galvanized steel, phosphatized, with factory-painted finish of **[baked enamel] [zinc chromate, iron oxide, phenolic resin paint] [asphalt base coating formulated to protect surfaces, seal seams and joints, and provide insulation and sound deadening] [three coat system of epoxy applied over shot blasted surface, to total thickness of 5-6 mils]** with pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.
1. Finish: Unit base, framework, and fan assembly shall be painted with 3 mil thick industrial primer with built in rust inhibitors and one coat of DTM enamel.
 2. Weatherproof Casing Finish: Seal fixed joints with flexible weather tight sealer. Seal removable joints with closed-cell foam gasket. Pitch roof panels for drainage. Reinforce roof for winter snow loading. Provide cap strips over roof flanges. Provide rain caps and gaskets on access doors.
 3. Exterior Casing Thickness: **[0.052 inch (1.3 mm)] [0.0626 inch (1.6 mm)] [0.079 inch (2.0 mm)] <Insert thickness>** thick.
- C. Inner Casing Fabrication Requirements:
1. Inside Casing: Galvanized steel, **[0.034 inch (0.86 mm)] [0.028 inch (0.7 mm)] <Insert thickness>** thick[, **perforated 40 percent free area**].
- D. Casing Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
1. Materials: ASTM C 1071, Type I.
 2. Thickness: **[2] <Insert number>** inch thick, 3 lbs per cu ft density, neoprene coated, glass fiber insulation, "K" value at 75 degrees F maximum 0.26 Btu/inch/sq ft/degrees F/hr, applied to internal surfaces with adhesive and secured with pins and washers. Coat exposed edges of insulation with adhesive.
 3. Liner materials shall have air-stream surface coated with an erosion- and temperature-resistant coating or faced with a plain or coated fibrous mat or fabric.
 4. Liner Adhesive: Comply with ASTM C 916, Type I.

- E. Walk-in Access Doors: **[18 x 40] [24 x 48] [24 x 60] [30 x 60] [30 x 72]** inch of galvanized steel insulated sandwich construction, for flush mounting, with hinges, gasket, latch, and handle assemblies [, **and 12 X 12 inch inspection window of 1/4 inch thick plexiglass**]. **[Provide welded channel frame to set door out from casing to permit external insulation.]**
- F. Inspection Doors: 10 x 10 inch, of galvanized steel for flush mounting, with gasket, latch, and handle assembly **[and 1/4 inch thick plexiglass inspection window]**. **[Provide welded channel frame to set door out from casing to permit external insulation.]**
- G. Inspection Doors: 18 x 22 inch of galvanized steel for flush mounting, with gasket, latch, and handle assemblies **[and 12 x 12 inch inspection window of 1/4 inch thick plexiglass]**. **[Provide welded channel frame to set door out from casing to permit external insulation.]**
- H. Louvers: **[Stationary] [Adjustable]**, of galvanized steel, **[4] [6]** inch deep with plenum, **[nylon bearings,]** 1/2 inch mesh, 0.04 inch galvanized wire bird screen in **[aluminum] [galvanized]** frame, and bearing AMCA Certified Ratings Seal in accordance with AMCA 500. **[Furnish adjustable louvers with hollow vinyl bulb edging on blades and foam side stops to limit leakage to maximum 2 percent at 4-inch wg differential pressure when sized for 2000 fpm face velocity.]**
- I. Condensate Drain Pans: Formed sections of **[single] [double]** thickness **[galvanized] [stainless]**-steel sheet, a minimum of **2 inches (50 mm)** deep[, **and complying with ASHRAE 62.1**], **[with insulation between layers]** with welded corners. Cross break and pitch to drain connection. Provide drain pans under **[fan section] [heating coil section] [cooling coil section] [mixing section] [humidifier section] [plenum sections] [with asphalt base coating]**. Provide drain pans under cooling coil section outside air section with asphalt base coating. Humidifier drain section shall be constructed of 304 stainless steel.
1. Double-Wall Construction: Fill space between walls with foam insulation and seal moisture tight.
 2. Drain Connections: Threaded nipple[**both sides of drain pan**].
 3. Pan-Top Surface Coating: Corrosion-resistant compound.
 4. Provide vapor-sealed 1-inch thick insulation under drain pan, and 1-inch trapped drain discharging to roof surface.
- J. Supplemental Condensate Drain Pans:
1. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air-conditioning equipment.
 2. Supplemental drain pans to be constructed of 20 gauge (minimum) galvanized

- steel, minimum depth 2 inches, fabricated, braced, and supported to ensure stability.
3. Provide drain piping conforming to provisions 221116 "Domestic Water Piping" and other Division 22 Sections, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.
- K. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- L. Bottom Inlet/outlet Units: Provide steel or aluminum walking grate on structural supports.
- M. Strength: Provide structure to brace casings for suction pressure of 4-inch wg, with maximum deflection of 1 in 200.

2.3 FANS

- A. Direct-Driven Supply-Air Fans: Double width, **[forward curved]** **[backward inclined]**, centrifugal; with permanently lubricated, **[multispeed]** **[ECM]** motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and galvanized- or painted-steel fan scrolls.
- B. Belt-Driven Supply-Air Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the casing. Aluminum or painted-steel wheels, and galvanized- or painted-steel fan scrolls.
- C. Condenser-Coil Fan: Propeller, mounted on shaft of permanently lubricated motor.
- D. Relief-Air Fan: **[Propeller]** **[Forward curved]** **[Backward inclined]**, shaft mounted on permanently lubricated motor.
- E. Seismic Fabrication Requirements: Fabricate fan section, internal mounting frame and attachment to fans, fan housings, motors, casings, accessories, and other fan section components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when fan-mounted frame and RTU-mounted frame are anchored to building structure.
- F. Fan Motor: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
- G. Mounting: Locate fan and motor internally on welded steel base coated with corrosion resistant paint. Factory mount motor on slide rails. Provide access to motor, drive, and bearings through removable casing panels or hinged access doors. Mount base on vibration isolators. Refer to Section 230548.13 "Vibration Controls for HVAC".
- H. Flexible Connection: Separate fan, discharge, and coil sections. Refer to Section 233300 "Air Duct Accessories".

- I. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

2.4 BEARINGS AND DRIVES

- A. Bearings: AFBMA 9, AFBMA 11, L-10 life at 120,000 hours pillow block type, self-aligning, grease-lubricated roller bearings.
- B. Shafts: Solid, hot rolled steel, ground and polished, with key-way, and protectively coated with lubricating oil.
- C. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, bored to fit shafts and keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
- D. Belt Guard: Fabricate to SMACNA Standard; 12 gage thick, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

2.5 COILS

- A. Casing: Provide access to both sides of coils. Enclose coils with headers and return bends fully contained within casing. Slide coils into casing through removable end panel with blank off sheets and sealing collars at connection penetrations.
- B. Eliminators: Three break of galvanized steel on coils, and Type 304 stainless steel on evaporative humidifier, mounted over drain pan.
- C. Supply-Air Refrigerant Coil:
1. **[Aluminum] [Copper]**-plate fin and seamless **[internally grooved]** copper tube in steel casing with equalizing-type vertical distributor.
 2. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.
 3. Coil Split: Interlaced.
 4. **[Baked phenolic] [Cathodic epoxy]** coating.
 5. Condensate Drain Pan: **[Galvanized steel with corrosion-resistant coating] [Stainless steel]** formed with pitch and drain connections **[complying with ASHRAE 62.1]**. 24 inch downstream of coil and down spouts for cooling coil banks more than one coil high.

D. Outdoor-Air Refrigerant Coil:

1. **[Aluminum] [Copper]**-plate fin and seamless **[internally grooved]** copper tube in steel casing with equalizing-type vertical distributor.
2. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.
3. **[Baked phenolic] [Cathodic epoxy]** coating.

E. Hot-Gas Reheat Refrigerant Coil:

1. **[Aluminum] [Copper]**-plate fin and seamless **[internally grooved]** copper tube in steel casing with equalizing-type vertical distributor.
2. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.
3. **[Baked phenolic] [Cathodic epoxy]** coating.

F. Electric-Resistance Heating:

1. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.
2. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box.
3. Overcurrent Protection: Manual-reset thermal cutouts, factory wired in each heater stage.
4. Control Panel: Unit mounted with disconnecting means and overcurrent protection. Include the following controls:
 - a. **[Magnetic] [Mercury]** contactors.
 - b. Step Controller: Pilot lights and override toggle switch for each step.
 - c. SCR Controller: Pilot lights operate on load ratio, a minimum of five steps.
 - d. Time-delay relay.
 - e. Airflow proving switch.

2.6 REFRIGERANT CIRCUIT COMPONENTS

A. Number of Refrigerant Circuits: **[One (1)] [Two (2)] <Insert number>**.

B. Compressor: **[Hermetic, reciprocating] [Semihhermetic, reciprocating] [Hermetic, scroll]**, mounted on vibration isolators; with internal overcurrent and high-temperature protection, internal pressure relief, **and crankcase heater**].

C. Refrigeration Specialties:

1. Refrigerant: **[R-22] [R-407C] [R-410A] <Insert type>**.
2. Refrigerant: R-407C or R-410A.
3. Expansion valve with replaceable thermostatic element.

4. Refrigerant filter/dryer.
5. Manual-reset high-pressure safety switch.
6. Automatic-reset low-pressure safety switch.
7. Minimum off-time relay.
8. Automatic-reset compressor motor thermal overload.
9. Brass service valves installed in compressor suction and liquid lines.
10. Low-ambient kit high-pressure sensor.
11. Hot-gas reheat solenoid valve with a replaceable magnetic coil.
12. Hot-gas bypass solenoid valve with a replaceable magnetic coil.
13. Four-way reversing valve with a replaceable magnetic coil, thermostatic expansion valves with bypass check valves, and a suction line accumulator.

2.7 SPRAYED COIL DEHUMIDIFIER

- A. Units: Assembly with casing, tank, nozzles, spray headers, eliminators, water and drain connections [, **spray pump**,] and cooling coils. [**Refer to Section 238413 "Humidifiers".**]
- B. Insulation: Externally insulate casing. Mount on 2-inch thick rigid insulation board.
- C. Performance: Operate at [**3 inch wg negative**] [**3 inch wg positive**] [**6 inch wg positive**] operating static pressure.
- D. Coil: Refer to coil specification for size and cooling capacity.
- E. Casing: 14 gage galvanized steel reinforced and braced with galvanized angles.
- F. Drain Tank: [**10 gage**] [**3/16 inch**] welded black steel with coating of [**1/8 inch waterproof mastic**] [**3/32 inch minimum epoxy**].] [**glass fiber reinforced plastic.**] [**10 gage stainless steel.**] Provide with 2" drain, 1-1/2" water make-up connection, and 3" overflow connection.
- G. Coils: Copper, drainable.
- H. Spray Headers: Galvanized steel pipe.
- I. Spray Nozzles: Bronze, self-cleaning.
- J. Spray Pump: Vertical in-line operating at 1750 rev/min.
- K. Float Valve: Adjustable, with brass rod, brass float ball, and brass valve with replaceable neoprene seat.
- L. Low Water Cut-off: Float operated.

2.8 HUMIDIFIER

- A. Humidifiers: Certify capacities and selection in accordance with ARI 610.

- B. Steam Grid Humidifier: Stainless steel distribution tube with evenly spaced orifices extended full width of unit, factory mounted **[in plenum with drain pan for draw-thru units] [in diffuser section of blow-thru units]**. **[Refer to Section 238413 "Humidifiers".]**
- C. Evaporative Pan Humidifier: Factory mounted in plenum with drain pan, float box, copper pan, water immersion type sheathed heating element, and low water cut-off switch. **[Refer to Section 238413 "Humidifiers".]**
- D. Wet Glass Cell Washer: Section with 3-inch deep cells with random packed, glass fiber media in **[galvanized] [stainless]** steel frames, access door, spray tree assembly with **[brass] [stainless steel]** nozzles and **[galvanized] [stainless]** steel piping, and **[galvanized] [stainless]** steel eliminator plates. Assemble over welded **[stainless]** steel tank **[with interior and exterior surfaces blasted and painted with zinc chromate paint.]** Provide copper suction screen, drain, overflow, and suction connections in tank with make-up connection, **[brass]** float valve, and quick-fill connection. Insulate exterior with duct insulation. Mount tank on 2-inch thick rigid closed-cell insulation board.
- E. Evaporative Humidifier: Section with watertight **[cast iron]** door with brass fittings, wire glass window, and locking handles, **[spray tree assembly with brass nozzles and galvanized piping, galvanized eliminator plates with flooding nozzles and header, and galvanized anti-splash baffles] [water distribution assembly with brass nozzles and galvanized piping and cross fluted cellulose media]**. Assemble over welded steel tank with interior and exterior surfaces blasted and painted with zinc chromate paint. Provide copper suction screen, drain, overflow, and suction connections in tank with make-up connection, **[brass]** float valve, and quick-fill connection. Insulate exterior with duct insulation. Mount tank on 2-inch thick rigid closed-cell insulation board. **[Refer to Section 238413 "Humidifiers".]**

2.9 AIR BLENDERS

- A. For air handling units as indicated, provide casing section fitted with static air mixing devices. Each section shall be designed to accurately match flange geometry and bolting provisions of adjacent sections, and air mixing device assembly design shall be established by the air blender manufacturer to ensure specified mixing performance for the airflow rates and flow patterns produced by air handler configurations. Furnish blender section mixing box generally consisting of air blenders and mixing section fitted together in one rigid unit, as shown on drawings.
- B. Housing shall be constructed of 18-gage steel finished with corrosion resistant paint or zinc coating. Housing shall be manufactured and sized to fit up to air handler unit without any major field modification. Housing shall be internally insulated the same as specified for the air handler unit casings.
- C. The Blender of the blender section shall incorporate a minimum of 0.08 in thick, (0.125 in for blenders larger than 96 inches), all welded multiple static mixing devices which shall impart a patented counter rotational mixing of the air stream thereby producing a minimum standard deviation through a plane parallel with the blenders between

entering air stream. Simple mixing devices, which do not produce counter rotational mixed air streams as described above, will not be acceptable. The pressure drop through the blender section shall not exceed 0.1 inch WG at 400 ft/min plenum velocity, 0.15 inch WG at 500 ft/min plenum velocity, or 0.2 inches WG at 600 ft/min plenum velocity. The blender's performance range shall be from 600 through 2500 ft/min with no loss in mixing performance.

- D. The unit shall be capable of providing a minimum mixing effectiveness of 75% and +/- 6 degrees F standard deviation when mixing at 50% OA with 50% RA at 50 degrees F inlet temperature differential, and minimum mixing effectiveness of 80% and +/- 5 degrees F standard deviation when mixing 30% OA with 70% RA at 50 degrees F inlet temperature differential. The mixing section shall provide acceptable performance throughout the entire operating range of the air handler, including system turn down.
- E. The velocity profile at the blender section discharge shall provide uniform velocity across filters, coils and control thermostats to insure proper performance and accurate temperature sensing. The mixing section shall yield a minimum Velocity Variation Coefficient (Cv) of 0.3 based on the following expression:
1. $Cv = Vsd/Vave$. Where:
 - a. Vsd = Velocity Standard Deviation, and
 - b. Vave = Average Plenum Velocity.
- F. The unit shall have provisions for floor or ceiling mounting corresponding to mounting provisions forming a part of the air handling unit assembly in which the blended unit is installed. Each blender section shall be equipped with connection flanges, sized to match the inlet side of the Air Handling Unit and outlet of mixing box, with no additional or field transitions necessary.

2.10 AIR FILTRATION

- A. Filter Box: Section with filter guides, access doors from both sides, for face loading.
- B. Filter Media: UL 900 listed, Class I or Class II, approved by local authorities.
- C. Flat Panel Prefilter: Arrangement with 2 and 4-inch deep disposable, extended area panel filters.
- D. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
1. Glass Fiber: Minimum [80] <Insert number> percent arrestance, and [MERV 5] <Insert value>.
 2. Pleated: Minimum [90] <Insert number> percent arrestance, and [MERV 7] <Insert value>.

2.11 GAS FURNACE

- A. Description: Factory assembled, piped, and wired; complying with ANSI Z21.47 and NFPA 54.
 - 1. CSA Approval: Designed and certified by and bearing label of CSA.
- B. Burners: Stainless steel.
 - 1. Fuel: **[Natural] [Propane]** gas.
 - 2. Ignition: Electronically controlled electric spark or hot-surface igniter with flame sensor.
 - 3. High-Altitude **[Model] [Kit]**: For Project elevations more than 2000 feet (610 m) above sea level.
- C. Heat Exchanger and Drain Pan: Stainless steel.
- D. Venting: Gravity vented[**with vertical extension**].
- E. Power Vent: Integral, motorized centrifugal fan interlocked with gas valve[**with vertical extension**].
- F. Safety Controls:
 - 1. Gas Control Valve: **[Single stage] [Two stage] [Modulating]**.
 - 2. Gas Train: Single-body, regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff.

2.12 DAMPERS

- A. Outdoor-Air Damper: Linked damper blades, for 0 to 25 percent outdoor air, with **[manual] [motorized]** damper filter.
- B. Outdoor- and Return-Air Mixing Dampers: Parallel- or opposed-blade galvanized-steel dampers mechanically fastened to cadmium plated for galvanized-steel operating rod in reinforced cabinet, and edge seals in galvanized frame, with galvanized steel axles in self-lubricating brass bearings, in opposed air foil blade arrangement with damper blades positioned across short air opening dimension. Provide removable, full width rack for supporting freeze protection thermostat, with removable end panel to permit rack removal. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.
 - 1. Damper Motor: Modulating with adjustable minimum position.
 - 2. Relief-Air Damper: Gravity actuated or motorized, as required by ASHRAE/IESNA 90.1, with bird screen and hood.
 - 3. Damper Leakage: Maximum 1 percent at 6 inch w.g. differential pressure when sized for 2000 fpm face velocity.

2.13 ELECTRICAL POWER CONNECTION, REQUIREMENTS AND CHARACTERISTICS

- A. Provide for single connection of power to unit with[**unit-mounted disconnect switch accessible from outside unit and**] control-circuit transformer with built-in overcurrent protection.
- B. Work of this section includes:
1. Factory or field installed motor controllers for all motors. Refer to Section 262913 "Enclosed Controllers", Section 262923 "Variable Frequency Motor Controllers" and Section 260583 "Electrical Connections".
 2. Furnishing and installation of a main disconnect switch, which will interrupt all power serving the packaged air handling assembly. This switch will comprise a single point of connection for the power supply feeder installed under Division 26.
 - a. For equipment designated by the manufacturer as requiring a maximum fuse size or circuit protection ampere rating, the main disconnect switch shall be a fusible switch or circuit breaker conforming to manufacturer's specified limitations. Where no limitations are imposed, main disconnect shall be an unfused switch or acceptable substitute.
 3. Disconnect shall be mounted on the AHU and be furnished with two normally open contacts.
 4. Furnishing and installation of all required wiring extending from the main disconnect to the components requiring power, in accordance with Division 26 specifications. Include all protective devices required for circuits developed for unit requirements.
- C. VFD controllers shall be remote mounted and not integral to the AHU.
- D. Motor: Open drip proof.
- E. Wiring Terminations: Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated. Enclose terminal lugs in terminal box sized to NFPA 70.
- F. Factory wire motors, variable frequency drives, starters and disconnects for a single source of electrical connection. In addition, factory wire convenience outlets for an additional 115V single source of electrical connection.

2.14 CONTROLS

- A. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Basic Unit Controls:
1. Control-voltage transformer.

2. Wall-mounted thermostat or sensor with the following features:
 - a. Heat-cool-off switch.
 - b. Fan on-auto switch.
 - c. Fan-speed switch.
 - d. **[Manual] [Automatic]** changeover.
 - e. Adjustable deadband.
 - f. **[Concealed] [Exposed]** set point.
 - g. **[Concealed] [Exposed]** indication.
 - h. **[Degree F] [Degree C]** indication.
 - i. Unoccupied-period-override push button.
 - j. Data entry and access port to input temperature[**and humidity**] set points, occupied and unoccupied periods, and output room temperature[**and humidity**], supply-air temperature, operating mode, and status.

3. Wall-mounted humidistat or sensor with the following features:
 - a. **[Concealed] [Exposed]** set point.
 - b. **[Concealed] [Exposed]** indication.

4. **[Remote Wall] [Unit]-Mounted Annunciator Panel for Each Unit:**
 - a. Lights to indicate power on, cooling, heating, fan running, filter dirty, and unit alarm or failure.
 - b. DDC controller or programmable timer and interface with HVAC instrumentation and control system.
 - c. Digital display of outdoor-air temperature, supply-air temperature, return-air temperature, economizer damper position, indoor-air quality, and control parameters.

- C. **[Electronic] [DDC] Controller:**
 1. Controller shall have volatile-memory backup.
 2. Safety Control Operation:
 - a. Smoke Detectors: Stop fan and close outdoor-air damper if smoke is detected. Provide additional contacts for alarm interface to fire alarm control panel.
 - b. Firestats: Stop fan and close outdoor-air damper if air greater than **[130 deg F (54 deg C)] <Insert temperature>** enters unit. Provide additional contacts for alarm interface to fire alarm control panel.
 - c. Fire Alarm Control Panel Interface: Provide control interface to coordinate with operating sequence described in Section 283111 "Digital, Addressable Fire-Alarm System" and Section 283112 "Zoned (DC Loop) Fire-Alarm System."
 - d. Low-Discharge Temperature: Stop fan and close outdoor-air damper if supply air temperature is less than **[40 deg F (4 deg C)] <Insert temperature>**.
 - e. Defrost Control for Condenser Coil: Pressure differential switch to initiate defrost sequence.

3. Scheduled Operation: Occupied and unoccupied periods on **[seven]** **[365]**-day clock with a minimum of **[two]** **[four]** programmable periods per day.
4. Unoccupied Period:
 - a. Heating Setback: **[10 deg F (5.6 deg C)]** **<Insert temperature>**.
 - b. Cooling Setback: System off.
 - c. Override Operation: **[Two]** **<Insert number>** hours.
5. Supply Fan Operation:
 - a. Occupied Periods: Run fan continuously.
 - b. Unoccupied Periods: Cycle fan to maintain setback temperature.
6. Refrigerant Circuit Operation:
 - a. Occupied Periods: Cycle or stage compressors[, **and operate hot-gas bypass**] to match compressor output to cooling load to maintain **[room]** **[discharge]** temperature[**and humidity**]. Cycle condenser fans to maintain maximum hot-gas pressure. Operate low-ambient control kit to maintain minimum hot-gas pressure.
 - b. Unoccupied Periods: **[Compressors off]** **[Cycle compressors and condenser fans for heating to maintain setback temperature]**.
 - c. Switch reversing valve for heating or cooling mode on air-to-air heat pump.
7. Hot-Gas Reheat-Coil Operation:
 - a. Occupied Periods: Humidistat opens hot-gas valve to provide hot-gas reheat, and cycles compressor.
 - b. Unoccupied Periods: Reheat not required.
8. Gas Furnace Operation:
 - a. Occupied Periods: **[Cycle]** **[Stage]** **[Modulate]** burner to maintain **[room]** **[discharge]** temperature.
 - b. Unoccupied Periods: Cycle burner to maintain setback temperature.
9. Electric-Heating-Coil Operation:
 - a. Occupied Periods: **[Cycle]** **[Stage]** **[Modulate]** coil to maintain **[room]** **[discharge]** temperature.
 - b. Unoccupied Periods: Energize coil to maintain setback temperature.
 - c. Operate supplemental electric heating coil with compressor for heating with outdoor temperature below **[25 deg F (minus 4 deg C)]** **<Insert temperature>**.
10. Fixed Minimum Outdoor-Air Damper Operation:
 - a. Occupied Periods: Open to **[25]** **<Insert percent>** percent.
 - b. Unoccupied Periods: Close the outdoor-air damper.

11. Economizer Outdoor-Air Damper Operation:

- a. Occupied Periods: Open to **[10] [25] <Insert percent>** percent fixed minimum intake, and maximum 100 percent of the fan capacity to comply with ASHRAE Cycle II. Controller shall permit airside economizer operation when outdoor air is less than **[60 deg F (15 deg C)] <Insert temperature>**. Use **[outdoor-air temperature] [mixed-air and outdoor-air temperature] [outdoor-air enthalpy] [mixed-air temperature and select between outdoor-air and return-air enthalpy]** to adjust mixing dampers. **[Start relief-air fan with end switch on outdoor-air damper.]** During economizer cycle operation, lock out cooling.
- b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.
- c. Outdoor-Airflow Monitor: Accuracy maximum plus or minus 5 percent within 15 and 100 percent of total outdoor air. Monitor microprocessor shall adjust for temperature, and output shall range from **[2- to 10-V dc] [4 to 20 mA] <Insert value>**.

12. Carbon Dioxide Sensor Operation:

- a. Occupied Periods: Reset minimum outdoor-air ratio down to minimum **[10] <Insert percent>** percent to maintain maximum **[1000-ppm] <Insert concentration>** concentration.
- b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

13. VVT Relays:

- a. Provide heating- and cooling-mode changeover relays compatible with VVT terminal control system required in Section 233600 "Air Terminal Units" and Section 230923 "Direct Digital Control (DDC) System for HVAC."

D. Interface Requirements for HVAC Instrumentation and Control System:

1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at the central workstation and diagnostic code storage.
3. Provide **[BACnet] [or] [LonWorks]** compatible interface for central HVAC control workstation for the following:
 - a. Adjusting set points.
 - b. Monitoring supply fan start, stop, and operation.
 - c. Inquiring data to include **[outdoor-air damper position,]** supply- and room-air temperature **[and humidity]**.
 - d. Monitoring occupied and unoccupied operations.
 - e. Monitoring constant and variable motor loads.
 - f. Monitoring variable-frequency drive operation.
 - g. Monitoring cooling load.
 - h. Monitoring economizer cycles.
 - i. Monitoring air-distribution static pressure and ventilation air volume.

2.15 ACCESSORIES

- A. Electric heater with integral thermostat maintains minimum 50 deg F (10 deg C) temperature in gas burner compartment.
- B. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include transformer if required. [**Outlet shall be energized even if the unit main disconnect is open.**]
 - 1. Provide in accessible sections suitable for damp locations a duplex outlet mounted on casing exterior.
- C. Lighting: Provide vapor-proof incandescent lights with guards in each accessible maintenance area. Include weatherproof switches with pilot lights on outside surface of casing for control of lighting.
- D. Low-ambient kit using [staged] [damper on] [variable-speed] condenser fans for operation down to [35 deg F (1.7 deg C)] <Insert temperature>.
- E. Filter differential pressure switch with sensor tubing on either side of filter. Set for final filter pressure loss.
- F. Coil guards of painted, galvanized-steel wire.
- G. Hail guards of galvanized steel, painted to match casing.
- H. Concentric diffuser with white louvers and polished aluminum return grilles, insulated diffuser box with mounting flanges, and interior transition.

2.16 ROOF CURBS

- A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
 - 1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
 - a. Materials: ASTM C 1071, Type I or II.
 - b. Thickness: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert thickness>.
 - 2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
 - a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging

- liner when applied as recommended by manufacturer and without causing leakage in cabinet.
- c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.
 - d. Liner Adhesive: Comply with ASTM C 916, Type I.

C. Curb Height: [**14 inches (355 mm)**] [**24 inches (610 mm)**] [**36 inches (910 mm)**] <Insert height>.

D. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match RTU, used to anchor unit to the curb, and designed for loads at Project site. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for wind-load requirements.

2.17 CAPACITIES AND CHARACTERISTICS

A. Supply-Air Fan:

1. Airflow: <Insert cfm (L/s)>.
2. External Static Pressure: <Insert inches wg (kPa)>.
3. Fan Speed: <Insert rpm>.
4. Motor Horsepower: <Insert value>.
5. Motor Speed: <Insert rpm>.

B. Relief-Air Fan:

1. Airflow: <Insert cfm (L/s)>.
2. External Static Pressure: <Insert inches wg (kPa)>.
3. Fan Speed: <Insert rpm>.
4. Motor Horsepower: <Insert value>.
5. Motor Speed: <Insert rpm>.

C. Outdoor-Air-Intake Relief-Air Fan:

1. Airflow: <Insert cfm (L/s)>.
2. Static Pressure: <Insert inches wg (kPa)>.
3. Fan Speed: <Insert rpm>.
4. Motor Horsepower: <Insert value>.
5. Motor Speed: <Insert rpm>.

D. Supply-Air Refrigerant Coil:

1. Total Cooling Capacity: <Insert Btu/h (kW)>.
2. Sensible Cooling Capacity: <Insert Btu/h (kW)>.
3. Entering-Air Dry-Bulb Temperature: <Insert deg F (deg C)>.
4. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
5. Coating: [**Baked phenolic**] [**Cathodic epoxy**].

E. Outdoor-Air Refrigerant Coil:

1. Ambient-Air Temperature: <Insert deg F (deg C)>.
2. Coating: [**Baked phenolic**] [**Cathodic epoxy**].
3. Fan Motor: <Insert value>.
4. Number of Fans: <Insert number>.

F. Hot-Gas Reheat Coil:

1. Heating Capacity: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Air-Temperature Rise: <Insert deg F (deg C)>.
4. Coating: [**Baked phenolic**] [**Cathodic epoxy**].

G. Electric-Resistance Heating Coil:

1. Capacity: <Insert kilowatts>.
2. Number of Steps: <Insert number>.

H. Compressors:

1. Suction Temperature: <Insert deg F (deg C)>.
2. Power Input: <Insert kilowatts>.
3. Energy-Efficiency Ratio (EER): <Insert value>.
4. Seasonal Energy-Efficiency Ratio (SEER): <Insert value>.
5. Coefficient of Performance (COP): <Insert value>.

I. Gas Furnace:

1. Airflow: <Insert cfm (L/s)>.
2. Minimum AFUE: <Insert number> percent.
3. Minimum Thermal Efficiency: <Insert number> percent.
4. Minimum Combustion Efficiency: <Insert number> percent.
5. Input: <Insert Btu/h (kW)>.
6. Output: <Insert Btu/h (kW)>.
7. Entering-Air Temperature: <Insert deg F (deg C)>.
8. Air-Temperature Rise: <Insert deg F (deg C)>.

J. Recirculating-Air Filters:

1. Minimum Face Area: <Insert sq. ft. (sq. m)>.
2. Thickness: [**1 inch (25 mm)**] [**2 inches (50 mm)**] <Insert thickness>.
3. Initial Resistance: <Insert inches wg (kPa)>.
4. Final Resistance: <Insert inches wg (kPa)>.

K. Outdoor-Air Filters:

1. Minimum Face Area: <Insert sq. ft. (sq. m)>.
2. Thickness: [**1 inch (25 mm)**] [**2 inches (50 mm)**] <Insert thickness>.
3. Initial Resistance: <Insert inches wg (kPa)>.

4. Final Resistance: <Insert inches wg (kPa)>.
- L. Electrical Characteristics for Single-Point Connection:
1. Voltage: <Insert value>.
 2. Phase: <Insert value>.
 3. Hertz: <Insert value>.
 4. Full-Load Amperes: <Insert value>.
 5. Minimum Circuit Ampacity: <Insert value>.
 6. Maximum Overcurrent Protection: <Insert amperage>.
- M. Sound Power: Radiated from condenser casing.
1. 1st Octave: <Insert value> dB.
 2. 2nd Octave: <Insert value> dB.
 3. 3rd Octave: <Insert value> dB.
 4. 4th Octave: <Insert value> dB.
 5. 5th Octave: <Insert value> dB.
 6. 6th Octave: <Insert value> dB.
 7. 7th Octave: <Insert value> dB.
 8. 8th Octave: <Insert value> dB.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of RTUs.
- B. Examine roughing-in for RTUs to verify actual locations of piping and duct connections before equipment installation.
- C. Examine roofs for suitable conditions where RTUs will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. General:
 1. Install units level and plumb.
 2. Anchor units to structure.
 3. Install seismic restraints.
 4. Install static-pressure probe.
 5. Install water-cooled units with thermometer and pressure gage at the water supply and return connection.

B. Equipment Mounting:

1. Install RTUs on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

C. Roof Curb: Install on roof structure or concrete base, level and secure, according to [**NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts."**] [**ARI Guideline B.**] Install RTUs on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 077200 "Roof Accessories." Secure RTUs to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.

D. Unit Support: Install unit level on structural [**curbs**] [**pilings**]. Coordinate wall penetrations and flashing with wall construction. Secure RTUs to structural support with anchor bolts.

3.3 CONNECTIONS

A. Install condensate drain, minimum connection size, with trap and indirect connection to nearest roof drain or area drain.

B. Install piping adjacent to RTUs to allow service and maintenance.

1. Gas Piping: Comply with applicable requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Connect gas piping to burner, full size of gas train inlet, and connect with union and shutoff valve with sufficient clearance for burner removal and service.

C. Piping installation requirements are specified in other Division 22 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

1. Water Coil Connections: Comply with requirements in Section 232113 "Hydronic Piping". Connect to supply and return coil with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.
2. Remote Water-Cooled Condenser Connections: Comply with requirements in Section 232113 "Hydronic Piping". Connect to supply and return with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.

D. Refrigerant Piping: Connect to supply and return coil tappings with shutoff valve and

union or flange at each connection.

- E. Install piping adjacent to unit to allow service and maintenance.
- F. Duct installation requirements are specified in other HVAC Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
 - 1. Install ducts to termination at top of roof curb.
 - 2. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.
 - 3. Connect supply ducts to RTUs with flexible duct connectors specified in Section 233300 "Air Duct Accessories."
 - 4. Install return-air duct continuously through roof structure.
 - 5. Install normal-weight, **3000-psi (20.7-MPa)**, compressive strength (28-day) concrete mix inside roof curb, [**4 inches (100 mm)**] **<Insert thickness>** thick. Concrete, formwork, and reinforcement are specified with concrete.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
- B. Perform tests and inspections and prepare test reports.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing. Report results in writing.
- C. Tests and Inspections:
 - 1. After installing RTUs and after electrical circuitry has been energized, test units for compliance with requirements.
 - 2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
 - 3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 4. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Remove and replace malfunctioning units and retest as specified above.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.

- B. Complete installation and startup checks according to manufacturer's written instructions and do the following:
1. Inspect for visible damage to unit casing.
 2. Inspect for visible damage to furnace combustion chamber.
 3. Inspect for visible damage to compressor, coils, and fans.
 4. Inspect internal insulation.
 5. Verify that labels are clearly visible.
 6. Verify that clearances have been provided for servicing.
 7. Verify that controls are connected and operable.
 8. Verify that filters are installed.
 9. Clean condenser coil and inspect for construction debris.
 10. Clean furnace flue and inspect for construction debris.
 11. Connect and purge gas line.
 12. Remove packing from vibration isolators.
 13. Inspect operation of barometric relief dampers.
 14. Verify lubrication on fan and motor bearings.
 15. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
 16. Adjust fan belts to proper alignment and tension.
 17. Start unit according to manufacturer's written instructions.
 - a. Start refrigeration system.
 - b. Do not operate below recommended low-ambient temperature.
 - c. Complete startup sheets and attach copy with Contractor's startup report.
 18. Inspect and record performance of interlocks and protective devices; verify sequences.
 19. Operate unit for an initial period as recommended or required by manufacturer.
 20. Perform the following operations for both minimum and maximum firing. Adjust burner for peak efficiency.
 - a. Measure gas pressure on manifold.
 - b. Inspect operation of power vents.
 - c. Measure combustion-air temperature at inlet to combustion chamber.
 - d. Measure flue-gas temperature at furnace discharge.
 - e. Perform flue-gas analysis. Measure and record flue-gas carbon dioxide and oxygen concentration.
 - f. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
 21. Calibrate thermostats.
 22. Adjust and inspect high-temperature limits.
 23. Inspect outdoor-air dampers for proper stroke and interlock with return-air dampers.
 24. Start refrigeration system and measure and record the following when ambient is a minimum of 15 deg F (8 deg C) above return-air temperature:
 - a. Coil leaving-air, dry- and wet-bulb temperatures.

- b. Coil entering-air, dry- and wet-bulb temperatures.
 - c. Outdoor-air, dry-bulb temperature.
 - d. Outdoor-air-coil, discharge-air, dry-bulb temperature.
25. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.
26. Measure and record the following minimum and maximum airflows. Plot fan volumes on fan curve.
- a. Supply-air volume.
 - b. Return-air volume.
 - c. Relief-air volume.
 - d. Outdoor-air intake volume.
27. Simulate maximum cooling demand and inspect the following:
- a. Compressor refrigerant suction and hot-gas pressures.
 - b. Short circuiting of air through condenser coil or from condenser fans to outdoor-air intake.
28. Verify operation of remote panel including pilot-light operation and failure modes. Inspect the following:
- a. High-temperature limit on gas-fired heat exchanger.
 - b. Low-temperature safety operation.
 - c. Filter high-pressure differential alarm.
 - d. Economizer to minimum outdoor-air changeover.
 - e. Relief-air fan operation.
 - f. Smoke and firestat alarms.
29. After startup and performance testing and prior to Substantial Completion, replace existing filters with new filters.

3.6 CLEANING AND ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two]** <Insert number> visits to site during other-than-normal occupancy hours for this purpose.
- B. After completing system installation and testing, adjusting, and balancing RTU and air-distribution systems, clean filter housings and install new filters.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain RTUs. Refer to Section 017900 "Demonstration and Training."

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237413

SECTION 237423.13 - PACKAGED, DIRECT-FIRED, OUTDOOR, HEATING-ONLY MAKEUP-AIR UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes direct-fired heating and ventilating units.

1.3 DEFINITIONS

- A. DDC: Direct digital control.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and configuration of outdoor, direct-fired heating and ventilating unit.
 - 1. Include rated capacities, operating characteristics, weights, fan performance, gages, and finishes of materials, electrical characteristics, connection requirements, and furnished specialties and accessories.
 - 2. Provide data for filter media, filter performance data, filter assembly, and filter frames.
 - 3. Provide fan curves with specified operating point clearly plotted.
 - 4. Submit sound power level data for both fan outlet and casing radiation at rated capacity.
 - 5. Submit electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
 - 6. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For each type and configuration of outdoor, direct-fired heating and ventilating unit.

1. Signed, sealed, and prepared by or under the supervision of a qualified professional engineer.
2. Include plans, elevations, sections, and **[mounting] [attachment]** details.
3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail fabrication and assembly of gas-fired heating and ventilating units, as well as procedures and diagrams.
5. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
6. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
7. Include diagrams for power, signal, and control wiring.
8. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.5 INFORMATIONAL SUBMITTALS

- A. Startup service reports.
- B. Sample Warranty: For manufacturer's special warranty.
- C. Seismic Qualification Certificates: For outdoor, direct-fired heating and ventilating units, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For direct-fired heating and ventilating units to include in emergency, operation, and maintenance manuals.
 1. Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300

"Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: **[One (1)]** <Insert number> set(s) for each unit.
 - 2. Fan Belts: **[One (1)]** <Insert number> set(s) for each unit.

1.8 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this Section with minimum three (3) years documented experience, who issues complete catalog data on total product.
- B. Comply with NFPA 70.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.9 ENVIRONMENTAL REQUIREMENTS

- A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.
- B. Do not operate units for temporary heating or cooling prior to substantial completion without approval by DEN Project Manager.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Accept products on site in factory-fabricated protective containers, with factory-installed shipping skids and lifting lugs. Inspect for damage.
- C. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.

1.11 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of direct-fired heating and ventilating units that fail in materials or workmanship within specified warranty period.
1. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [AbsolutAire, Inc.](#)
 2. [Applied Air.](#)
 3. [ARES.](#)
 4. [Bananza; Div. of Roberts-Gordon LLC.](#)
 5. [BessamAire, Inc.](#)
 6. [Cambridge Engineering, Inc.](#)
 7. [CaptiveAire Systems.](#)
 8. [Energy Jet U.S.](#)
 9. [Engineered Air.](#)
 10. [Greenheck Fan Corporation.](#)
 11. [Hastings HVAC; Division of Eric, Inc.](#)
 12. [I.C.E. Manufacturing Ltd.; Industrial Commercial Equipment - I.C.E. \(US\), Inc.](#)
 13. [Jackson & Church.](#)
 14. [LCSystems.](#)
 15. [Modine Manufacturing Company.](#)
 16. [Powrmatic, Inc.](#)
 17. [Rapid Engineering, Inc.](#)
 18. [Reznor/Thomas & Betts Corporation.](#)
 19. [Sterling HVAC Products.](#)
 20. [Temprite.](#)
 21. [Titan Air Incorporated.](#)
 22. [Trane Inc.](#)
 23. [Weather-Rite, Inc.](#)
 24. **<Insert manufacturer's name>**.
 25. or approved equal.

2.2 SYSTEM DESCRIPTION

- A. Factory-assembled, prewired, self-contained unit consisting of cabinet, supply fan, controls, **[filters]**, and direct-fired gas burner to be installed exterior to the building.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 UNIT CASINGS

- A. General Fabrication Requirements for Casings:
 - 1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
 - 2. Casing Joints: Sheet metal screws or pop rivets, factory sealed with water-resistant sealant.
 - 3. Factory Finish for **[Steel]** **[and]** **[Galvanized-Steel]** Casings: Apply manufacturer's standard primer immediately after cleaning and pretreating.
 - 4. Factory Finish for **[Steel]** **[and]** **[Galvanized-Steel]** Casings: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked-on enamel finish, consisting of prime coat and thermosetting topcoat.
 - 5. Casing Coating: **[Thermoplastic vinyl]** **[Epoxy]** **[Zinc]** **[Synthetic resin]** **[Phenolic]** **[Polytetrafluoroethylene]** **[Vinyl ester]** **[Hot-dip galvanized]** **[Powder-baked enamel]** **<Insert special coating>**.
 - 6. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling-unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when air-handling-unit frame is anchored to building structure.
 - 7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- B. Configuration: Horizontal unit with **[top]** **[horizontal]** **[bottom]** discharge for **[roof-mounting]** **[concrete-base]** installation.
- C. Cabinet: **[Galvanized-steel]** **[Aluminized- or galvanized-steel]** **[Aluminized-steel]** panels, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs. Duct flanges at inlet and outlet. Pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.
- D. Outer Casing: **[0.0598-inch- ((1.519-mm-))]** **[0.0478-inch- ((1.214-mm-))]** **[0.0359-inch- ((0.912-mm-))]** thick steel with **[heat-resistant, baked-enamel]** **[enamel-painted]**

[baked-on, polyester-powder] [unpainted] [over-corrosion-resistant-treated surface in color to match fan section] [finish].

E. Inner Casing:

1. Burner Section Inner Casing: 0.0299-inch- (0.759-mm-) thick steel.
2. Double-wall casing with inner wall of **[perforated] [solid]** steel[.],[, **for the following sections:**]
 - a. Blower section.
 - b. Filter section.
 - c. Mixing box.
 - d. Inlet plenum.
 - e. Discharge plenum.
 - f. Access **[Doors] [Panels]: [Lift out] [Piano hinged with cam-lock fasteners] [Hinged with handles]** for burner and fan motor assemblies on both sides of unit.
3. Internal Insulation: Fibrous-glass duct lining, neoprene coated, comply with ASTM C 1071, Type II, applied on **[complete unit] [burner and fan sections only]**.
 - a. Thickness: **[1 inch (25 mm)] [2 inches (50 mm)]**.
 - b. Insulation Adhesive: Comply with ASTM C 916, Type I.
 - c. Density: **[1.5 lb/cu. ft. ((24.0 kg/cu. m))] [2.0 lb/cu. ft. ((32.0 kg/cu. m))] [3.0 lb/cu. ft. ((48.0 kg/cu. m))]**.
 - d. Mechanical Fasteners: Galvanized steel suitable for adhesive, mechanical, or welding attachment to casing without damaging liner when applied as recommended by manufacturer and without causing air leakage.

F. Discharge Section:

1. **[Galvanized] [Aluminized]**-steel assembly with **[gravity] [individually adjustable, vaned,] [two-position, motorized,]** parallel-blade dampers with nylon bushings.
 - a. Pattern: **[Single] [Double]** deflection.
 - b. Leakage: **[Standard] [Low]** leakage.
2. Trapezoidal cowls with horizontal louvers.
3. Plenum with **[two] [four]** sides louvered.
4. Down-discharge plenum insulated with **1-inch (25-mm), 1.5-lb/cu. ft. (24.0-kg/cu. m)** fibrous glass.

G. Casing Insulation and Adhesive:

1. Materials: ASTM C 1071, **[Type I] [Type II]**.
2. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the heating-coil section.

- a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive, mechanical, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have airstream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric, depending on service-air velocity.
3. Location and Application: Encased between outside and inside casing.
- H. Inspection and Access Panels and Access Doors:
1. Panel and Door Fabrication: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.
 2. Inspection and Access Panels:
 - a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.
 3. Access Doors:
 - a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Fabricate windows in **[fan section's]**doors of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.
 - d. Size: At least **[18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension>** wide by full height of unit casing up to a maximum height of **[60 inches (1500 mm)] [72 inches (1800 mm)] <Insert dimension>**.
 4. Locations and Applications:
 - a. Fan Section: **[Inspection and access panels] [Doors] [Doors and inspection and access panels]**.
 - b. Access Section: Doors.
 - c. Coil Section: Inspection and access panels.
 - d. Damper Section: **[Inspection and access panels] [Doors]**.
 - e. Filter Section: **[Inspection and access panels] [Doors]** large enough to allow periodic removal and installation of filters.
 - f. Mixing Section: Doors.
 5. Service Light: 100-W vaporproof fixture with switched junction box located **[outside] [inside]** adjacent to door.

- a. Locations: **[Each section accessed with door] [Fan section] <Insert location>**.

2.4 ACCESSORIES

- A. Service Platform: **[Steel] [Galvanized steel] [Aluminum]**, **[42 inches (1070 mm)] <Insert dimension>** wide running entire length of unit and located on service access side, with angle side rails, **4-inch (100-mm)** kick plates, and expanded metal floor. Provide platform with a fixed ladder that extends from the top of the side rail to the floor.
- B. Electric heater with integral thermostat maintains minimum **50 deg F (10 deg C)** temperature in gas burner compartment.
- C. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include transformer if required. **[Outlet shall be energized even if the unit main disconnect is open.]**
- D. Lighting: Provide vapor-proof incandescent lights with guards in each accessible maintenance area. Include weatherproof switches with pilot lights on outside surface of casing for control of lighting.
- E. Low-ambient kit using **[staged] [damper on] [variable-speed]** condenser fans for operation down to **[35 deg F (1.7 deg C)] <Insert temperature>**.
- F. Filter differential pressure switch with sensor tubing on either side of filter. Set for final filter pressure loss.
- G. Coil guards of painted, galvanized-steel wire.
- H. Hail guards of galvanized steel, painted to match casing.

2.5 OUTDOOR-AIR INTAKE HOOD

- A. Type: Manufacturer's standard hood or louver.
- B. Materials: Match cabinet.
- C. Bird Screen: Comply with requirements in ASHRAE 62.1.
- D. Filter: Aluminum, **[1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>** cleanable.
- E. Configuration: Designed to inhibit wind-driven rain and snow from entering unit.

2.6 ROOF CURBS

- A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
 - 1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
 - a. Materials: ASTM C 1071, Type I or Type II.
 - b. Thickness: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] **<Insert dimension>**.
 - 2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
 - a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.
 - d. Liner Adhesive: Comply with ASTM C 916, Type I.
- C. Curb Height: [14 inches (355 mm)] [24 inches (610 mm)] [36 inches (910 mm)] **<Insert dimension>**.
- D. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match unit, used to anchor unit to the curb, and designed for loads at Project site. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for wind-load requirements.

2.7 SUPPLY-AIR FAN

- A. Fan Type: Centrifugal, rated according to AMCA 210; statically and dynamically balanced, galvanized steel; mounted on solid-steel shaft with heavy-duty[, **self-aligning, permanently lubricated ball bearings**][, **pillow-block bearings**]. Bearing rating: [L10 of 60,000 hours] [L10 of 120,000 hours] [L10 of 150,000 hours] **<Insert value>**.
- B. Drive: V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly.
- C. Mounting: Fan wheel, motor, and drives shall be mounted in fan casing with **[restrained,] [elastomeric] [spring]** isolators.

- D. Fan-Shaft Lubrication Lines: Extended to a location outside the casing.
- E. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000Hz	2000Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

2.8 BEARINGS AND DRIVES

- A. Bearings: AFBMA 9, AFBMA 11, L-10 life at 120,000 hours pillow block type, self-aligning, grease-lubricated roller bearings.
- B. Shafts: Solid, hot rolled steel, ground and polished, with key-way, and protectively coated with lubricating oil.
- C. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, bored to fit shafts and keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
- D. Belt Guard: Fabricate to SMACNA Standard; 12 gage thick, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

2.9 AIR FILTERS

- A. Filter Box: Section with filter guides, access doors from both sides, for face loading.
- B. Filter Media: UL 900 listed, Class I or Class II, approved by local authorities.
- C. Comply with **[NFPA 90A]** **[NFPA 90B]**.
- D. Cleanable Filters: Cleanable metal mesh.
 - 1. Thickness: **[1 inch (25 mm)] [2 inches (50 mm)]**.
 - 2. Maximum Face Velocity: **<Insert fpm ((m/s))>**.
- E. Disposable Panel Filters: Factory-fabricated, flat-panel-type, disposable air filters with holding frames, **with a MERV 6 according to ASHRAE 52.2**.
 - 1. Thickness: **[1 inch (25 mm)] [2 inches (50 mm)]**.
 - 2. Media: Interlaced **[glass]** **[polyester]** fibers.
 - 3. Frame: Galvanized steel.
 - 4. Maximum Face Velocity: **<Insert fpm ((m/s))>**.

2.10 DAMPERS

- A. Outdoor-Air [**and Return-Air**] Damper: Galvanized-steel, opposed-blade dampers with vinyl blade seals and stainless-steel jamb seals, having a maximum leakage of **10 cfm/sq. ft.** (51 L/s per sq. m) of damper area, at a differential pressure of **2-inch wg** (448 Pa).
- B. Damper Operator: Direct coupled, electronic with spring return or fully modulating as required by the control sequence.

2.11 DIRECT-FIRED GAS BURNER

- A. Description: Factory assembled, piped, and wired; and complying with ANSI Z21.47, "Gas-Fired Central Furnaces," and with NFPA 54, "National Fuel Gas Code."
 - 1. CSA Approval: Designed and certified by and bearing label of CSA.
 - 2. Burners: [**Aluminized steel with stainless-steel inserts**] [**Stainless steel**].
 - a. Gas Control Valve: [**Single stage**] [**Two stage**] [**Modulating**].
 - b. Fuel: [**Natural**] [**Propane**] gas.
 - c. Minimum Combustion Efficiency: [**95**] <Insert number> percent.
 - d. Ignition: Electronically controlled electric spark with flame sensor.
 - e. High-Altitude [**Model**] [**Kit**]: For Project elevation above sea level.
- B. Safety Controls:
 - 1. Vent Flow Verification: [**Differential pressure switch to verify open vent**] [**Flame rollout switch**].
 - 2. Control Transformer: 24-V ac.
 - 3. High Limit: Thermal switch or fuse to stop burner.
 - 4. Gas Train: Regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, [**hydraulic**] [**electronic**]-modulating temperature control valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
 - 5. Purge-period timer shall automatically delay burner ignition and bypass low-limit control.
 - 6. Gas Manifold: Safety switches and controls complying with ANSI standards [**and**] [**FM Global**] [**XL Insurance**].
 - 7. Airflow Proving Switch: Differential pressure switch senses correct airflow before energizing pilot.
 - 8. Automatic-Reset, High-Limit Control Device: Stops burner and closes main gas valve if high-limit temperature is exceeded.
 - 9. Safety Lockout Switch: Locks out ignition sequence if burner fails to light after three tries. Controls are reset manually by turning the unit off and on.

2.12 UNIT CONTROL PANEL

- A. Factory-wired, fuse-protected control transformer, connection for power supply and field-wired unit to remote control panel.

- B. Control Panel: **[Surface-mounted] [Recessed, with trim ring,]** remote panel, with engraved plastic cover and the following lights and switches:
1. **[On-off] [On-off-auto]** fan switch.
 2. Heat-vent-off switch.
 3. Supply-fan operation indicating light.
 4. Heating operation indicating light.
 5. Thermostat.
 6. Damper position potentiometer.
 7. Dirty-filter indicating light operated by unit-mounted differential pressure switch.
 8. Safety-lockout indicating light.
 9. Enclosure: NEMA 250, **[Type 1] [Type 3R] [Type 4] [Explosion proof]**.

2.13 CONTROLS

- A. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for control equipment and sequence of operation.
- B. Control Devices:
1. Remote Thermostat: Adjustable room thermostat with temperature readout.
 2. Remote Setback Thermostat: Adjustable room thermostat without temperature readout.
 3. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
 4. Fire-Protection Thermostats: Fixed or adjustable settings to operate at not less than **75 deg F (24 deg C)** above normal maximum operating temperature.
 5. Timers: Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
 6. Timers: Solid-state, programmable time control with four separate programs; 24-hour battery carryover; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; and system fault alarm.
 7. Ionization-Type Smoke Detectors: 24-V dc, nominal; self-restoring; plug-in arrangement; integral visual-indicating light; sensitivity that can be tested and adjusted in place after installation; integral addressable module; remote controllability; responsive to both visible and invisible products of combustion; self-compensating for changes in environmental conditions.
- C. Fan Control: Interlock fan to start with exhaust fan(s) to which this heating and ventilating unit is associated for makeup air.
- D. Fan Control: Timer starts and stops direct-fired heating and ventilating unit and exhaust fan(s).

1. Smoke detectors, located in supply[**and return**] air, shall stop fans when the presence of smoke is detected.
- E. Outdoor-Air Damper Control, 100 Percent Outdoor-Air Units: Outdoor-air damper shall open when supply fan starts, and close when fan stops.
- F. Mixed Outdoor- and Return-Air Damper Control: When fan is running, outdoor- and return-air dampers shall modulate to supply minimum outdoor air as follows:
 1. Minimum **[30]** **<Insert number>** percent outdoor air.
 2. Outdoor-air quantity adjusted by potentiometer on control panel.
 3. Outdoor-air quantity to maintain minimum building static pressure.
- G. Temperature Control: Operates gas valve to maintain supply-air temperature.
 1. Operates gas valve to maintain discharge-air temperature with factory-mounted sensor in blower outlet.
 2. Operates gas valve to maintain space temperature with wall-mounting, field-wired sensor[**with temperature adjustment,**] **[and unit-mounted control adjustment]** **[and adjustment on remote-control panel]**.
 3. Timer shall select remote setback thermostat to maintain space temperature at **[50 deg F (10 deg C)]** **<Insert temperature>**.
 4. Burner Control: Two or four steps of control using one or two burner sections in series.
 5. Burner Control: 20 to 100 percent modulation of the firing rate. 10 to 100 percent with dual burner units.
- H. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display status and alarms of heating and ventilating unit.
 1. Hardwired Points:
 - a. Room temperature.
 - b. Discharge-air temperature.
 - c. Burner operating.
 2. **[ASHRAE 135.1 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol]** **<Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the heating and ventilating unit from an operator workstation. Control features and monitoring points displayed locally at heating and ventilating unit control panel shall be available through the DDC system for HVAC.

2.14 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Enclosure: [**Open, dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].
 2. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 3. Motor Bearings: <Insert requirements>.
 4. Unusual Service Conditions:
 - a. Ambient Temperature: <Insert deg C>.
 - b. Altitude: <Insert feet (m)> above sea level.
 - c. High humidity.
 - d. <Insert conditions>.
 5. Efficiency: [**Premium efficient**] [**EPAct compliant**].
 6. NEMA Design: <Insert designation>.
 7. Service Factor: <Insert value>.

2.15 CAPACITIES AND CHARACTERISTICS

- A. Fan:
1. Discharge Configuration: [**Horizontal**] [**Vertical**].
 2. Airflow in CFM (L/s): <Insert quantity>.
 3. External Static Pressure: <Insert inches wg (kPa)>.
 4. Maximum RPM: <Insert number>.
 5. Minimum Size: <Insert inches (mm)>.
 6. Altitude: <Insert feet ((m))>.
- B. Fan Motor:
1. Horsepower: <Insert value>.
 2. RPM: <Insert value>.
 3. Service Factor: <Insert value>.
 4. Speed: [**Single**] [**Two**].
- C. Single-Point Electrical Connection:
1. Volts: [**120**] [**240**] [**277**] [**480**] <Insert value>.
 2. Phase: [**Single**] [**Three**].
 3. Hertz: 60.
 4. Full-Load Amperes: <Insert value>.
 5. Minimum Circuit Ampacity: <Insert value>.
 6. Maximum Overcurrent Protection: <Insert amperage>.

D. Direct-Fired Gas Burner:

1. Minimum Combustion Efficiency: <Insert number> percent.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Airflow: <Insert cfm (L/s)>.
5. Gas Input: <Insert MBh (kW)>.
6. Burner Output: <Insert MBh (kW)>.
7. Number of Stages: <Insert value>.
8. Minimum Inlet Pressure: <Insert inches wg ((Pa))>.
9. Maximum Inlet Pressure: <Insert inches wg ((Pa))>.
10. Gas Piping Connection Size: <Insert NPS ((DN))>.
11. Vent Diameter: <Insert inches ((mm))>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping, ducts, and electrical systems to verify actual locations of piping and electrical connections before equipment installation.
- C. Verify cleanliness of airflow path to include inner-casing surfaces, filters, coils, turning vanes, fan wheels, and other components.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. General:

1. Install units level and plumb.
2. Anchor units to structure.
3. Install seismic restraints.
4. Install static-pressure probe.

B. Equipment Mounting:

1. Install heating and ventilating unit on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete. "] [Section 033053 "Miscellaneous Cast-in-Place Concrete. "]**
2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
 - C. Unit Support: Install heating and ventilating unit level on structural [**curbs**] [**pilings**]. Coordinate wall penetrations and flashing with wall construction. [**Secure units to structural support with anchor bolts.**]
 - D. Install gas-fired units according to NFPA 54, "National Fuel Gas Code."
 - E. Install controls and equipment shipped by manufacturer for field installation with direct-fired heating and ventilating units.
 - F. Roof Curb: Install on roof structure or concrete base, level and secure, according to [**NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts."**] [**AHRI Guideline B.**] Install units on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 077200 "Roof Accessories." Secure units to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.
 - G. Unit Support: Install unit level on structural [**curbs**] [**pilings**]. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts.
- 3.3 CONNECTIONS
- A. Drawings indicate general arrangement of piping, fittings, and specialties.
 1. Gas Piping: Comply with requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Connect gas piping with shutoff valve and union, and with sufficient clearance for burner removal and service. Make final connections of gas piping to unit with corrugated, stainless-steel tubing flexible connectors complying with ANSI LC 1/CSA 6.26 equipment connections.
 - B. Drain: Comply with requirements in Section 221316 "Sanitary Waste and Vent Piping" for traps and accessories on piping connections to condensate drain pans under condensing heat exchangers. Where installing piping adjacent to heating and ventilating units, allow space for service and maintenance.
 - C. Duct Connections: Connect supply[**and return**] ducts to direct-fired heating and ventilating units with flexible duct connectors. Comply with requirements in Section 233300 "Air Duct Accessories" for flexible duct connectors.
 - D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
 - E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].
- C. Units will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
- B. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - 1. Inspect for visible damage to burner combustion chamber.
 - 2. Inspect casing insulation for integrity, moisture content, and adhesion.
 - 3. Verify that clearances have been provided for servicing.
 - 4. Verify that controls are connected and operable.
 - 5. Verify that filters are installed.
 - 6. Purge gas line.
 - 7. Inspect and adjust vibration isolators[**and seismic restraints**].
 - 8. Verify bearing lubrication.
 - 9. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
 - 10. Adjust fan belts to proper alignment and tension.
- C. Start unit according to manufacturer's written instructions.
 - 1. Complete startup sheets and attach copy with Contractor's startup report.
 - 2. Inspect and record performance of interlocks and protective devices; verify sequences.
 - 3. Operate unit for run-in period recommended by manufacturer.
 - 4. Perform the following operations for both minimum and maximum firing, and adjust burner for peak efficiency:
 - a. Measure gas pressure at manifold.
 - b. Measure combustion-air temperature at inlet to combustion chamber.
 - c. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
 - 5. Calibrate thermostats.
 - 6. Adjust and inspect high-temperature limits.

7. Inspect dampers, if any, for proper stroke and interlock with return-air dampers.
8. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.
9. Measure and record airflow. Plot fan volumes on fan curve.
10. Verify operation of remote panel, including pilot-operation and failure modes.
Inspect the following:
 - a. High-limit heat.
 - b. Alarms.
11. After startup and performance testing, change filters, verify bearing lubrication, and adjust belt tension.
12. Verify drain-pan performance.
13. Verify outdoor-air damper operation.

3.6 ADJUSTING

- A. Adjust initial temperature set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain heating and ventilating units.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237423.13

SECTION 237423.16 - PACKAGED, INDIRECT-FIRED, OUTDOOR, HEATING-ONLY MAKEUP-AIR UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes indirect-fired makeup-air units.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

- A. DDC: Direct digital control.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and configuration of outdoor, indirect-fired makeup-air unit.
 - 1. Include rated capacities, operating characteristics, weights, fan performance, gages, and finishes of materials, electrical characteristics, connection requirements, and furnished specialties and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For each type and configuration of outdoor, indirect-fired heating and ventilating unit.
 - 1. Signed, sealed, and prepared by or under the supervision of a qualified professional engineer.
 - 2. Include plans, elevations, sections, and **[mounting] [attachment]** details.

3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail fabrication and assembly of gas-fired heating and ventilating units, as well as procedures and diagrams.
5. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
6. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
7. Include diagrams for power, signal, and control wiring.
8. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.5 INFORMATIONAL SUBMITTALS

- A. Startup service reports.
- B. Sample Warranty: For manufacturer's special warranty.
- C. Seismic Qualification Certificates: For outdoor, indirect-fired makeup-air units, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For indirect-fired makeup-air units to include in emergency, operation, and maintenance manuals.
 1. Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: **[One (1)] <Insert number>** set(s) for each unit.
 - 2. Fan Belts: **[One (1)] <Insert number>** set(s) for each unit.

1.8 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this Section with minimum three (3) years documented experience, who issues complete catalog data on total product.
- B. Comply with NFPA 70.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.9 ENVIRONMENTAL REQUIREMENTS

- A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.
- B. Do not operate units for temporary heating or cooling prior to substantial completion without approval by DEN Project Manager.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Accept products on site in factory-fabricated protective containers, with factory-installed shipping skids and lifting lugs. Inspect for damage.
- C. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.

1.11 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of indirect-fired heating and ventilating units that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [AbsolutAire, Inc.](#)
 2. [Applied Air.](#)
 3. [ARES.](#)
 4. [Banza; Div. of Roberts-Gordon LLC.](#)
 5. [BessamAire, Inc.](#)
 6. [Cambridge Engineering, Inc.](#)
 7. [CaptiveAire Systems.](#)
 8. [CES Group.](#)
 9. [Des Champs Technologies.](#)
 10. [Energy Jet U.S.](#)
 11. [Engineered Air.](#)
 12. [Greenheck Fan Corporation.](#)
 13. [Hastings HVAC; Division of Eric, Inc.](#)
 14. [I.C.E. Manufacturing Ltd.; Industrial Commercial Equipment - I.C.E. \(US\), Inc.](#)
 15. [Jackson & Church.](#)
 16. [LCSystems.](#)
 17. [Modine Manufacturing Company.](#)
 18. [Powrmatic, Inc.](#)
 19. [Rapid Engineering, Inc.](#)
 20. [Reznor/Thomas & Betts Corporation.](#)
 21. [Sterling HVAC Products.](#)
 22. [Temprite.](#)
 23. [Titan Air Incorporated.](#)
 24. [Trane Inc.](#)
 25. [Weather-Rite, Inc.](#)
 26. **<Insert manufacturer's name>**.
 27. or approved equal.

2.2 SYSTEM DESCRIPTION

- A. Factory-assembled, prewired, self-contained unit consisting of cabinet, supply fan, controls, **[filters]**, and indirect-fired gas burner to be installed exterior to the building.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 UNIT CASINGS

- A. General Fabrication Requirements for Casings:
 - 1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
 - 2. Casing Joints: Sheet metal screws or pop rivets, factory sealed with water-resistant sealant.
 - 3. Factory Finish for **[Steel]** **[and]** **[Galvanized-Steel]** Casings: Apply manufacturer's standard primer immediately after cleaning and pretreating.
 - 4. Factory Finish for **[Steel]** **[and]** **[Galvanized-Steel]** Casings: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked-on enamel finish, consisting of prime coat and thermosetting topcoat.
 - 5. Casing Coating: **[Thermoplastic vinyl]** **[Epoxy]** **[Zinc]** **[Synthetic resin]** **[Phenolic]** **[Polytetrafluoroethylene]** **[Vinyl ester]** **[Hot-dip galvanized]** **[Powder-baked enamel]** <Insert special coating>.
 - 6. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.
 - a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling-unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when air-handling-unit frame is anchored to building structure.
 - 7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- B. Configuration: Horizontal unit with **[top]** **[horizontal]** **[bottom]** discharge for **[roof-mounting]** **[concrete-base]** installation.
- C. Cabinet: **[Galvanized-steel]** **[Aluminized- or galvanized-steel]** **[Aluminized-steel]** panels, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs. Duct flanges at inlet and outlet. Pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.
- D. Outer Casing: **[0.0598-inch- ((1.519-mm-))]** **[0.0478-inch- ((1.214-mm-))]** **[0.0359-inch- ((0.912-mm-))]** thick steel with **[heat-resistant, baked-enamel]** **[enamel-painted]**

[baked-on, polyester-powder] [unpainted] [over-corrosion-resistant-treated surface in color to match fan section] [finish].

E. Inner Casing:

1. Burner Section Inner Casing: 0.0299-inch- (0.759-mm-) thick steel.
2. Double-wall casing with inner wall of **[perforated] [solid]** steel[.], **for the following sections:**
 - a. Blower section.
 - b. Filter section.
 - c. Mixing box.
 - d. Inlet plenum.
 - e. Discharge plenum.
 - f. Access **[Doors] [Panels]: [Lift out] [Piano hinged with cam-lock fasteners] [Hinged with handles]** for burner and fan motor assemblies on both sides of unit.
3. Internal Insulation: Fibrous-glass duct lining, neoprene coated, comply with ASTM C 1071, Type II, applied on **[complete unit] [burner and fan sections only]**.
 - a. Thickness: **[1 inch (25 mm)] [2 inches (50 mm)]**.
 - b. Insulation Adhesive: Comply with ASTM C 916, Type I.
 - c. Density: **[1.5 lb/cu. ft. ((24.0 kg/cu. m))] [2.0 lb/cu. ft. ((32.0 kg/cu. m))] [3.0 lb/cu. ft. ((48.0 kg/cu. m))]**.
 - d. Mechanical Fasteners: Galvanized steel suitable for adhesive, mechanical, or welding attachment to casing without damaging liner when applied as recommended by manufacturer and without causing air leakage.

F. Discharge Section:

1. **[Galvanized] [Aluminized]**-steel assembly with **[gravity] [individually adjustable, vaned,] [two-position, motorized,]** parallel-blade dampers with nylon bushings.
 - a. Pattern: **[Single] [Double]** deflection.
 - b. Leakage: **[Standard] [Low]** leakage.
2. Trapezoidal cowls with horizontal louvers.
3. Plenum with **[two] [four]** sides louvered.
4. Down-discharge plenum insulated with **1-inch (25-mm), 1.5-lb/cu. ft. (24.0-kg/cu. m)** fibrous glass.

G. Casing Insulation and Adhesive:

1. Materials: ASTM C 1071, **[Type I] [Type II]**.
2. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the heating-coil section.

- a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive, mechanical, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have airstream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric, depending on service-air velocity.
3. Location and Application: Encased between outside and inside casing.
- H. Inspection and Access Panels and Access Doors:
1. Panel and Door Fabrication: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.
 2. Inspection and Access Panels:
 - a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.
 3. Access Doors:
 - a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
 - b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Fabricate windows in **[fan section's]**doors of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.
 - d. Size: At least **[18 inches (450 mm)] [24 inches (600 mm)] <Insert dimension>** wide by full height of unit casing up to a maximum height of **[60 inches (1500 mm)] [72 inches (1800 mm)] <Insert dimension>**.
 4. Locations and Applications:
 - a. Fan Section: **[Inspection and access panels] [Doors] [Doors and inspection and access panels]**.
 - b. Access Section: Doors.
 - c. Coil Section: Inspection and access panels.
 - d. Damper Section: **[Inspection and access panels] [Doors]**.
 - e. Filter Section: **[Inspection and access panels] [Doors]** large enough to allow periodic removal and installation of filters.
 - f. Mixing Section: Doors.
 5. Service Light: 100-W vaporproof fixture with switched junction box located **[outside] [inside]** adjacent to door.

- a. Locations: **[Each section accessed with door] [Fan section] <Insert location>**.
- I. Condensate Drain Pans:
1. Fabricated with **[one] [two]** percent slope in at least two planes to collect condensate from condensate-producing heat exchangers and from humidifiers, and to direct water toward drain connection.
 - a. Length: Extend drain pan downstream from leaving face **[to comply with ASHRAE 62.1] <Insert distance>**.
 - b. Depth: A minimum of **[2 inches (50 mm)] <Insert dimension>** deep.
 2. **[Formed sections] [Integral part of floor plating]**.
 3. Single-wall, **[galvanized] [stainless]**-steel sheet.
 4. Double-wall, **[galvanized] [stainless]**-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
 5. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on **[one end] [both ends]** of pan.
 - a. Minimum Connection Size: **[NPS 1 (DN 25)] [NPS 2 (DN 50)] <Insert pipe size>**.
 6. Pan-Top Surface Coating: Asphaltic waterproofing compound.

2.4 ACCESSORIES

- A. Service Platform: **[Steel] [Galvanized steel] [Aluminum]**, **[42 inches (1070 mm)] <Insert dimension>** wide running entire length of unit and located on service access side, with angle side rails, **4-inch (100-mm)** kick plates, and expanded metal floor. Provide platform with a fixed ladder that extends from the top of the side rail to the floor.
- B. Electric heater with integral thermostat maintains minimum **50 deg F (10 deg C)** temperature in gas burner compartment.
- C. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include transformer if required. **[Outlet shall be energized even if the unit main disconnect is open.]**
- D. Lighting: Provide vapor-proof incandescent lights with guards in each accessible maintenance area. Include weatherproof switches with pilot lights on outside surface of casing for control of lighting.
- E. Low-ambient kit using **[staged] [damper on] [variable-speed]** condenser fans for operation down to **[35 deg F (1.7 deg C)] <Insert temperature>**.
- F. Filter differential pressure switch with sensor tubing on either side of filter. Set for final filter pressure loss.

- G. Coil guards of painted, galvanized-steel wire.
- H. Hail guards of galvanized steel, painted to match casing.

2.5 OUTDOOR-AIR INTAKE HOOD

- A. Type: Manufacturer's standard hood or louver.
- B. Materials: Match cabinet.
- C. Bird Screen: Comply with requirements in ASHRAE 62.1.
- D. Filter: Aluminum, 1 inch (25 mm) cleanable.
- E. Configuration: Designed to inhibit wind-driven rain and snow from entering unit.

2.6 ROOF CURBS

- A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
 - 1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
 - a. Materials: ASTM C 1071, Type I or Type II.
 - b. Thickness: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] **<Insert dimension>**.
 - 2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
 - a. Liner Adhesive: Comply with ASTM C 916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.
 - d. Liner Adhesive: Comply with ASTM C 916, Type I.
- C. Curb Height: [14 inches (355 mm)] [24 inches (610 mm)] [36 inches (910 mm)] **<Insert dimension>**.
- D. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match unit, used to anchor unit to the curb, and designed for loads at

Project site. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for wind-load requirements.

2.7 SUPPLY-AIR FAN

- A. Fan Type: Centrifugal, rated according to AMCA 210; statically and dynamically balanced, galvanized steel; mounted on solid-steel shaft with heavy-duty[, **self-aligning, permanently lubricated ball bearings**][, **pillow-block bearings**]. Bearing rating: [**L10 of 60,000 hours**] [**L10 of 120,000 hours**] [**L10 of 150,000 hours**] **<Insert value>**.
- B. Drive: V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly.
- C. Mounting: Fan wheel, motor, and drives shall be mounted in fan casing with [**restrained,**] [**elastomeric**] [**spring**] isolators.
- D. Fan-Shaft Lubrication Lines: Extended to a location outside the casing.
- E. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000Hz	2000Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

2.8 BEARINGS AND DRIVES

- A. Bearings: AFBMA 9, AFBMA 11, L-10 life at 120,000 hours pillow block type, self-aligning, grease-lubricated roller bearings.
- B. Shafts: Solid, hot rolled steel, ground and polished, with key-way, and protectively coated with lubricating oil.
- C. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, bored to fit shafts and keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
- D. Belt Guard: Fabricate to SMACNA Standard; 12 gage thick, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

2.9 AIR FILTERS

- A. Filter Box: Section with filter guides, access doors from both sides, for face loading.
- B. Filter Media: UL 900 listed, Class I or Class II, approved by local authorities.
- C. Comply with **[NFPA 90A]** **[NFPA 90B]**.
- D. Cleanable Filters: Cleanable metal mesh.
 - 1. Thickness: **[1 inch (25 mm)]** **[2 inches (50 mm)]**.
 - 2. Maximum Face Velocity: **<Insert fpm ((m/s))>**.
- E. Disposable Panel Filters: Factory-fabricated, flat-panel-type, disposable air filters with holding frames, **with a MERV 6 according to ASHRAE 52.2**.
 - 1. Thickness: **[1 inch (25 mm)]** **[2 inches (50 mm)]**.
 - 2. Media: Interlaced **[glass]** **[polyester]** fibers.
 - 3. Frame: Galvanized steel.
 - 4. Maximum Face Velocity: **<Insert fpm ((m/s))>**.

2.10 DAMPERS

- A. Outdoor-Air **[and Return-Air]**Damper: Galvanized-steel, opposed-blade dampers with vinyl blade seals and stainless-steel jamb seals, having a maximum leakage of **10 cfm/sq. ft. (51 L/s per sq. m)** of damper area, at a differential pressure of **2-inch wg (448 Pa)**.
- B. Damper Operator: Direct coupled, electronic with spring return or fully modulating as required by the control sequence.

2.11 INDIRECT-FIRED GAS BURNER

- A. Description: Factory assembled, piped, and wired; and complying with ANSI Z21.47, "Gas-Fired Central Furnaces," and with NFPA 54, "National Fuel Gas Code."
 - 1. CSA Approval: Designed and certified by and bearing label of CSA.
 - 2. Burners: **[Aluminized steel with stainless-steel inserts]** **[Stainless steel]**.
 - a. Gas Control Valve: **[Single stage]** **[Two stage]** **[Modulating]**.
 - b. Fuel: **[Natural]** **[Propane]** gas.
 - c. Minimum Combustion Efficiency: **[80]** **<Insert number>** percent.
 - d. Ignition: Electronically controlled electric spark with flame sensor.
 - e. High-Altitude **[Model]** **[Kit]**: For Project elevation above sea level.
- B. Venting: Gravity vented.

- C. Venting: Power vented, with integral, motorized centrifugal fan interlocked with gas valve.
- D. Combustion-Air Intake: Separate combustion-air intake and vent terminal assembly.
- E. Heat Exchanger: **[Aluminized]** **[Stainless]** steel.
- F. Heat-Exchanger Drain Pan: Stainless steel.
- G. Safety Controls:
 - 1. Vent Flow Verification: **[Differential pressure switch to verify open vent]** **[Flame rollout switch]**.
 - 2. Control Transformer: 24-V ac.
 - 3. High Limit: Thermal switch or fuse to stop burner.
 - 4. Gas Train: Regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, **[hydraulic]** **[electronic]**-modulating temperature control valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
 - 5. Purge-period timer shall automatically delay burner ignition and bypass low-limit control.
 - 6. Gas Manifold: Safety switches and controls complying with ANSI standards **[and]** **[FM Global]** **[XL Insurance]**.
 - 7. Airflow Proving Switch: Differential pressure switch senses correct airflow before energizing pilot.
 - 8. Automatic-Reset, High-Limit Control Device: Stops burner and closes main gas valve if high-limit temperature is exceeded.
 - 9. Safety Lockout Switch: Locks out ignition sequence if burner fails to light after three tries. Controls are reset manually by turning the unit off and on.

2.12 UNIT CONTROL PANEL

- A. Factory-wired, fuse-protected control transformer, connection for power supply and field-wired unit to remote control panel.
- B. Control Panel: **[Surface-mounted]** **[Recessed, with trim ring,]** remote panel, with engraved plastic cover and the following lights and switches:
 - 1. **[On-off]** **[On-off-auto]** fan switch.
 - 2. Heat-vent-off switch.
 - 3. Supply-fan operation indicating light.
 - 4. Heating operation indicating light.
 - 5. Thermostat.
 - 6. Damper position potentiometer.
 - 7. Dirty-filter indicating light operated by unit-mounted differential pressure switch.
 - 8. Safety-lockout indicating light.
 - 9. Enclosure: NEMA 250, **[Type 1]** **[Type 3R]** **[Type 4]** **[Explosion proof]**.

2.13 CONTROLS

- A. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for control equipment and sequence of operation.
- B. Control Devices:
1. Remote Thermostat: Adjustable room thermostat with temperature readout.
 2. Remote Setback Thermostat: Adjustable room thermostat without temperature readout.
 3. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
 4. Fire-Protection Thermostats: Fixed or adjustable settings to operate at not less than **75 deg F (24 deg C)** above normal maximum operating temperature.
 5. Timers: Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
 6. Timers: Solid-state, programmable time control with four separate programs; 24-hour battery carryover; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; and system fault alarm.
 7. Ionization-Type Smoke Detectors: 24-V dc, nominal; self-restoring; plug-in arrangement; integral visual-indicating light; sensitivity that can be tested and adjusted in place after installation; integral addressable module; remote controllability; responsive to both visible and invisible products of combustion; self-compensating for changes in environmental conditions.
- C. Fan Control: Interlock fan to start with exhaust fan(s) to which this heating and ventilating unit is associated for makeup air.
- D. Fan Control: Timer starts and stops indirect-fired heating and ventilating unit and exhaust fan(s).
1. Smoke detectors, located in supply[**and return**] air, shall stop fans when the presence of smoke is detected.
- E. Outdoor-Air Damper Control, 100 Percent Outdoor-Air Units: Outdoor-air damper shall open when supply fan starts, and close when fan stops.
- F. Mixed Outdoor- and Return-Air Damper Control: When fan is running, outdoor- and return-air dampers shall modulate to supply minimum outdoor air as follows:
1. Minimum [**30**] **<Insert number>** percent outdoor air.
 2. Outdoor-air quantity adjusted by potentiometer on control panel.
 3. Outdoor-air quantity to maintain minimum building static pressure.
- G. Temperature Control: Operates gas valve to maintain supply-air temperature.

1. Operates gas valve to maintain discharge-air temperature with factory-mounted sensor in blower outlet.
 2. Operates gas valve to maintain space temperature with wall-mounting, field-wired sensor[**with temperature adjustment,**] [**and unit-mounted control adjustment**] [**and adjustment on remote-control panel**].
 3. Timer shall select remote setback thermostat to maintain space temperature at **[50 deg F (10 deg C)]** **<Insert temperature>**.
 4. Burner Control: Two or four steps of control using one or two burner sections in series.
 5. Burner Control: 20 to 100 percent modulation of the firing rate. 10 to 100 percent with dual burner units.
- H. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display status and alarms of heating and ventilating unit.
1. Hardwired Points:
 - a. Room temperature.
 - b. Discharge-air temperature.
 - c. Burner operating.
 2. **[ASHRAE 135.1 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol]** **<Insert type of interface>** communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the heating and ventilating unit from an operator workstation. Control features and monitoring points displayed locally at heating and ventilating unit control panel shall be available through the DDC system for HVAC.

2.14 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Enclosure: **[Open, dripproof] [Totally enclosed, fan cooled] [Totally enclosed, air over] [Open, externally ventilated] [Totally enclosed, nonventilated] [Severe duty] [Explosion proof] [Dust-ignition-proof machine]**.
 2. Enclosure Materials: **[Cast iron] [Cast aluminum] [Rolled steel]**.
 3. Motor Bearings: **<Insert requirements>**.
 4. Unusual Service Conditions:
 - a. Ambient Temperature: **<Insert deg C>**.
 - b. Altitude: **<Insert feet (m)>** above sea level.
 - c. High humidity.
 - d. **<Insert conditions>**.

5. Efficiency: [**Premium efficient**] [**EPAct compliant**].
6. NEMA Design: <Insert designation>.
7. Service Factor: <Insert value>.

2.15 CAPACITIES AND CHARACTERISTICS

A. Fan:

1. Discharge Configuration: [**Horizontal**] [**Vertical**].
2. Airflow in CFM (L/s): <Insert quantity>.
3. External Static Pressure: <Insert inches wg (kPa)>.
4. Maximum RPM: <Insert number>.
5. Minimum Size: <Insert inches (mm)>.
6. Altitude: <Insert feet ((m))>.

B. Fan Motor:

1. Horsepower: <Insert value>.
2. RPM: <Insert value>.
3. Service Factor: <Insert value>.
4. Speed: [**Single**] [**Two**].

C. Single-Point Electrical Connection:

1. Volts: [**120**] [**240**] [**277**] [**480**] <Insert value>.
2. Phase: [**Single**] [**Three**].
3. Hertz: 60.
4. Full-Load Amperes: <Insert value>.
5. Minimum Circuit Ampacity: <Insert value>.
6. Maximum Overcurrent Protection: <Insert amperage>.

D. Indirect-Fired Gas Burner:

1. Minimum Combustion Efficiency: <Insert number> percent.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Airflow: <Insert cfm (L/s)>.
5. Gas Input: <Insert MBh (kW)>.
6. Burner Output: <Insert MBh (kW)>.
7. Number of Stages: <Insert value>.
8. Minimum Inlet Pressure: <Insert inches wg ((Pa))>.
9. Maximum Inlet Pressure: <Insert inches wg ((Pa))>.
10. Gas Piping Connection Size: <Insert NPS ((DN))>.
11. Vent Diameter: <Insert inches ((mm))>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping, ducts, and electrical systems to verify actual locations of connections before equipment installation.
- C. Verify cleanliness of airflow path to include inner-casing surfaces, filters, coils, turning vanes, fan wheels, and other components.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. General:
 - 1. Install units level and plumb.
 - 2. Anchor units to structure.
 - 3. Install seismic restraints.
 - 4. Install static-pressure probe.
- B. Equipment Mounting:
 - 1. Install heating and ventilating units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete."]** **[Section 033053 "Miscellaneous Cast-in-Place Concrete."]**
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- C. Unit Support: Install heating and ventilating unit level on structural **[curbs] [pilings]**. Coordinate wall penetrations and flashing with wall construction. **[Secure units to structural support with anchor bolts.]**
- D. Install gas-fired units according to NFPA 54, "National Fuel Gas Code."
- E. Install controls and equipment shipped by manufacturer for field installation with indirect-fired heating and ventilating units.
- F. Roof Curb: Install on roof structure or concrete base, level and secure, according to **[NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts."]** **[ARI Guideline B.]** Install units on curbs and coordinate roof penetrations and flashing with

roof construction specified in Section 077200 "Roof Accessories." Secure units to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.

- G. Unit Support: Install unit level on structural [**curbs**] [**pilings**]. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts.

3.3 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.
 - 1. Gas Piping: Comply with requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**] Connect gas piping with shutoff valve and union, and with sufficient clearance for burner removal and service. Make final connections of gas piping to unit with corrugated, stainless-steel tubing flexible connectors complying with ANSI LC 1/CSA 6.26 equipment connections.
- B. Drain: Comply with requirements in Section 221316 "Sanitary Waste and Vent Piping" for traps and accessories on piping connections to condensate drain pans under condensing heat exchangers. Where installing piping adjacent to heating and ventilating units, allow space for service and maintenance.
- C. Duct Connections: Connect supply[**and return**] ducts to indirect-fired heating and ventilating units with flexible duct connectors. Comply with requirements in Section 233300 "Air Duct Accessories" for flexible duct connectors.
- D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].
- C. Units will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
- B. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - 1. Inspect for visible damage to burner combustion chamber.
 - 2. Inspect casing insulation for integrity, moisture content, and adhesion.
 - 3. Verify that clearances have been provided for servicing.
 - 4. Verify that controls are connected and operable.
 - 5. Verify that filters are installed.
 - 6. Purge gas line.
 - 7. Inspect and adjust vibration isolators[**and seismic restraints**].
 - 8. Verify bearing lubrication.
 - 9. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
 - 10. Adjust fan belts to proper alignment and tension.
- C. Start unit according to manufacturer's written instructions.
 - 1. Complete startup sheets and attach copy with Contractor's startup report.
 - 2. Inspect and record performance of interlocks and protective devices; verify sequences.
 - 3. Operate unit for run-in period recommended by manufacturer.
 - 4. Perform the following operations for both minimum and maximum firing, and adjust burner for peak efficiency:
 - a. Measure gas pressure at manifold.
 - b. Measure combustion-air temperature at inlet to combustion chamber.
 - c. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
 - 5. Calibrate thermostats.
 - 6. Adjust and inspect high-temperature limits.
 - 7. Inspect dampers, if any, for proper stroke and interlock with return-air dampers.
 - 8. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.
 - 9. Measure and record airflow. Plot fan volumes on fan curve.
 - 10. Verify operation of remote panel, including pilot-operation and failure modes. Inspect the following:
 - a. High-limit heat.
 - b. Alarms.
 - 11. After startup and performance testing, change filters, verify bearing lubrication, and adjust belt tension.
 - 12. Verify drain-pan performance.
 - 13. Verify outdoor-air damper operation.

3.6 ADJUSTING

- A. Adjust initial temperature set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain heating and ventilating units.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237423.16

SECTION 237433 - DEDICATED OUTDOOR-AIR UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes factory-packaged units capable of supplying up to 100 percent outdoor air and providing cooling **[only] [and heating]**.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include rated capacities, operating characteristics, weights, fan performance, gages, and finishes of materials, electrical characteristics, connection requirements, and furnished specialties and accessories.
 - 1. Provide data for filter media, filter performance data, filter assembly, and filter frames.
 - 2. Provide fan curves with specified operating point clearly plotted.
 - 3. Submit sound power level data for both fan outlet and casing radiation at rated capacity.
 - 4. Submit electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
 - 5. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1.
 - 2. Product Data for Prerequisite EA 3: Documentation indicating that refrigerants comply.
 - 3. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 - 4. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
 - 5. Product Data for Credit IEQ 1: Documentation indicating that units are equipped with a direct outdoor airflow-measuring device capable of measuring the

minimum outdoor airflow with accuracy within 15 percent of the design minimum airflow rate, as defined by ASHRAE 62.1.

6. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.
7. Laboratory Test Reports for Credit IEQ 4: For solvent cements and adhesive primers, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
8. Product Data for Credit IEQ 5: Documentation indicating that units include MERV 13 filters rated according to ASHRAE 52.2.

C. Shop Drawings:

1. Include plans, elevations, sections, and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Prepare the following by or under the supervision of a qualified professional engineer:
 - a. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
 - b. Include diagrams for power, signal, and control wiring.
4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

D. Delegated-Design Submittal: For design of **[vibration isolation]** **[seismic restraints]** **[and]** **[wind restraints]**, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Unit fabrication and assembly details.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
3. Design Calculations:
 - a. Calculate requirements for selecting vibration isolators **[and seismic restraints]** **[and wind restraints]** and for designing vibration isolation bases.
 - b. Indicate compliance with "Performance Requirements" article.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Roof-curb mounting details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Size and location of unit-mounted rails and anchor points and methods for anchoring units to roof curb.
 2. Required roof penetrations for ducts, pipes, and electrical raceways, including size and location of each penetration.
- B. Seismic Qualification Certificates: For dedicated outdoor-air units, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Startup service reports.
- D. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For units to include in emergency, operation, and maintenance manuals.
1. Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fan Belts: **[One (1)]** <Insert number> set[s] for each belt-driven fan.
 2. Filters: **[One (1)]** <Insert number> set[s] for each unit.

1.7 QUALITY ASSURANCE

- A. Manufacturer: Company specializing in manufacturing the Products specified in this

Section with minimum three (3) years documented experience, who issues complete catalog data on total product.

B. ARI Compliance:

1. Comply with ARI 203/110 and ARI 303/110 for testing and rating energy efficiencies for RTUs.
2. Comply with ARI 270 for testing and rating sound performance for RTUs.

C. ASHRAE Compliance:

1. Comply with ASHRAE 15 for refrigeration system safety.
2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.
3. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

D. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

E. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.

F. UL Compliance: Comply with UL 1995.

G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.8 ENVIRONMENTAL REQUIREMENTS

- A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.
- B. Do not operate units for temporary heating or cooling prior to substantial completion without approval by DEN Project Manager.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, handle and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1
- B. Accept products on site in factory-fabricated protective containers, with factory-installed shipping skids and lifting lugs. Inspect for damage.
- C. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.

1.10 WARRANTY

- A. Special Warranty: Manufacturer agrees to replace components of units that fail in materials or workmanship within specified warranty period.
1. Warranty Period for Compressors: **[Five (5)] <Insert number>** years from date of Substantial Completion.
 2. Warranty Period for Heat Exchangers: **[Five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [AAON.](#)
 2. [Addison.](#)
 3. [Desert Aire.](#)
 4. [Engineered Air.](#)
 5. [LCSystems.](#)
 6. [Munters Corporation, Dehumidification Division; Des Champs Products.](#)
 7. [Thomas & Betts Corporation; Reznor HVAC Division.](#)
 8. **<Insert manufacturer's name>.**
 9. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. General Fabrication Requirements: Comply with requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment," and Section 7 - "Construction and System Start-up."
- B. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design **[vibration isolation] [seismic restraints] [and] [wind restraints]**.
- C. Seismic Performance: Units shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
- D. Wind-Restraint Performance:
1. Basic Wind Speed: **<Insert value>**.
 2. Building Classification Category: [I] [II] [III] [IV].
 3. Minimum **10 lb/sq. ft** (48.8 kg/sq. m) multiplied by the maximum area of unit projected on a vertical plane that is normal to the wind direction and 45 degrees either side of normal.
- E. Cabinet Thermal Performance:
1. Maximum Overall U-Value: Comply with requirements in ASHRAE/IESNA 90.1.
 2. Maximum Overall U-Value: [0.10 Btu/h x sq. ft. x deg F (0.57 W/sq. m x deg K)] **<Insert value>**.
 3. Include effects of metal-to-metal contact and thermal bridges in the calculations.
- F. Cabinet Surface Condensation:
1. Cabinet shall have additional insulation and vapor seals if required to prevent condensation on the interior and exterior of the cabinet.
 2. Portions of cabinet located downstream from the cooling coil shall have a thermal break at each thermal bridge between the exterior and interior casing to prevent condensation from occurring on the interior and exterior surfaces. The thermal break shall not compromise the structural integrity of the cabinet.
- G. Maximum Cabinet Leakage: **[0.5] [1] [2] <Insert number>** percent of the total supply-air flow at a pressure rating equal to the fan shut-off pressure.
- H. Cabinet Deflection Performance:
1. Walls and roof deflection shall be within **[1/200] [1/240] <Insert value>** of the span at the design working pressure equal to the fan shut-off pressure. Deflection limits shall be measured at any point on the surface.
 2. Floor deflections shall be within **[1/240] [1/300] [1/360] <Insert value>** of the span considering the worst-case condition caused by the following:
 - a. Service personnel.
 - b. Internal components.
 - c. Design working pressure defined for the walls and roof.
- I. Electrical components, devices, and accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- J. Capacities and Characteristics:
1. Supply Airflow: **<Insert cfm (L/s)>**.
 2. External Static Pressure: **<Insert inches wg (Pa)>**.

3. Supply Fan:
 - a. Size: **<Insert wheel size>**.
 - b. Speed: **<Insert rpm>**.
 - c. Brake Horsepower: **<Insert value>**.

4. Supply Fan Motor:
 - a. Size: **<Insert horsepower>**.
 - b. Speed: **<Insert rpm>**.
 - c. Volts: **[120] [208] [230] [460] <Insert value>**.
 - d. Phase: **[Single] [Three]**.
 - e. Hertz: 60.

5. Refrigerant Cooling:
 - a. Capacity: **<Insert tons (kW)>**.
 - b. Full-Load Efficiency (EER or COP): **<Insert number>**.
 - c. Condenser Ambient-Air Temperature: **<Insert deg F (deg C)>**.
 - d. Evaporator Coil:
 - 1) Sensible Heat-Transfer Rate: **<Insert Btu/h (kW)>**.
 - 2) Total Heat-Transfer Rate: **<Insert Btu/h (kW)>**.
 - 3) Entering-Air, Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - 4) Entering-Air, Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 - 5) Leaving-Air, Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - 6) Leaving-Air, Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 - 7) Face Area: **<Insert sq. ft. (sq. m)>**.
 - 8) Maximum Face Velocity: **<Insert fpm (m/s)>**.
 - 9) Maximum Air-Side, Static-Pressure Drop: **<Insert inches wg (Pa)>**.
 - 10) Fin Spacing: **<Insert fins per inch (cm)>**.
 - 11) Fin Thickness: **<Insert inches (mm)>**.
 - 12) Number of Rows: **<Insert number>**.

6. Chilled-Water Cooling Coil:
 - a. Fluid: **[Chilled water] [Refrigerant] <Insert fluid>**.
 - b. Sensible Heat-Transfer Rate: **<Insert Btu/h (kW)>**.
 - c. Total Heat-Transfer Rate: **<Insert Btu/h (kW)>**.
 - d. Entering-Air, Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - e. Entering-Air, Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 - f. Leaving-Air, Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - g. Leaving-Air, Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 - h. Face Area: **<Insert sq. ft. (sq. m)>**.
 - i. Maximum Face Velocity: **<Insert fpm (m/s)>**.
 - j. Maximum Air-Side, Static-Pressure Drop: **<Insert inches wg (Pa)>**.
 - k. Coil Type: **[Continuous circuit] [Self-draining] [Cleanable]**.
 - l. Piping Connections: **[Threaded] [Flanged], [same end] [opposite ends]** of coil.
 - m. Tube Thickness: **<Insert inches (mm)>**.

- n. Fin Spacing: <Insert fins per inch (cm)>.
 - o. Fin Thickness: <Insert inches (mm)>.
 - p. Number of Rows: <Insert number>.
 - q. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.
 - r. Fluid Flow: <Insert gpm (L/s)>.
 - s. Maximum Fluid-Pressure Drop: <Insert feet of head (kPa)>.
 - t. Entering-Fluid Temperature: <Insert deg F (deg C)>.
 - u. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
 - v. Fluid Velocity: <Insert fpm (L/s)>.
7. Electric-Resistance Heating Coils:
- a. Heat-Transfer Rate: <Insert Btu/h (kW)>.
 - b. Entering-Air Temperature: <Insert deg F (deg C)>.
 - c. Leaving-Air Temperature: <Insert deg F (deg C)>.
 - d. Power Input: <Insert kilowatts>.
 - e. Volts: [120] [208] [230] [480] <Insert value>.
 - f. Phase: [Single] [Three].
 - g. Hertz: 60.
 - h. Full-Load Amperes: <Insert value>.
 - i. Maximum Overcurrent Protection: <Insert amperage>.
 - j. Capacity Control Number of Steps: <Insert number>.
8. Gas-Fired Furnace Heating:
- a. Heat-Transfer Rate: <Insert Btu/h (kW)>.
 - b. Entering-Air Temperature: <Insert deg F (deg C)>.
 - c. Leaving-Air Temperature: <Insert deg F (deg C)>.
 - d. Efficiency: [80] <Insert number> percent.
 - e. Fuel: [Natural] [Propane] gas.
 - f. Gas Heating Value: <Insert Btu/cu. ft. (kJ/L)>.
 - g. Gas Input: <Insert cfh (mL/s)>.
 - h. Gas Burner Electrical Characteristics:
 - 1) Power Input: <Insert kilowatts>.
 - 2) Volts: [120] [208] [230] [460] <Insert value>.
 - 3) Phase: [Single] [Three].
 - 4) Hertz: 60.
 - 5) Full-Load Amperes: <Insert value>.
 - 6) Minimum Circuit Ampacity: <Insert value>.
 - 7) Maximum Overcurrent Protection: <Insert amperage>.
9. [Hot-Water] [Steam] Heating Coils:
- a. Heat-Transfer Rate: <Insert Btu/h (kW)>.
 - b. Entering-Air Temperature: <Insert deg F (deg C)>.
 - c. Leaving-Air Temperature: <Insert deg F (deg C)>.
 - d. Face Area: <Insert sq. ft. (sq. m)>.
 - e. Maximum Face Velocity: <Insert fpm (m/s)>.

- f. Maximum Air-Side, Static-Pressure Drop: <Insert inches wg (Pa)>.
- g. Coil Type: [**Continuous circuit**] [**Self-draining**] [**Cleanable**].
- h. Piping Connections: [**Threaded**] [**Flanged**]; [**same end**] [**opposite ends**] of coil.
- i. Tube Thickness: <Insert inches (mm)>.
- j. Fin Spacing: <Insert fins per inch (cm)>.
- k. Fin Thickness: <Insert inches (mm)>.
- l. Number of Rows: <Insert number>.
- m. Coil Working-Pressure Ratings: [200 psig (1380 kPa), 325 deg F (163 deg C)] <Insert value>.
- n. Fluid Flow: <Insert gpm (L/s)>.
- o. Maximum Fluid-Pressure Drop: <Insert feet of head (kPa)>.
- p. Entering-Fluid Temperature: <Insert deg F (deg C)>.
- q. Leaving-Fluid Temperature: <Insert deg F (deg C)>.
- r. Fluid Velocity: <Insert fpm (L/s)>.
- s. Steam Flow: <Insert lb/h (g/s)>.
- t. Inlet Steam Pressure: <Insert psig (kPa)>.

10. Overall Unit Electrical Characteristics:

- a. Volts: [120] [208] [230] [460] <Insert value>.
- b. Phase: [**Single**] [**Three**].
- c. Hertz: 60.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.3 CABINET

- A. General Fabrication Requirements for Casings: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

- 1. Fabricate on channel base, welded frame construction and drain pan of welded steel coated externally with manufacturers standard paint finish. Assemble sections with gaskets and bolts. Casing/frame assembly shall be capable of withstanding 30 lb. per square foot snow load and 100 MPH winds.

- B. Exterior Casing Material: G-90 galvanized steel, phosphatized, with factory-painted finish of [**baked enamel**] [**zinc chromate, iron oxide, phenolic resin paint**] [**asphalt base coating formulated to protect surfaces, seal seams and joints, and provide insulation and sound deadening**] [**three coat system of epoxy applied over shot blasted surface, to total thickness of 5-6 mils**] with pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.

- 1. Finish: Unit base, framework and fan assembly shall be painted with 3 mil thick industrial primer with built in rust inhibitors and one coat of DTM enamel.
- 2. Weatherproof Casing Finish: Seal fixed joints with flexible weather tight sealer. Seal removable joints with closed-cell foam gasket. Pitch roof panels for

- drainage. Reinforce roof for winter snow loading. Provide cap strips over roof flanges. Provide rain caps and gaskets on access doors.
3. Exterior Casing Thickness: [0.052 inch (1.3 mm)] [0.0626 inch (1.6 mm)] [0.079 inch (2.0 mm)] **<Insert thickness>** thick.
 4. Interior Casing Material: Galvanized steel, [0.034 inch (0.86 mm)] [0.028 inch (0.7 mm)] **<Insert thickness>** thick[, **perforated 40 percent free area**].
- C. Casing Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
1. Materials: ASTM C 1071, Type I.
 2. Thickness: [2] **<Insert number>** inch thick, 3 lbs per cu ft density, neoprene coated, glass fiber insulation, "K" value at 75 degrees F maximum 0.26 Btu/inch/sq ft/degrees F/hr, applied to internal surfaces with adhesive and secured with pins and washers. Coat exposed edges of insulation with adhesive.
 3. Liner materials shall have air-stream surface coated with an erosion- and temperature-resistant coating or faced with a plain or coated fibrous mat or fabric.
 4. Liner Adhesive: Comply with ASTM C 916, Type I.
- D. Lifting and Handling Provisions: Factory-installed shipping skids and lifting lugs.
- E. Base Rails: [**Galvanized**] [**Stainless**]-steel rails for mounting on roof curb or pad as indicated.
- F. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
- G. Service Doors: Hinged access doors with gaskets. Material and construction of doors shall match material and construction of cabinet in which doors are installed.
- H. Walk-in Access Doors: [**18 x 40**] [**24 x 48**] [**24 x 60**] [**30 x 60**] [**30 x 72**] inch of galvanized steel insulated sandwich construction, for flush mounting, with hinges, gasket, latch, and handle assemblies [, **and 12 X 12 inch inspection window of 1/4 inch thick plexiglass**]. [**Provide welded channel frame to set door out from casing to permit external insulation.**].
- I. Inspection Doors: 10 x 10 inch, of galvanized steel for flush mounting, with gasket, latch, and handle assembly [**and 1/4 inch thick plexiglass inspection window**]. [**Provide welded channel frame to set door out from casing to permit external insulation.**]
- J. Inspection Doors: 18 x 22 inch of galvanized steel for flush mounting, with gasket, latch, and handle assemblies [**and 12 x 12 inch inspection window of 1/4 inch thick plexiglass**]. [**Provide welded channel frame to set door out from casing to permit external insulation.**]
- K. Louvers: [**Stationary**] [**Adjustable**], of galvanized steel, [**4**] [**6**] inch deep with plenum, [**nylon bearings**,] 1/2 inch mesh, 0.04 inch galvanized wire bird screen in [**aluminum**] [**galvanized**] frame, and bearing AMCA Certified Ratings Seal in accordance with

AMCA 500. **[Furnish adjustable louvers with hollow vinyl bulb edging on blades and foam side stops to limit leakage to maximum 2 percent at 4 inch wg differential pressure when sized for 2000 fpm face velocity.]**

- L. Roof: Standing seam or membrane; sloped to drain water.
- M. Floor: Reinforced, metal surface; reinforced to limit deflection when walked on by service personnel. Insulation shall be below metal walking surface.
- N. Cabinet Insulation:
1. Type: **[Fibrous-glass duct lining complying with ASTM C 1071, Type II] [or] [flexible elastomeric insulation complying with ASTM C 534, Type II, sheet materials.]**
 2. Thickness: **[1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.**
 3. Insulation Adhesive: Comply with ASTM C 916, Type I.
 4. Mechanical Fasteners: Suitable for adhesive, mechanical, or welding attachment to casing without damaging liner and without causing air leakage when applied as recommended by manufacturer.
- O. Condensate Drain Pans:
1. Shape: Rectangular, with **[1] [2]** percent slope in at least two planes to direct water toward drain connection.
 2. Size: Large enough to collect condensate from cooling coils including coil piping connections, coil headers, and return bends.
 - a. Length: Extend drain pan downstream from leaving face **[to comply with ASHRAE 62.1] <Insert distance>.**
 - b. Depth: A minimum of **[2 inches (50 mm)] <Insert dimension>** deep.
 3. Configuration: Single wall.
 4. Configuration: Double wall, with space between walls filled with foam insulation and moisture-tight seal.
 5. Material: Galvanized-steel sheet with asphaltic waterproofing compound coating on pan top surface.
 6. Material: Stainless-steel sheet.
 7. Drain Connection:
 - a. Located on **[one end] [both ends]** of pan, at lowest point of pan.
 - b. Terminated with threaded nipple.
 - c. Minimum Connection Size: **[NPS 1 (DN 25)] [NPS 2 (DN 50)] <Insert size>.**
 8. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
 9. Provide vapor-sealed 1-inch thick insulation under drain pan, and 1-inch trapped drain discharging to roof surface.
- P. Supplemental Condensate Drain Pans:

1. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment.
2. Supplemental drain pans to be constructed of 20 gauge (minimum) galvanized steel, minimum depth 2 inches, fabricated, braced, and supported so as to ensure stability.
3. Provide drain piping conforming to provisions 221116 "Domestic Water Piping" and other Division 22 Sections, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.

Q. Surfaces in Contact with Airstream: Comply with requirements in ASHRAE 62.1 for resistance to mold and erosion.

R. Bottom Inlet/outlet Units: Provide steel or aluminum walking grate on structural supports.

S. Strength: Provide structure to brace casings for suction pressure of 4 inch wg, with maximum deflection of 1 in 200.

T. Roof Curb: Full-perimeter curb of sheet metal, minimum [8 inches (200 mm)] [12 inches (300 mm)] [16 inches (400 mm)] <Insert number> high, with wood nailer, neoprene sealing strip, and welded Z-bar flashing.

1. Comply with requirements in "The NRCA Roofing Manual."

2.4 SUPPLY FAN

A. Forward-Curved Fan Type: Centrifugal; statically and dynamically balanced.

1. Fan Wheel Material: **[Galvanized] [Painted] [Coated]** steel, mounted on solid-steel shaft.
2. Bearings: **[Self-aligning, permanently lubricated ball bearings] [Pillow-block bearings rated L₅₀ for 200,000 hours and having external grease fittings].**

B. Plenum Fan Type: Single width, non-overloading, with backward-inclined or airfoil blades.

1. Fan Wheel Material: Aluminum; attached directly to motor shaft.
2. Fan Wheel Drive and Arrangement: Direct drive, AMCA Arrangement 4.
3. Fan panel and frame Material: Powder-coated steel, stainless steel, or aluminum.
4. Fan Enclosure: Easily removable enclosure around rotating parts.
5. Fan Balance: Precision balance fan below 0.08 inch/s (2.0 mm/s) at design speed with filter in.

- C. Service Factor for Belt Drive Applications: **[Multiple]**V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly with minimum **[1.4] [1.5] [2.0]** **<Insert value>** service factor.
- D. Motors:
1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Enclosure: **[Open dripproof] [Totally enclosed]**.
 3. Enclosure Materials: **[Cast iron] [Cast aluminum] [Rolled steel]**.
 4. Motor Bearings: **<Insert requirements>**.
 5. Unusual Service Conditions:
 - a. Ambient Temperature: **<Insert deg C>**.
 - b. Altitude: **<Insert feet (m)>** above sea level.
 - c. High humidity.
 - d. **<Insert conditions>**.
 6. Efficiency: Premium efficient.
 7. NEMA Design: **<Insert designation>**.
 8. Service Factor: **[1.0] [1.15] <Insert value>**.
- E. Mounting: Fan wheel, motor, and drives shall be mounted to fan casing with [restrained] [elastomeric] [spring] isolators. Locate fan and motor internally on welded steel base coated with corrosion resistant paint. Factory mount motor on slide rails. Provide access to motor, drive, and bearings through removable casing panels or hinged access doors. Mount base on vibration isolators. Refer to Section 230548.13 "Vibration Controls for HVAC".
- F. Flexible Connection: Separate fan, discharge and coil sections. Refer to Section 233300 "Air Duct Accessories".
- G. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000Hz	2000Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

2.5 BEARINGS AND DRIVES

- A. Bearings: AFBMA 9, AFBMA 11, L-10 life at 120,000 hours pillow block type, self-aligning, grease-lubricated roller bearings.
- B. Shafts: Solid, hot rolled steel, ground and polished, with key-way, and protectively coated with lubricating oil.

- C. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, bored to fit shafts and keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.
- D. Belt Guard: Fabricate to SMACNA Standard; 12 gage thick, 3/4 inch diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

2.6 COOLING COILS

- A. Casing: Provide access to both sides of coils. Enclose coils with headers and return bends fully contained within casing. Slide coils into casing through removable end panel with blank off sheets and sealing collars at connection penetrations.
- B. Eliminators: Three break of galvanized steel on coils, and Type 304 stainless steel on evaporative humidifier, mounted over drain pan.
- C. Capacity Ratings: Comply with ASHRAE 33 and ARI 410 [**and coil bearing the ARI label**].
- D. Coil Casing Material: [**Manufacturer's standard material**] [**Aluminum**] [**Galvanized steel**] [**Stainless steel**] <Insert material>.
- E. Tube Material: [**Copper**] <Insert material>.
- F. Tube Header Material: [**Manufacturer's standard material**] [**Copper**] [**Carbon steel**] [**Red brass**] <Insert material>.
- G. Fin Material: [**Aluminum**] [**Copper**] <Insert material>.
- H. Fin and Tube Joints: Mechanical bond.
- I. Leak Test: Coils shall be leak tested with air underwater.
- J. Refrigerant Coil Capacity Reduction: Circuit coils for [**face**] [**row**] [**interleaved**] control.
- K. Refrigerant Coil Suction and Distributor Header Materials: Seamless copper tube with brazed joints.
- L. Coating: Phenolic epoxy corrosion-protection coating after assembly.

2.7 REFRIGERATION SYSTEM

- A. Comply with requirements in ASHRAE 15, "Safety Standard for Refrigeration Systems."

- B. Refrigerant Charge: Factory charged with refrigerant and filled with oil.
- C. Compressors: [**Scroll**] [**Reciprocating or scroll**] compressors with integral vibration isolators, internal overcurrent and overtemperature protection, internal pressure relief[, **and crankcase heater**].
- D. Refrigerant: [**R-22**] [**R-134a**] [**R-407C**] [**R-410A**] [**HFC refrigerant**] <Insert other available type>.
1. Classified as Safety Group A1 according to ASHRAE 34.
 2. Provide unit with operating charge of refrigerant.
- E. Refrigeration System Specialties:
1. Expansion valve with replaceable thermostatic element.
 2. Refrigerant dryer.
 3. High-pressure switch.
 4. Low-pressure switch.
 5. Thermostat for coil freeze-up protection during low ambient temperature operation or loss of air.
 6. Brass service valves installed in discharge and liquid lines.
- F. Capacity Control:
1. Hot-gas bypass refrigerant control for capacity control with continuous dehumidification on a single compressor.
 2. Patented, Rawal APR control with zero to 100 percent modulating capacity control using hot-gas bypass. Evaporator coil shall be continuously active for dehumidification.
 3. Single compressor with evaporator and condenser coil within the refrigerant section to provide initial pre-cooling and to reheat for humidity control.
 4. Heat-pipe heat exchanger wrapped around the evaporator coil to pre-cool the air entering the evaporator coil and reheat the air leaving the evaporator coil to control humidity.
- G. Refrigerant [**condenser**] [**and**] [**reheat condenser**] coils:
1. Capacity Ratings: Complying with ASHRAE 33 and ARI 410 [**and coil bearing the ARI label**].
 2. Tube Material: Copper.
 3. Fin Material: [**Aluminum**] [**Copper**].
 4. Fin and Tube Joint: Mechanical bond.
 5. Leak Test: Coils shall be leak tested with air underwater.
 6. Coating: Phenolic epoxy corrosion-protection coating after assembly.
- H. Condenser Fan Assembly:
1. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades.
 2. Fan Motors:

- a. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Motor Enclosure: Totally enclosed non-ventilating (TENV) or totally enclosed air over (TEAO) enclosure.
 - c. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
 - d. Motor Bearings: [**Permanently lubricated bearings**] <Insert requirements>.
 - e. Unusual Service Conditions:
 - 1) Ambient Temperature: <Insert deg C>.
 - 2) Altitude: <Insert feet (m)> above sea level.
 - 3) High humidity.
 - 4) <Insert conditions>.
 - f. Built-in overcurrent and thermal-overload protection.
 - g. Efficiency: Premium efficient.
 - h. NEMA Design: <Insert designation>.
 - i. Service Factor: <Insert value>.
3. Fan Safety Guards: Steel with corrosion-resistant coating.
- I. Safety Controls:
1. Compressor motor and condenser coil fan motor low ambient lockout.
 2. Overcurrent protection for compressor motor.

2.8 ELECTRIC-RESISTANCE HEATING COIL

- A. UL Compliance: Comply with requirements in UL 1995, "Heating and Cooling Equipment."
- B. Electric-Resistance Heating Elements:
1. Coiled Resistance Wire: 80 percent nickel and 20 percent chromium.
 2. Tubular-Steel Sheath: Compacted magnesium oxide powder.
 3. Fins: Spiral-wound, copper-plated, steel fins continuously brazed to sheath.
 4. Heating Capacity: Low density **35 W per sq. in.** (54 kW per sq. m), factory wired for single-point wiring connection; with time delay for element staging and overcurrent- and overheat-protection devices.
 5. Safety Controls:
 - a. Blower-motor interlock, air-pressure switch.
 - b. Quiet mercury contactors.
 - c. Time delay between steps.
 - d. Integral, nonfused power disconnect switch.
- C. Electric-Resistance Heating Elements:
1. Open-Coil Resistance Wire: 80 percent nickel and 20 percent chromium.

2. Supports and Insulation: Floating ceramic bushings recessed into casing openings; fastened to supporting brackets and mounted in galvanized-steel frame.
3. Heating Capacity: Low density **35 W per sq. in.** (54 kW per sq. m), factory wired for single-point wiring connection; with time delay for element staging and overcurrent- and overheat-protection devices.
4. Safety Controls:
 - a. Blower-motor interlock, air-pressure switch.
 - b. Quiet mercury contactors.
 - c. Time delay between steps.
 - d. Integral, nonfused power disconnect switch.

2.9 DIRECT-FIRED GAS FURNACE HEATING

A. Furnace Assembly:

1. Factory assembled, piped, and wired.
2. Comply with requirements in NFPA 54, "National Fuel Gas Code"; ANSI Z83.4, "Non-Recirculating Direct Gas-Fired Industrial Air Heaters"; and ANSI Z83.18, "Recirculating Direct Gas-Fired Industrial Air Heaters."

B. Burners:

1. Cast-iron burner with stainless-steel mixing plates.
2. Rated for a maximum turndown ratio of 30:1.
3. Fuel: **[Natural] [Propane]** gas.

C. Safety Controls:

1. Gas manifold safety switches and controls shall comply with ANSI standards **[and FM Global] [and IRI]**.
2. Pilot: Intermittent spark igniter.
3. Purge-period timer shall automatically delay burner ignition and bypass low-limit control.
4. External gas-pressure regulator shall regulate pressure to not more than **0.5 psig** (3.4 kPa).
5. Airflow Proving Switch: Dual pressure switch senses correct airflow before energizing pilot and requires airflow to be maintained within minimum and maximum pressure settings across burner.
6. Manual-Reset, High-Limit Switch: Stops burner and closes main gas valve if high-limit temperature is exceeded.
7. Gas Train: Redundant main gas valves, electric pilot valve, main and pilot gas-pressure regulators, main and pilot manual shutoff valves[, **high-low gas-pressure switches**], and main and pilot pressure taps, **[to comply with FM Global requirements] [to comply with IRI requirements]**.

2.10 INDIRECT-FIRED GAS FURNACE HEATING

A. Furnace Assembly:

1. Factory assembled, piped, and wired.
2. Comply with requirements in NFPA 54, "National Fuel Gas Code," and ANSI Z21.47, "Gas-Fired Central Furnaces."
3. AGA Approval: Designed and certified by and bearing label of AGA.

B. Burners:

1. Heat-Exchanger Material: [**Aluminized steel with stainless-steel inserts**] [**Stainless steel**] with a minimum thermal efficiency of 80 percent.
2. Fuel: [**Natural**] [**Propane**] gas.
3. Ignition: Electronically controlled electric spark with flame sensor.
4. High-Altitude [**Model**] [**Kit**]: For Project elevations more than 2000 feet (610 m) above sea level.

C. Heat-Exchanger Drain Pan Material: Stainless steel.

D. Venting: Gravity vented.

E. Venting: Power vent with integral, motorized centrifugal fan interlocked with gas valve.

F. Safety Controls:

1. Gas Control Valve: [**Single stage**] [**Two stage**] [**Electronic modulating**].
2. Gas Train: Single-body, regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff.

2.11 HOT-WATER HEATING COIL

A. Capacity Ratings: Comply with ASHRAE 33 and ARI 410 [**and coil bearing the ARI label**].

B. Coil Casing Material: [**Manufacturer's standard material**] [**Aluminum**] [**Galvanized steel**] [**Stainless steel**] <Insert material>.

C. Tube Material: [**Copper**] <Insert material>.

D. Tube Header Material: [**Manufacturer's standard material**] [**Copper**] [**Carbon steel**] [**Red brass**] <Insert material>.

E. Fin Material: [**Aluminum**] [**Copper**] <Insert material>.

F. Fin and Tube Joints: Mechanical bond.

G. Leak Test: Coils shall be leak tested with air underwater.

- H. Coating: Phenolic epoxy corrosion-protection coating after assembly.

2.12 STEAM HEATING COIL

- A. Capacity Ratings: Comply with ASHRAE 33 and ARI 410 [**and coil bearing the ARI label**].
- B. Coil Type: Non-freeze, horizontal or vertical, tube arrangement.
- C. Casing Material: [**Manufacturer's standard material**] [**Aluminum**] [**Galvanized steel**] [**Stainless steel**] <Insert material>.
- D. Tube Material: [**Copper**] <Insert material>.
- E. Tube Header Material: [**Manufacturer's standard material**] [**Copper**] [**Carbon steel**] [**Red brass**] <Insert material>.
- F. Fin Material: [**Aluminum**] [**Copper**] <Insert material>.
- G. Fin and Tube Joints: Mechanical bond.
- H. Leak Test: Coils shall be leak tested with air underwater.
- I. Coating: Phenolic epoxy corrosion-protection coating after assembly.

2.13 SPRAYED COIL DEHUMIDIFIER

- A. Units: Assembly with casing, tank, nozzles, spray headers, eliminators, water and drain connections [, **spray pump**,] and cooling coils. [**Refer to Section 238413 "Humidifiers"**.]
- B. Insulation: Externally insulate casing. Mount on 2 inch thick rigid insulation board.
- C. Performance: Operate at [**3 inch wg negative**] [**3 inch wg positive**] [**6 inch wg positive**] operating static pressure.
- D. Coil: Refer to coil specification for size and cooling capacity.
- E. Casing: 14 gage galvanized steel reinforced and braced with galvanized angles.
- F. Drain Tank: [**10 gage**] [**3/16 inch**] welded black steel with coating of [**1/8 inch waterproof mastic**] [**3/32 inch minimum epoxy**].] [**glass fiber reinforced plastic.**] [**10 gage stainless steel.**] Provide with 2" drain, 1-1/2" water make-up connection, and 3" overflow connection.
- G. Coils: Copper, drainable.
- H. Spray Headers: Galvanized steel pipe.

- I. Spray Nozzles: Bronze, self-cleaning.
- J. Spray Pump: Vertical in-line operating at 1750 rev/min.
- K. Float Valve: Adjustable, with brass rod, brass float ball, and brass valve with replaceable neoprene seat.
- L. Low Water Cut-off: Float operated.

2.14 HUMIDIFIER

- A. Humidifiers: Certify capacities and selection in accordance with ARI 610.
- B. Steam Grid Humidifier: Stainless steel distribution tube with evenly spaced orifices extended full width of unit, factory mounted **[in plenum with drain pan for draw-thru units] [in diffuser section of blow-thru units]. [Refer to Section 238413 "Humidifiers".]**
- C. Evaporative Pan Humidifier: Factory mounted in plenum with drain pan, float box, copper pan, water immersion type sheathed heating element, and low water cut-off switch. **[Refer to Section 238413 "Humidifiers".]**
- D. Wet Glass Cell Washer: Section with 3 inch deep cells with random packed, glass fiber media in **[galvanized] [stainless]** steel frames, access door, spray tree assembly with **[brass] [stainless steel]** nozzles and **[galvanized] [stainless]** steel piping, and **[galvanized] [stainless]** steel eliminator plates. Assemble over welded **[stainless]** steel tank **[with interior and exterior surfaces blasted and painted with zinc chromate paint.]** Provide copper suction screen, drain, overflow, and suction connections in tank with make-up connection, **[brass]** float valve, and quick-fill connection. Insulate exterior with duct insulation. Mount tank on 2 inch thick rigid closed-cell insulation board.
- E. Evaporative Humidifier: Section with watertight **[cast iron]** door with brass fittings, wire glass window, and locking handles, **[spray tree assembly with brass nozzles and galvanized piping, galvanized eliminator plates with flooding nozzles and header, and galvanized anti-splash baffles] [water distribution assembly with brass nozzles and galvanized piping and cross fluted cellulose media]**. Assemble over welded steel tank with interior and exterior surfaces blasted and painted with zinc chromate paint. Provide copper suction screen, drain, overflow, and suction connections in tank with make-up connection, **[brass]** float valve, and quick-fill connection. Insulate exterior with duct insulation. Mount tank on 2 inch thick rigid closed-cell insulation board. **[Refer to Section 238413 "Humidifiers".]**

2.15 OUTDOOR-AIR INTAKE HOOD

- A. Type: Manufacturer's standard hood or louver.
- B. Materials: Match cabinet.

- C. Bird Screen: Comply with requirements in ASHRAE 62.1.
- D. Configuration: Designed to inhibit wind-driven rain and snow from entering unit.

2.16 FILTERS

- A. Filter Box: Section with filter guides, access doors from both sides, for face loading.
- B. Filter Media: UL 900 listed, Class I or Class II, approved by local authorities.
- C. Flat Panel Prefilter: Arrangement with 2 and 4 inch deep disposable, extended area panel filters.
- D. Cleanable Filters: **2-inch-** (50-mm-) thick, cleanable metal mesh.
- E. Disposable Panel Filters:
 - 1. Comply with NFPA 90A.
 - 2. Factory-fabricated, viscous-coated, flat-panel type.
 - 3. Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
 - 4. Initial Resistance: <Insert inches wg (Pa)>.
 - 5. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - 6. Minimum Arrestance: [80] <Insert value>, according to ASHRAE 52.1.
 - 7. Minimum Merv: [6] <Insert value>, according to ASHRAE 52.2.
 - 8. Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
- F. Extended-Surface, Disposable Panel Filters:
 - 1. Comply with NFPA 90A.
 - 2. Factory-fabricated, dry, extended-surface type.
 - 3. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
 - 4. Initial Resistance: <Insert inches wg (Pa)>.
 - 5. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - 6. Minimum Arrestance: [90] <Insert value>, according to ASHRAE 52.1.
 - 7. Minimum Merv: [7] <Insert value>, according to ASHRAE 52.2.
 - 8. Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
- G. Extended-Surface, Nonsupported-Media Filters:
 - 1. Comply with NFPA 90A.
 - 2. Factory-fabricated, dry, extended-surface, self-supporting type.
 - 3. Initial Resistance: <Insert inches wg (Pa)>.
 - 4. Recommended Final Resistance: <Insert inches wg (Pa)>.
 - 5. Minimum Arrestance: [95] <Insert value>, according to ASHRAE 52.1.
 - 6. Minimum Merv: [13] <Insert value>, according to ASHRAE 52.2.

7. Media: Fibrous material [**coated with an antimicrobial agent and**] constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.

H. Mounting Frames:

1. Panel filters arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or from access plenum.
2. Extended surface filters arranged for flat orientation, removable from access plenum.
3. Galvanized or stainless steel with gaskets and fasteners, suitable for bolting together into built-up filter banks[**with space for prefilter**].

2.17 ELECTRICAL POWER CONNECTIONS

- A. General Electrical Power Connection Requirements: Factory-installed and -wired switches, motor controllers, transformers, and other necessary electrical devices shall provide a [**single-point**] field power connection to unit.
- B. Enclosure: NEMA 250, [**Type 3R**] [**Type 4**] [**Type 4X**] <Insert type>, mounted in unit with hinged access door in unit cabinet having a lock and key or padlock and key,
- C. Wiring: Numbered and color-coded to match wiring diagram.
- D. Wiring Location: Install factory wiring outside an enclosure in a raceway.
- E. Power Interface: Field power interface shall be to [**wire lugs**] [**NEMA KS 1, heavy-duty, nonfused disconnect switch**].
- F. Factory Wiring: Branch power circuit to each motor and to controls with one of the following disconnecting means:
 1. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
 2. NEMA KS 1, heavy-duty, nonfusible switch.
 3. UL 489, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
- G. Factory-Mounted, Overcurrent-Protection Service: For each motor.
- H. Transformer: Factory mounted with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
- I. Controls: Factory wire unit-mounted controls where indicated.
- J. Lights: Factory wire unit-mounted lights.
- K. Receptacle: Factory wire unit-mounted, ground fault interrupt (GFI) duplex receptacle.

- L. Control Relays: Auxiliary and adjustable time-delay relays.

2.18 CONTROLS

- A. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Control Valves: Comply with requirements in Section 230923.11 "Control Valves."
- C. Control Wiring: Factory wire connection for controls' power supply.
- D. Control Devices: Sensors, transmitters, relays, switches, detectors, operators, actuators, and valves shall be manufacturer's standard items to accomplish indicated control functions.
- E. **[Remote] [Unit]-Mounted Status Panel:**
1. Cooling/Off/Heating Controls: Control operational mode.
 2. Damper Position: Indicate position of outdoor-air dampers in terms of percentage of outdoor air.
 3. Status Lights:
 - a. Filter dirty.
 - b. Fan operating.
 - c. Cooling operating.
 - d. Heating operating.
 - e. Smoke alarm.
 - f. General alarm.
 - g. **<Insert points>**.
 4. Digital Numeric Display:
 - a. Outdoor airflow.
 - b. Supply airflow.
 - c. Outdoor dry-bulb temperature.
 - d. Outdoor dew point temperature.
 - e. Space temperature.
 - f. Supply temperature.
 - g. Space relative humidity.
 - h. Space carbon dioxide level.
 - i. **<Insert points>**.
- F. Control Dampers:
1. Damper Location: Factory installed inside unit for ease of blade axle and bushing service. Arrange dampers located in a mixing box to achieve convergent airflow to minimize stratification.
 2. Damper Leakage: Comply with requirements in AMCA 500-D. Leakage shall not exceed **6.5 cfm per sq. ft.** (33 L/s per sq. m) at a static-pressure differential of **4.0**

- inches water column (1000 Pa) when a torque of 5 inch pounds per sq. ft. (30.1 Newton meters per sq. m) is applied to the damper jackshaft.
3. Damper Rating: Rated for close-off pressure equal to the fan shutoff pressure.
 4. Damper Label: Bear the AMCA seal for both air leakage and performance.
 5. Blade Configuration: Unless otherwise indicated, use parallel blade configuration for two-position control and equipment isolation service and use modulating control when mixing two airstreams. For other applications, use an opposed-blade configuration.
 6. Damper Frame Material: **[Extruded aluminum] [galvanized steel] [or] [stainless steel]**.
 7. Blade Type: **[Single-thickness metal reinforced with multiple V-grooves] [or] [hollow-shaped airfoil]**.
 8. Blade Material: **[Extruded aluminum] [galvanized steel] [or] [stainless steel]**.
 9. Maximum Blade Width: 6 inches (150 mm).
 10. Maximum Blade Length: 48 inches (1200 mm).
 11. Blade Seals: Replaceable, continuous perimeter vinyl seals and jambs with stainless-steel compression-type seals.
 12. Bearings: Thrust bearings for vertical blade axles.
 13. Airflow Measurement:
 - a. Monitoring System: Complete and functioning system of airflow monitoring as an integral part of the damper assembly where indicated.
 - b. Remote Monitoring Signal: 0-10 volt or 4-20 mA scaled signal.
 - c. Accuracy of flow measurement: Within **[5] [10] <Insert value>** percent of the actual flow rate between the range of the scheduled minimum and maximum airflow. For units with a large range between minimum and maximum airflow, configure the damper sections and flow measurement assembly as necessary to comply with accuracy.
 - d. Straightening Device: Integral to the flow measurement assembly if required to achieve the specified accuracy as installed.
 - e. Flow measuring device: Suitable for operation in untreated and unfiltered outdoor air. If necessary, include temperature and altitude compensation and correction to maintain the accuracy.

G. Damper Operators:

1. Factory-installed electric operator for each damper assembly with one operator for each damper assembly mounted to the damper frame.
2. Operator capable of shutoff against fan pressure and able to operate the damper with sufficient reserve power to achieve smooth modulating action and proper speed of response at the velocity and pressure conditions to which the damper is subjected.
3. Maximum Operating Time: Open or close damper 90 degrees in **[60] [90] <Insert value>** seconds.
4. Adjustable Stops: For both maximum and minimum positions.
5. Position Indicator and Graduated Scale: Factory installed on each actuator with words "OPEN" and "CLOSED," or similar identification, at travel limits.
6. Spring-return operator to fail-safe; either closed or open as required by application.

7. Operator Type: Direct coupled, designed for minimum 60,000 full-stroke cycles at rated torque.
8. Position feedback Signal: For remote monitoring of damper position.
9. Coupling: V-bolt and V-shaped, toothed cradle.
10. Circuitry: Electronic overload or digital rotation-sensing circuitry.

H. Chilled-Water Coil Controls:

1. **[Factory-mounted sensor in unit discharge] [Remote-sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to modulate factory-**[mounted] [furnished]** coil control valve to maintain temperature.
2. Space-temperature sensor with **[temperature adjustment] [unit-mounted temperature adjustment] [adjustment on remote-control panel]** to modulate factory-**[mounted] [furnished]** coil control valve to maintain temperature.

I. Refrigeration System Controls:

1. Unit-mounted enthalpy controller shall lock out refrigerant system when outdoor-air enthalpy is less than **[28 Btu/lb (65 kJ/kg)] <Insert value>** of dry air or outdoor-air temperature is less than **60 deg F (15 deg C) <Insert value>**.
2. Outdoor-air sensor de-energizes dehumidifier operation when outdoor-air temperature is less than **60 deg F (15 deg C) <Insert value>**.
3. Relative-humidity sensor energizes dehumidifier operation when relative humidity is more than **[50] <Insert value>** percent.

J. Furnace Controls:

1. **[Factory-mounted sensor in supply outlet] [Remote sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to modulate gas furnace burner to maintain space temperature.
2. Wall-mounted, space-temperature sensor with **[temperature adjustment] [unit-mounted temperature adjustment] [adjustment on remote-control panel]** to modulate gas furnace burner to maintain space temperature.
3. Remote Setback: Adjustable room thermostat selected by timer, set at **[50 deg F (10 deg C)] <Insert temperature>**; cycles supply fan and gas furnace burner to maintain space temperature.
4. Staged Burner Control: **[Two] [Four]** steps of control.
5. Electromechanical or Electronic Burner Control: 20 to 100 percent modulation of the firing rate; 10 to 100 percent with dual-furnace units.

K. Electric-Resistance Heat Controls:

1. **[Factory-mounted sensor in unit discharge] [Remote sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to control electric coil to maintain temperature.
2. Wall-mounted, space-temperature sensor with **[temperature adjustment] [unit-mounted temperature adjustment] [adjustment on remote-control panel]** to control electric coil to maintain temperature.
3. Capacity Controls: **[On/off] [Multiple steps] [Modulating SCR] <Insert type>**.

- L. **[Hot-Water] [and] [Steam]** Coil Controls: **[Factory-mounted sensor in unit discharge] [Remote sensor for field installation in supply-air duct]** with sensor adjustment located in control panel to modulate factory-**[mounted] [furnished]** coil control valve to maintain temperature.
- M. **[Hot-Water] [and] [Steam]** Coil Controls: Space-temperature sensor with **[temperature adjustment] [unit-mounted temperature adjustment] [adjustment on remote-control panel]** to modulate factory-**[mounted] [furnished]** coil control valve to maintain temperature.
- N. Damper Controls: Space pressure sensor modulates outdoor- and return-air dampers to maintain a positive pressure in space at a minimum of **[0.05 inch wg (12.4 Pa)]** **<Insert value>** with respect to outdoor reference.
- O. Integral Smoke Alarm: Smoke detector installed in **[supply] [and] [return]** air.
- P. DDC Temperature Control: Standalone control module for link between unit controls and DDC temperature-control system. Control module shall be compatible with control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC." Links shall include the following:
1. Start/stop interface relay, and relay to notify DDC temperature-control system alarm condition.
 2. Hardware interface or additional sensors for the following:
 - a. Room temperature.
 - b. Discharge-air temperature.
 - c. Refrigeration system operating.
 - d. Furnace operating.
 - e. Constant and variable motor loads.
 - f. Variable-frequency-controller operation.
 - g. Cooling load.
 - h. Economizer cycles.
 - i. Air-distribution static pressure and ventilation-air volumes.
- Q. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display unit status and alarms.
1. Hardwired Points:
 - a. Monitoring: On-off status, **[common trouble alarm] <Insert monitoring point>**.
 - b. Control: On-off operation, **[space temperature set-point adjustment] [supply temperature set-point adjustment] [space humidity set-point adjustment] [space pressure set-point adjustment] <Insert control point>**.
- 2.19 **[ASHRAE 135 (BACnet)] [LonTalk] [Modbus] [Industry-accepted, open-protocol]**

<Insert type of interface> communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the DDC system for HVAC.ACCESSORIES

- A. Service Lights and Switch: Factory installed in [fan section] [fan and coil sections] [each accessible section] <Insert locations> with weatherproof cover. Factory wire lights to a single-point field connection.
- B. Duplex Receptacle: Factory mounted in unit supply-fan section [and refrigeration section], with 20 amp 120 V GFI duplex receptacle and weatherproof cover.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping, ducts, and electrical systems to verify actual locations of connections before equipment installation.
- C. Examine roof curbs and equipment supports for suitable conditions where units will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. General:
 - 1. Install units level and plumb.
 - 2. Anchor units to structure.
 - 3. Install seismic restraints.
 - 4. Install static-pressure probe.
 - 5. Install water-cooled units with thermometer and pressure gage at the water supply and return connection.
- B. Comply with manufacturer's rigging and installation instructions for unloading units and moving to final locations.
- C. Curb Support: Install roof curb on roof structure according to "The NRCA Roofing Manual."
 - 1. Install and secure units on curbs and coordinate roof penetrations and flashing with roof construction.

2. Coordinate size, installation, and structural capacity of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 077200 "Roof Accessories."
 3. Coordinate size, location, and installation of unit manufacturer's roof curbs and equipment supports with roof Installer.
- D. Restrained Curb Support: Install restrained vibration isolation roof-curb rails on roof structure according to "The NRCA Roofing Manual."
- E. Equipment Mounting:
1. Install air units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- F. Suspended Units: Suspend[**and brace**] units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]
- G. Install wall- and duct-mounted sensors furnished by manufacturer for field installation. Install control wiring and make final connections to control devices and unit control panel.
- H. Install 3000-psi (20.7-MPa), compressive-strength (28-day) concrete base inside roof curb, [4 inches (100 mm)] <Insert dimension> thick. Concrete and reinforcement are specified with concrete.
- I. Comply with requirements for gas-fired furnace installation in NFPA 54, "National Fuel Gas Code."
- J. Install separate devices furnished by manufacturer and not factory installed.
- K. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.
- L. Install drain pipes from unit drain pans to sanitary drain.
1. Drain Piping: Drawn-temper copper water tubing complying with [ASTM B 88, Type L](#) (ASTM B 88M, Type B), with soldered joints.
 2. Drain Piping: Schedule 40 PVC pipe complying with ASTM D 1785, with solvent-welded fittings.
 - a. PVC solvent cement shall have a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

- b. Adhesive primer shall have a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
3. Pipe Size: Same size as condensate drain pan connection.

3.3 CONNECTIONS

- A. Where installing piping adjacent to units, allow space for service and maintenance.
- B. Gas Piping Connections:
1. Comply with requirements in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**]
 2. Connect gas piping to furnace, full size of gas train inlet, and connect with union[, **pressure regulator,**] and shutoff valve with sufficient clearance for burner removal and service.
 3. Install AGA-approved flexible connectors.
- C. Hydronic Piping Connections:
1. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties."
 2. Install shutoff valve and union or flange on each supply connection and install balancing valve and union or flange on each return connection.
- D. Steam Piping Connections:
1. Comply with requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties."
 2. Install shutoff valve and union or flange on each supply connection.
 3. Install, starting from the coil connection, union or flange, strainer, union, float and thermostatic trap, union, and shutoff valve.
- E. Duct Connections:
1. Comply with requirements in Section 233113 "Metal Ducts."
 2. Drawings indicate the general arrangement of ducts.
 3. Connect ducts to units with flexible duct connectors. Comply with requirements for flexible duct connectors in Section 233300 "Air Duct Accessories."
- F. Electrical Connections: Comply with requirements for power wiring, switches, and motor controls in electrical Sections.
1. Install electrical devices furnished by unit manufacturer but not factory mounted.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Inspect units for visible damage to furnace combustion chamber.
 3. Perform the following operations for both minimum and maximum firing and adjust burner for peak efficiency:
 - a. Measure gas pressure at manifold.
 - b. Measure combustion-air temperature at inlet to combustion chamber.
 - c. Measure flue-gas temperature at furnace discharge.
 - d. Perform flue-gas analysis. Measure and record flue-gas carbon dioxide and oxygen concentration.
 - e. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
 4. Verify operation of remote panel including pilot-light operation and failure modes. Inspect the following:
 - a. High-limit heat exchanger.
 - b. Alarms.
 5. Inspect units for visible damage to refrigerant compressor, condenser and evaporator coils, and fans.
 6. Start refrigeration system when outdoor-air temperature is within normal operating limits and measure and record the following:
 - a. Cooling coil leaving-air, dry- and wet-bulb temperatures.
 - b. Cooling coil entering-air, dry- and wet-bulb temperatures.
 - c. Condenser coil entering-air dry-bulb temperature.
 - d. Condenser coil leaving-air dry-bulb temperature.
 7. Simulate maximum cooling demand and inspect the following:
 - a. Compressor refrigerant suction and hot-gas pressures.
 - b. Short-circuiting of air through outside coil or from outside coil to outdoor-air intake.
 8. Inspect casing insulation for integrity, moisture content, and adhesion.
 9. Verify that clearances have been provided for servicing.
 10. Verify that controls are connected and operable.
 11. Verify that filters are installed.
 12. Clean coils and inspect for construction debris.
 13. Clean furnace flue and inspect for construction debris.
 14. Inspect operation of power vents.
 15. Purge gas line.
 16. Inspect and adjust vibration isolators and seismic restraints.

17. Verify bearing lubrication.
18. Clean fans and inspect fan-wheel rotation for movement in correct direction without vibration and binding.
19. Adjust fan belts to proper alignment and tension.
20. Start unit.
21. Inspect and record performance of interlocks and protective devices including response to smoke detectors by fan controls and fire alarm.
22. Operate unit for run-in period.
23. Calibrate controls.
24. Adjust and inspect high-temperature limits.
25. Inspect outdoor-air dampers for proper stroke[**and interlock with return-air dampers**].
26. Verify operational sequence of controls.
27. Measure and record the following airflows. Plot fan volumes on fan curve.
 - a. Supply-air volume.
 - b. Return-air flow.
 - c. Outdoor-air flow.

- B. After startup, change filters, verify bearing lubrication, and adjust belt tension.
- C. Remove and replace components that do not properly operate and repeat startup procedures as specified above.
- D. Prepare written report of the results of startup services.

3.5 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain units.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 237433

SECTION 238113.11 - PACKAGED TERMINAL AIR-CONDITIONERS, THROUGH-WALL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes packaged, terminal, through-the-wall air conditioners.
- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 1. Provide manufacturer's drawings indicating dimensions, rough-in connections, and electrical characteristics and connection requirements.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 - 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For packaged, terminal air conditioners.
 - 1. Include plans, elevations, sections, details for wall penetrations, [**seismic bracing,**] and attachments to other work.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
 - 4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:

- a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
- b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

D. Color Samples: For unit cabinet, discharge grille, and exterior louver, and for each color and texture specified.

1.4 INFORMATIONAL SUBMITTALS

- A. Product Test Reports: For packaged, terminal air conditioners, for tests performed by manufacturer and witnessed by a qualified testing agency.
- B. Field quality-control reports.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For packaged, terminal air conditioners to include in emergency, operation, and maintenance manuals.
 - 1. Include manufacturer's descriptive literature, operating instructions, installation instructions, and maintenance and repair data.
- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MOCKUP

- A. Install one (1) unit that includes inside cabinet, wall sleeve, and wall louver.
- B. Locate where directed by DEN Project Manager.
- C. Mockup may **[not]** remain as part of the Work.

1.7 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Protect finished cabinets from physical damage by leaving factory packing cases in place before installation and providing temporary covers after installation.

1.8 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of packaged, terminal air conditioners that fail in materials or workmanship within specified warranty period.
1. Warranty Period for Sealed Refrigeration System: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion, including components and labor.
 2. Warranty Period for Nonsealed System Parts: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion, including only components and excluding labor.
 3. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. Amana; a brand of Whirlpool Corporation.
 2. Carrier Corporation; a unit of United Technologies Corp.
 3. ClimateMaster, Inc.
 4. Comfort-Aire; a division of Heat Controller, Inc.
 5. Friedrich Air Conditioning Company.
 6. General Electric Company; GE Energy Management - Electrical Distribution.
 7. LG Appliances.
 8. McQuay International; Daikin Industries.
 9. Suburban Manufacturing Company; a division of AIRXCEL, Inc.
 10. Trane.
 11. York International.
 12. **<Insert manufacturer's name>**.
 13. or approved equal.

2.2 MANUFACTURED UNITS

- A. Description: Factory-assembled and -tested, self-contained, packaged, terminal **[air conditioning] [heat pump]** units with room cabinet, electric refrigeration system,

[electric] [hot water] [gas fired] [heating,] and [built-in] [remote] temperature controls; fully charged with refrigerant and filled with oil; with [cord-connected] [hardwired] chassis.

- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."
- D. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.
- E. ASHRAE Thermal Comfort: Applicable requirements in ASHRAE 55.
- F. UL listed and ETL performance certified.

2.3 CHASSIS

- A. Cabinet: [0.052-inch- (1.3-mm-)] <Insert dimension> thick [galvanized] [powder-coated] [epoxy coated] [baked enamel] steel with removable front panel with concealed latches.
 - 1. Mounting: [Wall with wall sleeve] [Floor with subbase].
 - 2. Top: [Angled] [Flat].
 - 3. Discharge Grille: [Punched-louver discharge grille allowing four-way discharge-air pattern] [Extruded-aluminum discharge grille] [Reversible-polycarbonate discharge grille allowing upward and horizontal airflow], tamperproof, and carrying a flame test rating in accordance with UL standard 494.
 - 4. Louvers: [Extruded aluminum with enamel finish] [Stamped aluminum with clear-anodized finish] [Stamped steel with enamel finish]; [white] [bronze] [brown] [beige] <Insert color> color.
 - 5. Finish: [Epoxy coating] [Baked enamel].
 - 6. Access Door: Hinged door in top of cabinet for access to controls.
 - 7. Cabinet Extension: Matching cabinet in construction and finish, allowing diversion of airflow to adjoining room; with grille.
 - 8. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
 - 9. Electrical Subbase: Enameled steel with four adjustable leveling feet and adjustable end plates[, with factory-installed and -wired, fused disconnect switch and receptacle sized for unit].
 - 10. Hydronic Subbase: Enameled steel with six adjustable leveling feet and adjustable end plates with two-row NPS 5/8 (DN 18) copper tube, aluminum-plate finned coil for use with hot water or steam, [normally open] [normally closed] low-voltage electric valve for [hot water] [steam] and provision for mounting receptacle[, with factory-installed and -wired, fused disconnect switch and receptacle sized for unit].

11. Wall Sleeves: **[Galvanized steel with polyester finish] [Galvanized steel with powder-coated paint] [Molded polymer] [Molded fiberglass-reinforced polyester]**.
 - B. Refrigeration System: Direct-expansion indoor coil with capillary restrictor and hermetically sealed scroll compressor with vibration isolation and overload protection.
 1. Indoor and Outdoor Coils: Seamless copper tubes mechanically expanded into aluminum fins **[with capillary tube distributor on indoor coil]**.
 2. Accumulator.
 3. Constant-pressure expansion valve.
 4. Reversing valve.
 5. Charge: **[R-407C] [R-410A]**.
 - C. Indoor Fan: Forward curved, centrifugal; with **[single-] [two-]**speed motor and positive-pressure ventilation damper with **[concealed manual] [electric]** operator.
 - D. Filters: Washable polyurethane in molded plastic frame.
 - E. Condensate Drain: Drain pan **[to direct condensate to outdoor coil for re-evaporation] [and piping to direct condensate to building waste and vent piping]**.
 1. Comply with ASHRAE 62.1 for drain pan construction and connections.
 - F. Outdoor Fan: **[Forward curved, centrifugal] [Propeller] [Forward curved, centrifugal or propeller]** type **[with separate] [driven by indoor fan]** motor.
 1. Indoor and Outdoor Fan Motors: Two speed; comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Fan Motors: Permanently lubricated split capacitor.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - c. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
- 2.4 HEATING
- A. Electric-Resistance Heating Coil: Nickel-chromium-wire, electric-resistance heating elements with contactor and high-temperature-limit switch.
 - B. Hot-Water Heating Coil: Seamless copper tubes mechanically expanded into aluminum fins with two-way modulating control valve and air vent
 - C. Gas Heat:

1. General Requirements for Gas-Fired, Noncondensing Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.86/CSA 2.32, "Vented Gas-Fired Space Heating Appliances," and with NFPA 54.
2. Type of Gas: **[Natural]** **[Propane]**.
3. Heat Exchanger: **[Aluminized]** **[Stainless]** steel.
4. Burner:
 - a. Gas Valve: 100 percent safety, single-stage main gas valve; main shutoff valve; pressure regulator; safety pilot with electronic flame sensor; limit control, transformer; and combination ignition/fan timer control board.
 - b. Ignition: Electric pilot ignition with hot-surface igniter or electric spark ignition.
5. Gas-Burner Safety Controls:
 - a. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
 - b. Flame Rollout Switch: Installed on burner box; prevents burner operation.
 - c. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
6. Combustion-Air Inducer: Centrifugal fan prepurges heat exchanger and vents combustion products; thermally protected motor includes sleeve bearings; pressure switch prevents operation if combustion-air inlet or flue outlet is blocked.
7. Furnace Controls: Solid-state board for integrating ignition, heat, cooling, and fan speeds; adjustable fan-on and fan-off timing; and terminals for connection to accessories.

2.5 CONTROLS

- A. Control Module: Unit-mounted digital panel with touchpad temperature control and with touchpad for heating, cooling, and fan operation. Include the following features:
 1. Low-Ambient Lockout Control: Prevents cooling-cycle operation below **40 deg F (5 deg C)** outdoor air temperature.
 2. Heat-Pump Ambient Control: Field-adjustable switch changes to heat-pump heating operation above **40 deg F (5 deg C)** and to supplemental heating below **plus 25 deg F (minus 4 deg C)**.
 3. Temperature-Limit Control: Prevents occupant from exceeding preset **[setback or]** setup temperature.
 4. Building Automation System Interface: Allows remote on-off control with setback temperature control.
 5. Reverse-Cycle Defrost: Solid-state sensor monitors frost buildup on **[indoor]** **[outdoor]** coil and reverses unit to melt frost.
- B. Remote Control: Standard unit-mounted controls with remote-mounted, low-voltage, adjustable thermostat with heat anticipator; **[heat-off-cool-auto]** **[heat-off-cool]** switch; and **[on-auto]** fan switch.

- C. Outdoor Air: Motorized intake damper. Open intake when unit indoor-air fan runs.
- D. Outdoor Air: Manual intake damper.

2.6 CAPACITIES AND CHARACTERISTICS

- A. Airflow: <Insert cfm (L/s)>.
- B. Outdoor-Air Intake Rate: <Insert cfm (L/s)>.
- C. Cooling Capacity:
 - 1. Total: <Insert Btu/h (kW)>.
 - 2. Sensible: <Insert Btu/h (kW)>.
 - 3. Energy-Efficiency Ratio: <Insert number>.
 - 4. Indoor Coil Entering-Air Dry Bulb Temperature: <Insert deg F (deg C)>.
 - 5. Indoor Coil Entering-Air Wet Bulb Temperature: <Insert deg F (deg C)>.
 - 6. Indoor Coil Leaving-Air Dry Bulb Temperature: <Insert deg F (deg C)>.
 - 7. Indoor Coil Leaving-Air Wet Bulb Temperature: <Insert deg F (deg C)>.
 - 8. Outdoor Coil Entering-Air Temperature: <Insert deg F (deg C)>.
- D. Heat-Pump Capacity:
 - 1. Total: <Insert Btu/h (kW)>.
 - 2. Outdoor Temperature: <Insert deg F (deg C)>.
- E. Electric Heat Capacity: <Insert Btu/h (kW)>.
- F. Hydronic Heat Capacity:
 - 1. Total: <Insert Btu/h (kW)>.
 - 2. Entering-Air Temperature: <Insert deg F (deg C)>.
 - 3. Leaving-Air Temperature: <Insert deg F (deg C)>.
 - 4. Water Flow: <Insert gpm (L/s)>.
 - 5. Entering-Water Temperature: <Insert deg F (deg C)>.
 - 6. Leaving-Water Temperature: <Insert deg F (deg C)>.
- G. Gas Heat Capacity:
 - 1. Input: <Insert Btu/h (kW)>.
 - 2. Output: <Insert Btu/h (kW)>.
 - 3. AFUE: [80] <Insert number> percent.
- H. Sound:
 - 1. Indoor: <Insert bels>.
 - 2. Outdoor: <Insert bels>.
- I. Electrical Characteristics:

1. Volts: <Insert value>.
2. Phase: [**Single**] [**Three**].
3. Hertz: 60.
4. Full-Load Amperes: <Insert value>.
5. Minimum Circuit Ampacity: <Insert value>.
6. Maximum Overcurrent Protection: <Insert amperage>.

2.7 SOURCE QUALITY CONTROL

- A. Sound-Power Level Ratings: Factory test to comply with AHRI 300, "Sound Rating and Sound Transmission Loss of Packaged Terminal Equipment."
- B. Unit Performance Ratings: Factory test to comply with AHRI 310/380/CSA C744, "Packaged Terminal Air-Conditioners and Heat Pumps."

2.8 SUPPLEMENTAL CONDENSATE DRAIN PANS

- A. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment.
- B. Supplemental drain pans to be constructed of 20 gauge (minimum) galvanized steel, minimum depth 2 inches, fabricated, braced, and supported so as to ensure stability.
- C. Provide drain piping conforming to provisions Division 22 Sections, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate installation of units with architectural, [**mechanical,**] and electrical work.
- C. Install units level and plumb, maintaining manufacturer's recommended clearances and tolerances.
- D. Install wall sleeves in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Section 079200 "Joint Sealants."

- E. Install and anchor wall sleeves to withstand, without damage to equipment and structure, seismic forces required by building code.
- F. On water coils, provide shut-off valve on supply line and [**balancing valve**] [**flow control and shut-off valve**] on return line. Provide [**manual**] [**float operated automatic**] air vents at high points complete with stop valve.

3.2 CONNECTIONS

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements for piping specified in Section 231123 "Facility Natural-Gas Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Install piping adjacent to machine to allow service and maintenance.

3.3 FIELD QUALITY CONTROL

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
 - 2. After installing packaged, terminal air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
 - 3. Unit is level on base and is flashed in exterior wall.
 - 4. Unit casing has no visible damage.
 - 5. Compressor, air-cooled condenser coil, and fans have no visible damage.
 - 6. Labels are clearly visible.
 - 7. Controls are connected and operable.
 - 8. Shipping bolts, blocks, and tie-down straps are removed.
 - 9. Filters are installed and clean.
 - 10. Drain pan and drain line are installed correctly.
 - 11. Electrical wiring installation complies with manufacturer's submittal and installation requirements in electrical Sections.
 - 12. Installation: Perform startup checks according to manufacturer's written instructions, including the following:
 - a. Lubricate bearings on fan.
 - b. Check fan-wheel rotation for correct direction without vibration and binding.

13. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
14. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

- D. After operational test, change filters.
- E. Packaged, terminal air conditioners will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

3.4 ADJUSTING

- A. Adjust initial temperature set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain packaged, terminal air conditioners.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238113.11

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SECTION 238113.12 - PACKAGED TERMINAL AIR-CONDITIONERS, FREESTANDING UNITS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify with manufacturers that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include packaged, terminal air conditioners may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes packaged, terminal, freestanding air conditioners.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
1. Provide manufacturer's drawings indicating dimensions, rough-in connections, and electrical characteristics and connection requirements.
 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

See "Sustainable Design Considerations" Article in the Evaluations for discussion on LEED prerequisites and credits.

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For packaged, terminal air conditioners.
1. Include plans, elevations, sections, details for wall penetrations, [**seismic bracing,**] and attachments to other work.
 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power, signal, and control wiring.
 4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
- D. Color Samples: For unit cabinet, discharge grille, and exterior louver, and for each color and texture specified.

1.4 INFORMATIONAL SUBMITTALS

- A. Product Test Reports: For packaged, terminal air conditioners, for tests performed by manufacturer and witnessed by a qualified testing agency.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For packaged, terminal air conditioners to include in emergency, operation, and maintenance manuals.
 - 1. Include manufacturer's descriptive literature, operating instructions, installation instructions, and maintenance and repair data.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Delete paragraph (and subparagraphs below) if mockups not required. If retaining, indicate location, size, and other details of mockups on drawings or with inserts.

Verify mockup requirements with DEN Project Manager.

1.6 MOCKUP

Use this article for assessing full sized erected assemblies required for review of construction coordination of work of several sections, testing, or observation of operation.

- A. Install one (1) unit that includes inside cabinet, wall sleeve, and wall louver.
- B. Locate where directed by DEN Project Manager.

Review requirement below with DEN Project Manager.

- C. Mockup may **[not]** remain as part of the Work.

1.7 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Protect finished cabinets from physical damage by leaving factory packing cases in place before installation and providing temporary covers after installation.

1.8 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace components of packaged, terminal air conditioners that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

1. Warranty Period for Sealed Refrigeration System: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion, including components and labor.
2. Warranty Period for Nonsealed System Parts: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion, including only components and excluding labor.
3. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion.]

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and Masterworks Paragraph Builder are neither recommended nor endorsed by the AIA or ARCOM. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carrier Corporation; a unit of United Technologies Corp.
 2. ClimateMaster, Inc.

3. [Friedrich Air Conditioning Company.](#)
4. [General Electric Company; GE Energy Management - Electrical Distribution.](#)
5. [McQuay International; Daikin Industries.](#)
6. [Suburban Manufacturing Company; a division of AIRXCEL, Inc.](#)
7. **<Insert manufacturer's name>.**
8. or approved equal.

2.2 MANUFACTURED UNITS

Retain first option in "Description" Paragraph below for heating and cooling units and for heat pumps with supplemental heat.

- A. Description: Factory-assembled and -tested, self-contained, packaged, [air conditioning] [**heat pump**] with room cabinet, electric refrigeration system, [**electric**] [**hot water**] [**gas fired**] [**heating,**] and [**built-in**] [**remote**] temperature controls; fully charged with refrigerant and filled with oil; with [**cord-connected**] [**hardwired**] chassis.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1. In addition to establishing minimum ventilation rates, ASHRAE 62.1 includes requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

- D. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.
- E. ASHRAE Thermal Comfort: Applicable requirements in ASHRAE 55.
- F. UL listed and ETL performance certified.

2.3 CHASSIS

- A. Cabinet: [0.052-inch- (1.32-mm-)] **<Insert dimension>** thick [**galvanized**] [**powder-coated**] [**epoxy coated**] [**baked enamel**] steel with removable front panel with concealed latches.

Retain "Mounting," "Top," and "Discharge Grille" subparagraphs below if units are not scheduled on Drawings.

1. Mounting: **[Floor with subbase] [Horizontal] [Vertical]**.
2. Top: **[Angled] [Flat]**.
3. Discharge Grille: **[Punched-louver discharge grille allowing four-way discharge-air pattern] [Extruded-aluminum discharge grille] [Reversible-polycarbonate discharge grille allowing upward and horizontal airflow]**, tamperproof, and carrying a flame test rating in accordance with UL standard 494.
4. Louvers: **[Extruded aluminum with enamel finish] [Stamped aluminum with clear-anodized finish] [Stamped steel with enamel finish]; [white] [bronze] [brown] [beige] <Insert color> color**.
5. Finish: **[Epoxy coating] [Baked enamel]**.
6. Access Door: Hinged door in top of cabinet for access to controls.
7. Cabinet Extension: Matching cabinet in construction and finish, allowing diversion of airflow to adjoining room; with grille.

Retain "Finish of Interior Surfaces" Subparagraph below to comply with LEED Prerequisite IEQ 1 or if required by Project requirements or authorities having jurisdiction. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

8. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Electrical Subbase" Subparagraph below for floor-mounted units.

9. Electrical Subbase: Enameled steel with four adjustable leveling feet and adjustable end plates[, **with factory-installed and -wired, fused disconnect switch and receptacle sized for unit**].
10. Hydronic Subbase: Enameled steel with six adjustable leveling feet and adjustable end plates with two-row **NPS 5/8 (DN 18)** copper tube, aluminum-plate finned coil for use with hot water or steam, **[normally open] [normally closed]** low-voltage electric valve for **[hot water] [steam]** and provision for mounting receptacle[, **with factory-installed and -wired, fused disconnect switch and receptacle sized for unit**].
11. Wall Sleeves: **[Galvanized steel with polyester finish] [Galvanized steel with powder coated paint] [Molded polymer] [Molded fiberglass-reinforced polyester]**.

B. Refrigeration System: Direct-expansion indoor coil with capillary restrictor and hermetically sealed scroll compressor with vibration isolation and overload protection.

1. Indoor and Outdoor Coils: Seamless copper tubes mechanically expanded into aluminum fins[**with capillary tube distributor on indoor coil**].

Retain first three subparagraphs below for heat-pump units.

2. Accumulator.
3. Constant-pressure expansion valve.
4. Reversing valve.
5. Charge: **[R-407C] [R-410A]**.

- C. Indoor Fan: Forward curved, centrifugal; with **[single-] [two-]**speed motor and positive-pressure ventilation damper with **[concealed manual] [electric]** operator.

Filters in "Filters" Paragraph below are optional feature. Washable filters may not comply with requirements in ASHRAE 62.1 for a minimum MERV 6, which would not fulfill LEED Prerequisite IEQ 1. Verify filter efficiency with manufacturers.

- D. Filters: Washable polyurethane in molded plastic frame.
- E. Condensate Drain: Drain pan **[to direct condensate to outdoor coil for re-evaporation] [and piping to direct condensate to building waste and vent piping]**.

In subparagraph below, verify drain pan construction and connection requirements with manufacturers if applying for LEED credits or if required by Project requirements or authorities having jurisdiction. ASHRAE 62.1 has specific requirements for drain pan construction and connections.

1. Comply with ASHRAE 62.1 for drain pan construction and connections.

- F. Outdoor Fan: **[Forward curved, centrifugal] [Propeller] [Forward curved, centrifugal or propeller]** type **[with separate] [driven by indoor fan]** motor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Indoor and Outdoor Fan Motors: Two speed; comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Fan Motors: Permanently lubricated split capacitor.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - c. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

2.4 HEATING

Retain "Electric-Resistance Heating Coil," "Hot-Water Heating Coil," or "Gas Heat" Paragraph below for heating and cooling units or for heat pumps with supplemental heat.

- A. Electric-Resistance Heating Coil: Nickel-chromium-wire, electric-resistance heating elements with contactor and high-temperature-limit switch.
- B. Hot-Water Heating Coil: Seamless copper tubes mechanically expanded into aluminum fins with two-way modulating control valve and air vent

Gas heat is only provided by Suburban Manufacturing Company.

C. Gas Heat:

1. General Requirements for Gas-Fired, Noncondensing Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.86/CSA 2.32, "Vented Gas-Fired Space Heating Appliances," and with NFPA 54.
2. Type of Gas: **[Natural]** **[Propane]**.
3. Heat Exchanger: **[Aluminized]** **[Stainless]** steel.
4. Burner:

In "Gas Valve" Subparagraph below, two-stage and modulating gas valves are optional features.

- a. Gas Valve: 100 percent safety, **[two-stage]** **[modulating]** main gas valve; main shutoff valve; pressure regulator; safety pilot with electronic flame sensor; limit control; transformer; and combination ignition/fan timer control board.
 - b. Ignition: Electric pilot ignition with hot-surface igniter or electric spark ignition.
5. Gas-Burner Safety Controls:
- a. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
 - b. Flame Rollout Switch: Installed on burner box; prevents burner operation.
 - c. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
6. Combustion-Air Inducer: Centrifugal fan prepurges heat exchanger and vents combustion products; thermally protected motor includes sleeve bearings; pressure switch prevents operation if combustion-air inlet or flue outlet is blocked.
7. Furnace Controls: Solid-state board for integrating ignition, heat, cooling, and fan speeds; adjustable fan-on and fan-off timing; and terminals for connection to accessories.

2.5 CONTROLS

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, Section 5 - "Systems and Equipment," for ventilation system controls. If applying for LEED credits or if required by Project requirements or authorities having jurisdiction, verify that manufacturers can provide units with controls that comply with requirements. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

Select applicable control options.

When packaged equipment needs to be connected to the BAS for monitoring or remote setpoint override, it is the responsibility of the engineer to verify that the packaged controls are fully compatible\controllable with the BAS. Any change orders for controls modifications to make new equipment work will be burdened by the engineer.

- A. Control Module: Unit-mounted digital panel with touchpad temperature control and with touchpad for heating, cooling, and fan operation. Include the following features:
1. Low-Ambient Lockout Control: Prevents cooling-cycle operation below 40 deg F (5 deg C) outdoor air temperature.

Retain "Heat-Pump Ambient Control" Subparagraph below for heat-pump units.

2. Heat-Pump Ambient Control: Field-adjustable switch changes to heat-pump heating operation above 40 deg F (5 deg C) and to supplemental heating below plus 25 deg F (minus 4 deg C).

Retain option "Temperature-Limit Control" Subparagraph below for heating and cooling units and for heat pumps.

3. Temperature-Limit Control: Prevents occupant from exceeding preset[**setback or**] setup temperature.
 4. Building Automation System Interface: Allows remote on-off control with setback temperature control.
 5. Reverse-Cycle Defrost: Solid-state sensor monitors frost buildup on [**indoor**] [**outdoor**] coil and reverses unit to melt frost.
- B. Remote Control: Standard unit-mounted controls with remote-mounted, low-voltage, adjustable thermostat with heat anticipator; [**heat-off-cool-auto**] [**heat-off-cool**] switch; and[**on-auto**] fan switch.

Retain one of two "Outdoor Air" paragraphs below. Retain first paragraph to comply with LEED Prerequisite IEQ 1, which requires compliance with ASHRAE 62.1, or if required by Project requirements or authorities having jurisdiction. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

- C. Outdoor Air: Motorized intake damper. Open intake when unit indoor-air fan runs.
- D. Outdoor Air: Manual intake damper.

2.6 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of packaged, terminal air conditioners, delete this article and schedule packaged, terminal air conditioners on Drawings.

- A. Airflow: <Insert cfm (L/s)>.

LEED Prerequisite IEQ 1 requires minimum ventilation rates according to ASHRAE 62.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

- B. Outdoor-Air Intake Rate: <Insert cfm (L/s)>.
- C. Cooling Capacity:
1. Total: <Insert Btu/h (kW)>.
 2. Sensible: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

3. Energy-Efficiency Ratio: <Insert number>.
4. Indoor Coil Entering-Air Dry Bulb Temperature: <Insert deg F (deg C)>.
5. Indoor Coil Entering-Air Wet Bulb Temperature: <Insert deg F (deg C)>.
6. Indoor Coil Leaving-Air Dry Bulb Temperature: <Insert deg F (deg C)>.
7. Indoor Coil Leaving-Air Wet Bulb Temperature: <Insert deg F (deg C)>.
8. Outdoor Coil Entering-Air Temperature: <Insert deg F (deg C)>.

D. Heat-Pump Capacity:

1. Total: <Insert Btu/h (kW)>.
2. Outdoor Temperature: <Insert deg F (deg C)>.

E. Electric Heat Capacity: <Insert Btu/h (kW)>.

F. Hydronic Heat Capacity:

1. Total: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Water Flow: <Insert gpm (L/s)>.
5. Entering-Water Temperature: <Insert deg F (deg C)>.
6. Leaving-Water Temperature: <Insert deg F (deg C)>.

G. Gas Heat Capacity:

1. Input: <Insert Btu/h (kW)>.
2. Output: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

3. AFUE: [80] <Insert number> percent.

H. Sound:

1. Indoor: <Insert bels>.
2. Outdoor: <Insert bels>.

I. Electrical Characteristics:

1. Volts: <Insert value>.
2. Phase: [Single] [Three].
3. Hertz: 60.
4. Full-Load Amperes: <Insert value>.
5. Minimum Circuit Ampacity: <Insert value>.
6. Maximum Overcurrent Protection: <Insert amperage>.

2.7 SOURCE QUALITY CONTROL

- A. Sound-Power Level Ratings: Factory test to comply with AHRI 300, "Sound Rating and Sound Transmission Loss of Packaged Terminal Equipment."
- B. Unit Performance Ratings: Factory test to comply with AHRI 310/380/CSA C744, "Packaged Terminal Air-Conditioners and Heat Pumps."

2.8 SUPPLEMENTAL CONDENSATE DRAIN PANS

- A. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment.
- B. Supplemental drain pans to be constructed of 20 gauge (minimum) galvanized steel, minimum depth 2 inches, fabricated, braced, and supported so as to ensure stability.
- C. Provide drain piping conforming to provisions Division 22 Sections, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate installation of units with architectural, [**mechanical,**] and electrical work.
- C. Install units level and plumb, maintaining manufacturer's recommended clearances and tolerances.
- D. Install exterior louver in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Section 079200 "Joint Sealants."

Retain paragraph below in seismic areas. Equipment protection may be required for some types of buildings. Verify requirements with model building codes and ASCE/SEI 7.

- E. Install and anchor exterior louver to withstand, without damage to equipment and structure, seismic forces required by building code.

Edit paragraph below.

- F. On water coils, provide shut-off valve on supply line and **[balancing valve] [flow control and shut-off valve]** on return line. Provide **[manual] [float operated automatic]** air vents at high points complete with stop valve.

3.2 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

Retain first paragraph below for units with hot-water supplemental heating.

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

Retain first paragraph below for units with gas-fired supplemental heating.

- B. Comply with requirements for piping specified in Section 231123 "Facility Natural-Gas Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Install piping adjacent to machine to allow service and maintenance.

3.3 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections **[with the assistance of a factory-authorized service representative]**:

1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
2. After installing packaged, terminal air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
3. Unit is level on base and is flashed in exterior wall.
4. Unit casing has no visible damage.
5. Compressor, air-cooled condenser coil, and fans have no visible damage.
6. Labels are clearly visible.
7. Controls are connected and operable.
8. Shipping bolts, blocks, and tie-down straps are removed.
9. Filters are installed and clean.
10. Drain pan and drain line are installed correctly.
11. Electrical wiring installation complies with manufacturer's submittal and installation requirements in electrical Sections.
12. Installation: Perform startup checks according to manufacturer's written instructions, including the following:
 - a. Lubricate bearings on fan.
 - b. Check fan-wheel rotation for correct direction without vibration and binding.
13. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
14. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. After performance test, change filters.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. Packaged, terminal air conditioners will be considered defective if they do not pass tests and inspections.

F. Prepare test and inspection reports.

3.4 ADJUSTING

A. Adjust initial temperature set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain packaged, terminal air conditioners.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238113.12

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SECTION 238113.13 - PACKAGED TERMINAL AIR-CONDITIONERS, OUTDOOR, WALL-MOUNTED UNITS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify with manufacturers that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include packaged, terminal air conditioners may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes packaged, terminal, outdoor, wall-mounted air conditioners.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
1. Provide manufacturer's drawings indicating dimensions, rough-in connections, and electrical characteristics and connection requirements.
 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

See "Sustainable Design Considerations" Article in the Evaluations for discussion on LEED prerequisites and credits.

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For packaged, terminal air conditioners.
1. Include plans, elevations, sections, details for wall penetrations, [**seismic bracing,**] and attachments to other work.
 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power, signal, and control wiring.
 4. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
- D. Color Samples: For unit cabinet, discharge grille, and exterior louver, and for each color and texture specified.

1.4 INFORMATIONAL SUBMITTALS

- A. Product Test Reports: For packaged, terminal air conditioners, for tests performed by manufacturer and witnessed by a qualified testing agency.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For packaged, terminal air conditioners to include in emergency, operation, and maintenance manuals.
 - 1. Include manufacturer's descriptive literature, operating instructions, installation instructions, and maintenance and repair data.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Delete paragraph (and subparagraphs below) if mockups not required. If retaining, indicate location, size, and other details of mockups on drawings or with inserts.

Verify mockup requirements with DEN Project Manager.

1.6 MOCKUP

Use this article for assessing full sized erected assemblies required for review of construction, coordination of work of several sections, testing, or observation of operation.

- A. Install one (1) unit that includes inside cabinet, wall sleeve, and wall louver.
- B. Locate where directed by DEN Project Manager.

Review requirement below with DEN Project Manager.

- C. Mockup may **[not]** remain as part of the Work.

1.7 DELIVERY, STORAGE, AND PROTECTION

- A. Deliver, store and protect products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Protect finished cabinets from physical damage by leaving factory packing cases in place before installation and providing temporary covers after installation.
- C. WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- D. Special Warranty: Manufacturer agrees to repair or replace components of packaged, terminal air conditioners that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

1. Warranty Period for Sealed Refrigeration System: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion, including components and labor.
2. Warranty Period for Nonsealed System Parts: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion, including only components and excluding labor.
3. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion.
4. Warranty Period for Energy Recovery Ventilator: : Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and Masterworks Paragraph Builder are neither recommended nor endorsed by the AIA or ARCOM. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Bard Manufacturing Company.

2. [Compu-Aire, Inc.](#)
3. [Liebert Corporation.](#)
4. [Marvair.](#)
5. <Insert manufacturer's name>.
6. or approved equal.

2.2 MANUFACTURED UNITS

Retain first option in "Description" Paragraph below for heating and cooling units and for heat pumps with supplemental heat.

- A. Description: Factory-assembled and -tested, self-contained, packaged, terminal [air conditioning] [heat pump] with room cabinet, electric refrigeration system, [**electric**] [**hot water**] [**gas fired**] [**heating**,] and [**built-in**] [**remote**] temperature controls; fully charged with refrigerant and filled with oil; with hardwired chassis and circuit breaker.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1. In addition to establishing minimum ventilation rates, ASHRAE 62.1 includes requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

- D. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.
- E. ASHRAE Thermal Comfort: Applicable requirements in ASHRAE 55.
- F. ASHRAE ERV Testing: Applicable requirements in ASHRAE 84.
- G. AHRI Rating: Applicable requirements in AHRI 1060.
- H. UL listed and ETL performance certified.

2.3 CHASSIS

- A. Cabinet: Sloped top, [0.052-inch- (1.32-mm-)] **<Insert dimension>** thick [**galvanized**] [**powder-coated**] [**epoxy coated**] [**baked enamel**] [**steel**] [**aluminum**] with removable front panel with concealed latches.

Retain "Mounting," "Discharge Grille," and "Return Grille" subparagraphs below if units are not scheduled on Drawings.

1. Mounting: On exterior wall.
2. Discharge Grille: [**Extruded-aluminum discharge grille**] [**Supply-air acoustical plenum**].
3. Return Grille: [**Extruded-aluminum grille**] [**Return-air acoustical plenum**].
4. Louvers: [**Extruded aluminum with enamel finish**] [**Stamped aluminum with clear-anodized finish**]; [**medium bronze**] [**dark bronze**] color.
5. Finish: [**Epoxy coating**] [**Baked enamel**].
6. Access Door: Hinged door in top of cabinet for access to controls.
7. Cabinet Extension: Matching cabinet in construction and finish, allowing diversion of airflow to adjoining room; with grille.
8. Insulation: Cooling and heating sections fully insulated with **1-inch (25-mm)**-thick fiberglass insulation.

Retain "Finish of Interior Surfaces" Subparagraph below to comply with LEED Prerequisite IEQ 1 or if required by Project requirements or authorities having jurisdiction. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

9. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Wall Sleeves" Subparagraph below for floor-mounted units.

10. Wall Sleeves: [**Galvanized steel with polyester finish**] [**Molded polymer**] [**Molded fiberglass-reinforced polyester**].
- B. Refrigeration System: Direct-expansion indoor coil with capillary restrictor and hermetically sealed[, **soft-start**] scroll compressor with [**crankcase heater**,] liquid line filter dryer, externally equalized expansion valve, high-pressure switch, [**low-pressure switch**,] [**low-pressure bypass timer**,] [**fan cycle, control, common alarm**,] [**fan cycle, variable speed control, common alarm**,] [**fan cycle, control, lockout relay, common alarm**,] [**fan cycle, variable speed control, lockout relay, common alarm**,] vibration isolation, and overload protection.
1. Indoor and Outdoor Coils: Seamless copper tubes mechanically expanded into aluminum fins[**with capillary tube distributor on indoor coil**].

Retain first three subparagraphs below for heat-pump units.

2. Accumulator.
3. Constant-pressure expansion valve.
4. Reversing valve.
5. Charge: [**R-407C**] [**R-410A**].

- C. Indoor Fan: Forward curved, centrifugal; with **[single] [twin] [constant-] [variable-]speed motor(s)** and positive-pressure ventilation damper with **[concealed manual] [electric]** operator.

Filters in "Filters" Paragraph below are optional feature. Washable filters may not comply with requirements in ASHRAE 62.1 for a minimum MERV 6, which would not fulfill LEED Prerequisite IEQ 1. Verify filter efficiency with manufacturers.

- D. Filters: **[Washable polyurethane in molded plastic frame] [2-inch (25-mm), pleated, disposable MERV 6]**, serviceable from front of the unit.
- E. Condensate Drain: Coated galvanized-steel drain pan **[to direct condensate to outdoor coil for re-evaporation] [and piping to direct condensate to building waste and vent piping]**.

In subparagraph below, verify drain pan construction and connection requirements with manufacturers if applying for LEED credits or if required by Project requirements or authorities having jurisdiction. ASHRAE 62.1 has specific requirements for drain pan construction and connections.

1. Comply with ASHRAE 62.1 for drain pan construction and connections.

- F. Outdoor Fan: **[High-ambient] [Forward curved, centrifugal] [Propeller] [Forward curved, centrifugal, or propeller]** type **[with separate] [driven by indoor fan]** motor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Indoor and Outdoor Fan Motors: Two speed; comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Fan Motors: Permanently lubricated split capacitor.
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - c. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

- G. Energy Recovery Wheel:

1. Casing: Steel with standard factory-painted finish.
2. Casing seals on periphery of rotor and on duct divider.
3. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings **[or permanently lubricated bearings]**. Support horizontal rotors on tapered roller bearing.
4. Rotor: Polymer segmented wheel strengthened with radial spokes impregnated with nonmigrating, water-selective, molecular-sieve desiccant coating.
5. Drive: Fractional horsepower motor, gear reducer, and self-adjusting multilink belt around outside of rotor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
6. Controls: Starting relay, factory mounted and wired, and manual motor starter for field wiring.

2.4 HEATING

Retain "Electric-Resistance Heating Coil" or "Gas Heat" Paragraph below for heating and cooling units or for heat pumps with supplemental heat.

- A. Electric-Resistance Heating Coil: Nickel-chromium-wire, electric-resistance heating elements with contactor and high-temperature-limit switch.
- B. Gas Heat:
1. General Requirements for Gas-Fired, Noncondensing Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.86/CSA 2.32, "Vented Gas-Fired Space Heating Appliances," and with NFPA 54.
 2. Type of Gas: **[Natural]** **[Propane]**.
 3. Heat Exchanger: **[Stainless]** steel.
 4. Burner:

In first subparagraph below, two-stage and modulating gas valves are optional features.

- a. Gas Valve: 100 percent safety, **[two-stage]** **[modulating]** main gas valve; main shutoff valve; pressure regulator; safety pilot with electronic flame sensor; limit control; transformer; and combination ignition/fan timer control board.
 - b. Ignition: Electric pilot ignition with hot-surface igniter or electric spark ignition.
 - c. Field conversion kit for high altitude.
5. Gas-Burner Safety Controls:
- a. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
 - b. Flame Rollout Switch: Installed on burner box; prevents burner operation.
 - c. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.

6. Combustion-Air Inducer: Centrifugal fan prepurges heat exchanger and vents combustion products; thermally protected motor includes sleeve bearings; pressure switch prevents operation if combustion-air inlet or flue outlet is blocked.
7. Furnace Controls: Solid-state board for integrating ignition, heat, cooling, and fan speeds; adjustable fan-on and fan-off timing; and terminals for connection to accessories.

2.5 CONTROLS

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, Section 5 - "Systems and Equipment," for ventilation system controls. If applying for LEED credits or if required by Project requirements or authorities having jurisdiction, verify that manufacturers can provide units with controls that comply with requirements. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

Select applicable control options.

When packaged equipment needs to be connected to the BAS for monitoring or remote setpoint override, it is the responsibility of the engineer to verify that the packaged controls are fully compatible\controllable with the BAS. any change orders for controls modifications to make new equipment work will be burdened by the engineer.

- A. Control Module: Unit-mounted digital panel with touchpad temperature control and with touchpad for heating, cooling, and fan operation. Include the following features:
 1. Low-Ambient Lockout Control: Prevents cooling-cycle operation below 40 deg F (5 deg C) outdoor air temperature.

Retain "Heat-Pump Ambient Control" Subparagraph below for heat-pump units.

2. Heat-Pump Ambient Control: Field-adjustable switch changes to heat-pump heating operation above 40 deg F (5 deg C) and to supplemental heating below plus 25 deg F (minus 4 deg C).

Retain option in "Temperature-Limit Control" Subparagraph below for heating and cooling units and for heat pumps.

3. Temperature-Limit Control: Prevents occupant from exceeding preset[**setback or**] setup temperature.
4. Building Automation System Interface: Allows remote on-off control with setback temperature control.
5. Reverse-Cycle Defrost: Solid-state sensor monitors frost buildup on [**indoor**] [**outdoor**] coil and reverses unit to melt frost.

- B. Remote Control: Standard unit-mounted controls with remote-mounted, low-voltage, adjustable thermostat with heat anticipator; [**heat-off-cool-auto**] [**heat-off-cool**] switch; and[**on-auto**] fan switch.

Retain one of two "Outdoor Air" paragraphs below. Retain first paragraph to comply with LEED Prerequisite IEQ 1, which requires compliance with ASHRAE 62.1, or if required by Project requirements

or authorities having jurisdiction. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

- C. Outdoor Air: Motorized intake damper. Open intake when unit indoor-air fan runs.
- D. Outdoor Air: Manual intake damper.
- E. Economizer Operation: Motorized intake-air damper controlled by an enthalpy sensor and a mixed-air sensor to provide natural cooling when the outdoor air temperature is favorable.
- F. Dual Unit Control (DUC): Hinged cover with two-stage heat/cool thermostat with individual heat/cool setpoints, adjustable interstage differentials and bimetallic elements. The control shall feature a solid-state timer with 1-2-4-8 day sequence, unit lead selector, Unit 1 and 2 power-on LEDs, Unit 1 or 2 lead unit LEDs, 48-hour program save on loss of power, industry standard connections, and 24-volt power from each unit. The DUC shall provide auto sequencing and displays on status and operating status parameters.
- G. Three-Phase Power Rotation Monitor: Three-phase monitoring to protect compressor from reverse rotation and to protect the unit from phase failure. Monitor manually reset.
- H. Ventilation:
 - 1. Extra Ventilation: Section internally mounted, allowing up to 50% outside air and exhaust air through the action of adjustable dampers.
 - 2. Energy Recovery Ventilator: **[One]** **[Two]** rotary washable desiccant wheel(s), insulated cassette frame with seals, three-speed drive motor and belt, and intake and exhaust blowers.
- I. Dehumidification Circuit: Supply-air stream, independent heat exchanger using a separate humidistat, hot gas three-way valve, separate desuperheating condenser circuit, and back drain orifice inserted between the reheat coil and suction line.

2.6 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of packaged, terminal air conditioners, delete this article and schedule packaged, terminal air conditioners on Drawings.

- A. Airflow: **<Insert cfm (L/s)>**.

LEED Prerequisite IEQ 1 requires minimum ventilation rates according to ASHRAE 62.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

- B. Outdoor-Air Intake Rate: **<Insert cfm (L/s)>**.
- C. Cooling Capacity:
 - 1. Total: **<Insert Btu/h (kW)>**.

2. Sensible: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

3. Energy-Efficiency Ratio: <Insert number>.
4. Indoor Coil Entering-Air Dry Bulb Temperature: <Insert deg F (deg C)>.
5. Indoor Coil Entering-Air Wet Bulb Temperature: <Insert deg F (deg C)>.
6. Indoor Coil Leaving-Air Dry Bulb Temperature: <Insert deg F (deg C)>.
7. Indoor Coil Leaving-Air Wet Bulb Temperature: <Insert deg F (deg C)>.
8. Outdoor Coil Entering-Air Temperature: <Insert deg F (deg C)>.

D. Heat-Pump Capacity:

1. Total: <Insert Btu/h (kW)>.
2. Outdoor Temperature: <Insert deg F (deg C)>.

E. Electric Heat Capacity: <Insert Btu/h (kW)>.

F. Hydronic Heat Capacity:

1. Total: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Leaving-Air Temperature: <Insert deg F (deg C)>.
4. Water Flow: <Insert gpm (L/s)>.
5. Entering-Water Temperature: <Insert deg F (deg C)>.
6. Leaving-Water Temperature: <Insert deg F (deg C)>.

G. Gas Heat Capacity:

1. Input: <Insert Btu/h (kW)>.
2. Output: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on this prerequisite.

3. AFUE: [80] <Insert number> percent.

H. Exhaust Air:

1. Airflow: <Insert cfm (L/s)>.
2. Face Velocity: <Insert fpm (m/s)>.
3. Summer:
 - a. Entering-Air Temperature, Dry Bulb: <Insert deg F (deg C)>.
 - b. Entering-Air Temperature, Wet Bulb: <Insert deg F (deg C)>.
 - c. Leaving-Air Temperature, Dry Bulb: <Insert deg F (deg C)>.
 - d. Leaving-Air Temperature, Wet Bulb: <Insert deg F (deg C)>.
4. Winter:
 - a. Entering-Air Temperature, Dry Bulb: <Insert deg F (deg C)>.

- b. Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - c. Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - d. Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 5. Air-Pressure Drop: **<Insert inches wg (Pa)>**.
- I. Supply Air:
 1. Airflow: **<Insert cfm (L/s)>**.
 2. Face Velocity: **<Insert fpm (m/s)>**.
 3. Summer:
 - a. Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - b. Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - c. Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - d. Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 4. Winter:
 - a. Entering-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - b. Entering-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 - c. Leaving-Air Temperature, Dry Bulb: **<Insert deg F (deg C)>**.
 - d. Leaving-Air Temperature, Wet Bulb: **<Insert deg F (deg C)>**.
 5. Air-Pressure Drop: **<Insert inches wg (Pa)>**.
- J. Wheel Drive:
 1. Motor Size: **<Insert horsepower>**.
 2. Motor Electrical Characteristics:
 - a. Volts: **[120] [208] [230] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
- K. Effectiveness: **<Insert percent>**.
- L. Sound:
 1. Indoor: **<Insert bels>**.
 2. Outdoor: **<Insert bels>**.
- M. Electrical Characteristics:
 1. Volts: **<Insert value>**.
 2. Phase: **[Single] [Three]**.
 3. Hertz: 60.
 4. Full-Load Amperes: **<Insert value>**.
 5. Minimum Circuit Ampacity: **<Insert value>**.
 6. Maximum Overcurrent Protection: **<Insert amperage>**.

2.7 SOURCE QUALITY CONTROL

- A. Sound-Power Level Ratings: Factory test to comply with AHRI 300, "Sound Rating and Sound Transmission Loss of Packaged Terminal Equipment."
- B. Unit Performance Ratings: Factory test to comply with AHRI 310/380/CSA C744, "Packaged Terminal Air-Conditioners and Heat Pumps."

2.8 SUPPLEMENTAL CONDENSATE DRAIN PANS

- A. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment.
- B. Supplemental drain pans to be constructed of 20 gauge (minimum) galvanized steel, minimum depth 2 inches, fabricated, braced, and supported so as to ensure stability.
- C. Provide drain piping conforming to provisions Division 22 Sections, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate installation of units with architectural, [**mechanical,**] and electrical work.
- C. Install units level and plumb, maintaining manufacturer's recommended clearances and tolerances.
- D. Install wall sleeves in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Section 079200 "Joint Sealants."

Retain paragraph below in seismic areas. Equipment protection may be required for some types of buildings. Verify requirements with model building codes and ASCE/SEI 7.

- E. Install and anchor wall sleeves to withstand, without damage to equipment and structure, seismic forces required by building code.

Edit paragraph below.

- F. On water coils, provide shut-off valve on supply line and **[balancing valve] [flow control and shut-off valve]** on return line. Provide **[manual] [float operated automatic]** air vents at high points complete with stop valve.

3.2 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

Retain first paragraph below for units with hot-water supplemental heating.

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

Retain first paragraph below for units with gas-fired supplemental heating.

- B. Comply with requirements for piping specified in Section 231123 "Facility Natural-Gas Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Install piping adjacent to machine to allow service and maintenance.

3.3 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections **[with the assistance of a factory-authorized service representative]**:

1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
2. After installing packaged, terminal air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
3. Unit is level on base and is flashed in exterior wall.
4. Unit casing has no visible damage.
5. Compressor, air-cooled condenser coil, and fans have no visible damage.
6. Labels are clearly visible.
7. Controls are connected and operable.
8. Shipping bolts, blocks, and tie-down straps are removed.
9. Filters are installed and clean.
10. Drain pan and drain line are installed correctly.
11. Electrical wiring installation complies with manufacturer's submittal and installation requirements in electrical Sections.
12. Installation: Perform startup checks according to manufacturer's written instructions, including the following:
 - a. Lubricate bearings on fan.
 - b. Check fan-wheel rotation for correct direction without vibration and binding.
13. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
14. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. After performance test, change filters.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. Packaged, terminal air conditioners will be considered defective if they do not pass tests and inspections.

F. Prepare test and inspection reports.

3.4 ADJUSTING

A. Adjust initial temperature set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain packaged, terminal air conditioners.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238113.13

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SECTION 238119 - SELF-CONTAINED AIR-CONDITIONERS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include self-contained air conditioners may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes packaged, [air] [water]-cooled air-conditioning units with refrigerant compressors and controls intended for indoor installations.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in

this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories.

1. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.
3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
 - a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
 - b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

D. Samples for Initial Selection: For units with factory-applied color finishes.

1.4 INFORMATIONAL SUBMITTALS

A. Warranty: Sample of special warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For self-contained air conditioners to include in emergency, operation, and maintenance manuals.

1. Include manufacturer's descriptive literature, operating instructions, installation

instructions, maintenance and repair data, and parts listing.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: [One (1)] <Insert number> set(s) of filters for each unit.
 - 2. Fan Belts: [One (1)] <Insert number> set(s) of belts for each unit.
 - 3. Gaskets: [One (1)] <Insert number> set(s) for each access door.
 - 4. Fuses: [One (1)] <Insert number> set(s) for each air-handling unit.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ARI Compliance:

Retain one or more of three subparagraphs below depending on types of units in Project. Retain first subparagraph for units with cooling capacity less than 65,000 Btu/h (19 kW); retain second subparagraph for units with cooling capacity from 65,000 to 250,000 Btu/h (19 to 73 kW); retain third subparagraph for vertical configuration in a commercial or industrial application.

- 1. Applicable requirements in ARI 210/240.
- 2. Applicable requirements in ARI 340/360.
- 3. Applicable requirements in ARI 390.

- C. ASHRAE Compliance:

- 1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1. In addition to establishing minimum ventilation rates, ASHRAE 62.1 includes requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. See "LEED Rating System" Article in the Evaluations for discussion on this

prerequisite. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

"ASHRAE/IESNA" Compliance Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite.

- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

1.8 COORDINATION

Retain this article for larger units to be installed on a base.

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Section 033000 "Cast-in-Place Concrete."

1.9 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of self-contained air conditioners that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components with manufacturers listed.

1. Warranty Period:

Retain the applicable level of warranty in three subparagraphs below. Flexibility exists in the level of warranty that can be purchased; not all manufacturers' standard warranty is the same and differences add/subtract base unit cost. Extended warranties will affect construction costs.

- a. For Compressor: Minimum **[One (1)] [Five (5)] <Insert number>** year(s) from date of Substantial Completion.
- b. For Parts: Minimum **[One (1)] [Five (5)] <Insert number>** year(s) from date of Substantial Completion.
- c. For Labor: Minimum **[One (1)] [Five (5)] <Insert number>** year(s) from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain the paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Bard Manufacturing Company.
 2. Carrier Corporation; Home Comfort and HVAC Building & Industrial Systems.
 3. Engineered Air.
 4. Marshall Engineered Products Co. (MEPCO).
 5. McQuay International.
 6. Trane Inc.
 7. USA Coil & Air.
 8. Whalen Company (The).
 9. **<Insert manufacturer's name>.**
 10. or approved equal.

2.2 PACKAGED UNITS

- A. Description: Factory assembled, wired, and tested; and fully charged with refrigerant and oil.

Retain one of three "Configuration" paragraphs below.

- B. Configuration: Horizontal, ceiling[-**plenum**] mounted.
- C. Configuration: Vertical, floor mounted; [**vertical**] [**and**] [**horizontal**] discharge.
- D. Configuration: Horizontal, ceiling mounted and vertical, floor mounted; [**vertical**] [**and**] [**horizontal**] discharge.
- E. Disconnect Switch: Factory mounted [**in control panel**] [**on cabinet**].

2.3 Cabinet

- A. Frame and Panels: Structural-steel frame with galvanized-steel panels and access doors or panels.

Retain first subparagraph below if units are exposed in finished spaces.

1. Exterior-Surface Finish: Factory painted in color selected by DEN Project Manager.

ASHRAE compliance in "Interior-Surface Finish" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite.

2. Interior-Surface Finish: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
 - B. Insulation: **1-inch-** (25-mm-) thick, glass-fiber duct liner complying with ASTM C 1091 and having a microbial coating on cabinet interior and control panel. **1/2-inch-** (13-mm-) thick liner is acceptable for units smaller than **15 tons** (50 kW).
 - C. Return-Air Opening: Rear, **[open] [flange for duct connection]**.
 - D. Corrosion-Resistant Treatment: Phenolic coating on unit interior and exterior.
- 2.4 Supply-air Fan
- A. Fan Material: Galvanized steel.

For units 15 tons (50 kW) and smaller, "forward-curved" option in first paragraph below may be the only fan choice.

- B. Configuration: Double-width, double-inlet, **[forward-curved] [airfoil]** centrifugal fan; statically and dynamically balanced. **[Vertical] [Horizontal]** discharge with flexible discharge collar.

Retain one of two drive types in first paragraph below. For units larger than 15 tons (50 kW), first option may be the only choice.

- C. Drive: **[Belt, with fan mounted on permanently lubricated bearings] [Direct, with fan and motor resiliently mounted]**.

Retain first three paragraphs below for belt-driven units.

- D. Fan Sheaves: Variable pitch, dynamically balanced, bored to fit shafts, and keyed for initial startup.
- E. Motor Sheave: Variable and adjustable pitch, dynamically balanced, and selected to achieve specified rpm when set at midposition.
- F. Belt Rating: As recommended by manufacturer or a minimum of one and one-half times nameplate rating of motor.

Retain "Bearings" and "Variable Air Volume" paragraphs below for units larger than 15 tons (50 kW).

- G. Bearings: Grease lubricated with grease lines extended to exterior of unit[**with L-50 life at 200,000 hours**].
- H. Variable Air Volume: Variable-frequency motor controller[**with bypass**].

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- I. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1. Special Motor Features: Premium efficiency, as defined in Section 230513 "Common Motor Requirements for HVAC Equipment."

If unique characteristics are required for motors in this Section, insert in subparagraph below.

- 2. **<Insert unique motor characteristics>**.

Retain first paragraph below for units larger than 15 tons (50 kW).

- J. Isolation: Mount fan and motor on common subbase and mount assembly on spring isolators with minimum static deflection of [**1 inch (25 mm)**] **<Insert dimension>**.
- K. Outdoor-Air-Intake Accessories:
 - 1. Barometric Outdoor-Air Damper: Adjustable-blade damper allowing induction of up to 25 percent outdoor air when evaporator fan is running.
 - 2. Motorized Outdoor-Air Damper: Motorized, two-position blade damper allowing induction of up to 25 percent outdoor air; with spring-return, low-voltage damper motor.
 - 3. Energy-Recovery Ventilator: Assembly of desiccant-coated, heat-recovery wheels and centrifugal exhaust fans to transfer approximately 67 percent of the difference between the sensible and latent heat of outdoor and exhaust air.
 - 4. Air-Side Economizer: Damper assembly allowing induction of up to 100 percent outdoor air to maintain a selected mixed-air temperature; and exhaust damper and spring-return, low-voltage, modulating damper motor with minimum position adjustment.

2.5 REFRIGERATION SYSTEM

- A. Compressor: Scroll type, hermetically sealed, 3600 rpm maximum, and resiliently mounted with positive lubrication and internal motor protection.
- B. Refrigerant Coils (Indoor and Outdoor for Air-Cooled Units): Seamless copper tubes expanded into aluminum fins.

Corrosion-resistant treatment in first subparagraph below is an optional feature.

- 1. Corrosion-Resistant Treatment: Phenolic coating applied with multiple dips and baked.

Retain options in first subparagraph below for units larger than 15 tons (50 kW).

2. Refrigerant Circuits: A separate circuit for each compressor, with externally equalized thermal-expansion valve[**with adjustable superheat**], filter dryer,[**sight glass, high-pressure relief valve,**] and charging valves.

ASHRAE compliance option in first subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain first option in first subparagraph to comply with LEED Prerequisite IEQ 1. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite.

3. Mount coil assembly over stainless-steel drain pan[**complying with ASHRAE 62.1**] [and] [having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir].

Retain option in first subparagraph below if any refrigerant type is acceptable. Delete to comply with LEED-NC, LEED-CS, and LEED for Schools Credit EA 4.

4. Refrigerant: [R-22,]R-407C or R-410A.

First subparagraph below is required for heat-pump units only. Retain other appropriate components to suit Project.

5. Expansion valve with replaceable thermostatic element.
6. Refrigerant dryer.
7. High-pressure switch.
8. Low-pressure switch.
9. Thermostat for coil freeze-up protection during low ambient temperature operation or loss of air.
10. Low ambient temperature switch.
11. Brass service valves installed in discharge and liquid lines.

C. Water-Cooled Condenser:

1. Description: Factory assembled and tested; tube in tube coaxial type with water-regulating valve.
2. Tubing: [Nonferrous] [Copper] [Cupro-nickel] inner tube; [steel with corrosion-resistant coating;]refrigerant and water-side leak tested to 400 psig (2760 kPa) underwater.

Retain "Water-Side Economizer Section" Paragraph below for water-cooled units only.

D. Water-Side Economizer Section:

1. Description: Factory assembled and tested; consisting of water coil, modulating valves, controls, piping with cleanouts, and access panels.
2. Water Coil: [Two] [Four] rows, copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and [copper] [cast-iron] headers; leak tested to 300 psig (2070 kPa) underwater; and having a two-position control valve.

2.6 Heating Coil

Retain one of two paragraphs below if unit includes heating.

- A. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm); leak tested to **300 psig** (2070 kPa) underwater; and having a two-position control valve.
- B. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow-proving device; and one-time fuses in terminal box for overcurrent protection.

2.7 CONTROLS

- A. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Control Package: Factory wired, including contactor, high- and low-pressure cutouts, internal-winding thermostat for compressor, control-circuit transformer, and noncycling reset relay.
- C. Time-Delay Relay: Five-minute delay to prevent compressor cycling.

Revise first paragraph below to suit unit configuration.

- D. Adjustable Thermostat: [**Unit mounted**] [**Remote**] to control the following:
 - 1. Supply fan.
 - 2. Compressor.
 - 3. Condenser.
 - 4. Hot-water coil valve.
 - 5. Electric heater.
- E. System Selector Switch: [**Heat-off-cool**] [**Off-heat-auto-cool**].
- F. Fan Control Switch: Auto-on.

Time clock in first paragraph below is an optional accessory for units larger than 15 tons (50 kW).

- G. Time Clock: Cycle unit on and off.
- H. Microprocessor Control Panel: Controls unit functions as standalone or network operation, including refrigeration and safety controls, with unit-mounted display, and the following:

Revise subparagraphs below to suit unit configuration.

- 1. Supply fan.
- 2. Supply-fan motor speed.
- 3. Compressors.
- 4. Air-cooled condenser.
- 5. Cooling tower pump.

6. Modulating, hot-water coil valve.
7. Multistep, electric heater.
8. Time-of-day control to cycle unit on and off.
9. Night-heat, morning warm-up cycle.
10. Economizer control.
11. Panel-mounted control switch to operate unit in remote or local control mode or to stop or reset.
12. Panel-mounted indication of the following:
 - a. Operating status.
 - b. System diagnostics and safety alarms.
 - c. Supply-air temperature set point.
 - d. Zone heating-temperature set point.
 - e. Supply-air pressure set point.
 - f. Economizer minimum position set point.
 - g. Supply-air-pressure, high-limit set point.

LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1 require continuous metering equipment for monitoring building's energy consumption performance over time. Retain five subparagraphs below if required to comply with the requirements for this credit. Verify availability of control features with unit manufacturers.

- h. Monitor constant and variable motor loads.
- i. Monitor variable-frequency drive operation.
- j. Monitor economizer cycle.
- k. Monitor cooling load.
- l. Monitor air distribution static pressure and ventilation air volumes.

If Project has more than one type or configuration of self-contained air conditioner, delete article below and schedule self-contained air conditioners on Drawings.

2.8 CAPACITIES AND CHARACTERISTICS

A. Cooling Capacity:

1. Total: <Insert Btu/h (kW)>.
2. Sensible: <Insert Btu/h (kW)>.

Retain first subparagraph below for units with cooling capacity of 5 tons (17 kW) or less.

3. Seasonal Energy Efficiency Ratio: [10.0] [12.0] [13.0] [14.0] [16.0] <Insert ratio>.

Retain first subparagraph below for units with cooling capacity of more than 5 tons (17 kW).

4. Energy Efficiency Ratio: [10.0] [12.0] [13.0] [14.0] [16.0] <Insert ratio>.
5. Moisture Removal Rate: <Insert pints/h (L/h)>.
6. Entering-Air Temperature:
 - a. Dry Bulb: <Insert deg F (deg C)>.
 - b. Wet Bulb: <Insert deg F (deg C)>.
7. Leaving-Air Temperature:

- a. Dry Bulb: <Insert deg F (deg C)>.
- b. Wet Bulb: <Insert deg F (deg C)>.

B. Heating Capacity:

1. Total: <Insert Btu/h (kW)>.
2. Air-Temperature Rise: <Insert deg F (deg C)>.
3. Heat Pump:
 - a. Coefficient of Performance: <Insert value>.
 - b. Heating Season Performance Factor: [7.7] [8.0] <Insert value>.
4. Hot Water:
 - a. Entering-Water Temperature: <Insert deg F (deg C)>.
 - b. Leaving-Water Temperature: <Insert deg F (deg C)>.
 - c. Water Flow: <Insert gpm (L/s)>.
 - d. Water Pressure Drop: <Insert feet of head (kPa)>.
5. Electric Heat:
 - a. Total Capacity: <Insert Btu/h (kW)>.
 - b. Air-Temperature Rise: <Insert deg F (deg C)>.
 - c. Control Steps: [One] [Two] [Three] <Insert number>.

Auxiliary heat may be required for heat-pump units.

C. Auxiliary Electric Heat:

1. Total Capacity: <Insert Btu/h (kW)>.
2. Air-Temperature Rise: <Insert deg F (deg C)>.
3. Control Steps: [One] [Two] [Three] <Insert number>.

D. Supply-Air Fan:

1. Fan motor.
2. Size: <Insert value> hp.
3. [Multispeed, PSC] [Open-dripproof] [Totally enclosed fan-cooled] type.
4. Total Airflow:

Retain first two subparagraphs below for variable-speed fans.

- a. High: <Insert cfm (L/s)>.
- b. Low: <Insert cfm (L/s)>.

5. Outdoor Airflow: <Insert cfm (L/s)>.

E. Air-Cooled Condenser:

1. Fan Quantity: [Two] [Four] <Insert number>.
2. Motor Speed: <Insert value> rpm.

3. Motor Horsepower: <Insert value>.

F. Water-Cooled Condenser:

1. Entering-Water Temperature: <Insert deg F (deg C)>.
2. Leaving-Water Temperature: <Insert deg F (deg C)>.
3. Water Flow: <Insert gpm (L/s)>.
4. Water Pressure Drop: <Insert feet of head (kPa)>.

G. Filters:

1. Prefilters:

- a. Type: [Flat] [Pleated] disposable panel.
- b. MERV: <Insert number>.
- c. Face Area: <Insert sq. ft. (sq. m)>.
- d. Surface Area: <Insert sq. ft. (sq. m)>.
- e. Thickness or Depth: [2 inches (50 mm)] [4 inches (100 mm)].
- f. Number of Filters: <Insert number>.
- g. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
- h. Initial Resistance: <Insert inches wg (Pa)>.
- i. Recommended Final Resistance: <Insert inches wg (Pa)>.
- j. Access Location: [Front] [Back] [Side].

2. Final Filter:

- a. Type: [Flat] [Pleated] disposable panel.

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite.

- b. MERV: <Insert number>.
- c. Face Area: <Insert sq. ft. (sq. m)>.
- d. Surface Area: <Insert sq. ft. (sq. m)>.
- e. Thickness or Depth: [2 inches (50 mm)] [4 inches (100 mm)].
- f. Number of Filters: <Insert number>.
- g. Maximum or Rated Face Velocity: <Insert fpm (m/s)>.
- h. Initial Resistance: <Insert inches wg (Pa)>.
- i. Recommended Final Resistance: <Insert inches wg (Pa)>.
- j. Access Location: [Front] [Back] [Side].

H. Accessories:

1. Manual outdoor-air damper.
2. Motorized outdoor-air damper.
3. Air-side economizer.
4. Water-side economizer.
5. Hot-gas bypass.

Retain subparagraph below for units larger than 15 tons (50 kW).

6. Air Pressure Switch: Indicates when differential pressure exceeds set point representing dirty filters.

- I. Single-Point Electrical Characteristics:
 - 1. Volts: [**120**] [**208**] [**230**] [**460**] <Insert value>.
 - 2. Phase: [**Single**] [**Three**].
 - 3. Hertz: 60.
 - 4. Full-Load Amperes: <Insert value>.
 - 5. Minimum Circuit Ampacity: <Insert value>.
 - 6. Maximum Overcurrent Protection: <Insert amperage>.

- J. Radiated Noise Requirements:
 - 1. Radiated noise shall not exceed the following values:
 - a. NC 35 – In Office.
 - b. NC 40 – Terminal/Concourse.
 - c. NC 45 – Maintenance Facilities.

2.9 SUPPLEMENTAL CONDENSATE DRAIN PANS

- A. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment.

Edit paragraph below.

- 1. Supplemental drain pans to be constructed [**as detailed on the drawings**] [**of 20 gauge (minimum) galvanized steel, minimum depth 2 inches, fabricated, braced, and supported so as to ensure stability.**]
- 2. Provide drain piping conforming to provisions Division 22 sections, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install units level and plumb.
- B. Install evaporator-fan components using manufacturer's standard mounting devices, and securely anchor units to structure.

Retain paragraph below if seismic design is required.

- C. Install seismic restraints.

Select one of two paragraphs below. First is minimum required.

- D. Install compressor-condenser components on restrained, spring isolators with a minimum static deflection of [**1 inch (25 mm)**] <Insert number>.
- E. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.
- F. Install ground-mounting, compressor-condenser components on 4-inch- (100-mm-) thick, reinforced concrete base; 4 inches (100 mm) larger on each side than unit. Concrete, reinforcement, and formwork are specified in Division 3. Coordinate anchor installation with concrete base.

Retain paragraph above or first paragraph below.

- G. Install ground-mounting, compressor-condenser components on polyethylene mounting base.

3.2 CONNECTIONS

Retain first two paragraphs below if unit has water piping connections. Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

Retain first subparagraph below for units with hot-water coils.

1. Water Coil Connections: Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Connect to supply and return coil with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.

Retain subparagraph below for units with water-cooled condenser.

2. Water-Cooled Condenser Connections: Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Connect to supply and return with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
 - C. Provide shut-off valves in condenser water inlet and outlet piping.

Select one option in paragraph below.

- D. Pipe drain pan condensate to [**nearest floor drain.**] [**condensate drainage system.**]

Retain paragraph below for units connected to ducts. Coordinate duct installation requirements with schematics on Drawings and with requirements specified for duct systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- E. Duct Connections: Duct installation requirements are specified in Section 233113 "Metal Ducts." Drawings indicate the general arrangement of ducts. Connect supply[**and return**] ducts to self-contained air conditioners with flexible duct connectors. Flexible duct connectors are specified in Section 233300 "Air Duct Accessories."
- F. Ground equipment according to Division 26.
- G. Electrical Connections: Comply with requirements in Division 26 for power wiring, switches, and motor controls.

3.3 FIELD QUALITY CONTROL

Retain first paragraph below to require a factory-authorized service representative to perform inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- C. Tests and Inspections:
 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation, and inspect for refrigerant leaks.
 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- D. Units will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. **<Insert startup steps if any.>**

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238119

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SECTION 238123 - COMPUTER-ROOM AIR-CONDITIONERS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify with manufacturers that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include computer-room air conditioners may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Floor-mounted computer-room air conditioners, 6 tons (21 kW) and larger.
 - 2. Floor-mounted computer-room air conditioners, 5 tons (18 kW) and smaller.
 - 3. Ceiling-mounted computer-room air conditioners.
 - 4. Console computer-room air conditioners.
- B. Related Sections:

Retain Sections in subparagraph below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230900 "Instrumentation and Control for HVAC" for installation and wiring of thermostats and control components.
2. Section 260583 "Electrical Connections for Equipment" for installation and wiring of thermostats and control components.

C. Scope:

1. These specifications describe requirements for a precision environmental control system. The system shall be designed to maintain temperature and humidity conditions in the rooms containing electronic equipment.
2. The manufacturer shall design and furnish all equipment to be fully compatible with heat dissipation requirements of the room.

D. Design Requirements and Ratings: As indicated on the drawings.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITION

Retain definition remaining after this Section has been edited.

- A. DDC: Direct digital control.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Computer-room air conditioners shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

- 1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 - 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: For computer-room air conditioners. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.

Coordinate sample requirements with DEN Project Manager.

- D. Color Samples: For unit cabinet, discharge grille, and exterior louver and for each color and texture specified.

1.6 INFORMATIONAL SUBMITTALS

Retain first paragraph below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, using input from Installers of the items involved.

Retain first paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For computer-room air conditioners, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- C. Field quality-control reports.
- D. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For computer-room air conditioners to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fan Belts: **[One (1)] <Insert number>** set(s) for each belt-driven fan.
 - 2. Filters: **[One (1)] <Insert number>** set(s) of filters for each unit.

1.9 MAINTENANCE SERVICE

Select one below. First number is minimum required.

- A. Furnish service and maintenance of computer room air conditioning unit system for **[one (1) year] [Insert number]** from Date of Substantial Completion.

1.10 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE Compliance:
 - 1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1. In addition to establishing minimum ventilation rates, ASHRAE 62.1 includes

requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

"ASHRAE/IESNA Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite.

- C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
- D. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

1.11 COORDINATION

Revise first paragraph below to delete or insert types of construction that penetrate, or are supported by, ceilings.

- A. Coordinate layout and installation of computer-room air conditioners and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
- B. Coordinate installation of computer-room air conditioners with computer-room access flooring Installer.

Retain first paragraph below for units mounted on concrete bases.

- C. Coordinate sizes and locations of concrete bases with actual equipment provided.

Retain paragraph below for remote air-cooled refrigerant condensers and remote, air-cooled, glycol-solution coolers.

- D. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.12 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to

repair or replace components of computer-room air conditioners that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components with manufacturers listed in Part 2 articles.

1. Warranty Period for Compressors: Manufacturer's standard, but not less than **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.
2. Warranty Period for Humidifiers: Manufacturer's standard, but not less than **[three (3)] <Insert number>** years from date of Substantial Completion.
3. Warranty Period for Control Boards: Manufacturer's standard, but not less than **[three (3)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Radiated noise shall not exceed:
 1. NC 35 - In Office.
 2. NC 40 - Terminal/Concourse.
 3. NC 45 - Maintenance Facilities.

2.2 FLOOR-MOUNTED UNITS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Liebert
 2. Data Aire, Inc.
 3. **<Insert manufacturer>**
 4. or approved equal.
- B. Cabinet and Frame Construction:
 1. The frame shall be constructed of welded tubular steel and shall be painted

using the autophoretic coating process for maximum corrosion protection. The exterior panels shall be insulated with a minimum 1 in of 1.5 lbs. density coated acoustic liner. Doors shall be not less than 18 gage steel, hinged and equipped with polyurethane gaskets and concealed fasteners. The main front panel shall have captive 1/4 turn fasteners. The main unit color shall be as selected by the DEN Project Manager. Panels and filter chambers shall be as follows:

Select from following options; edit as needed.

2. Heavy gauge panels (on upflow units): The exterior panels shall be 16 gauge steel for operation with high external static pressures.
3. Filter Chamber (Downflow units): The filter chamber shall be an integral part of the system, located within the cabinet serviceable from the end of the unit or the top of the unit (if there is no plenum). The filters shall be of 4-inch thickness and shall be rated not less than 85 % efficiency based on ASHRAE 52.1.
4. Filter chamber (upflow units w/front and bottom return): The filter chamber shall be an integral part of the system, located within the cabinet, serviceable from the end of the unit. The filters shall be of 4-inch thickness and shall be rated not less than 85 % efficiency based on ASHRAE 52.1.
5. Filter chamber (upflow units w/rear return): The filter units chamber shall be located on the back of the cabinet, serviceable from the end of the unit. The filters shall be of 4-inch thickness and shall be rated not less than 85 % efficiency based on ASHRAE 52.1.

C. Fan Section:

1. The fan section shall be designed for the specified CFM at an external static pressure of as indicated. The fans shall be centrifugal type, double width double inlet, and shall be statically and dynamically balanced as a completed assembly to a maximum vibration level of two mils in any plane. The shaft shall be heavy duty steel with self-aligning ball bearings with a minimum life span of 100,000 hours. The fan motor shall be mounted on an adjustable slide base. The drive package shall be multi-belt, variable speed, sized for 200% of the fan motor horsepower. The fans shall be located to draw air over the A-Frame coil to ensure even air distribution and maximum coil performance.

Sound testing and sound performance shall not be waived. review the table below for compliance with NC-40 criteria.

2. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

D. Humidifier:

Select type and edit as required for Project.

1. Infrared humidifier: The humidifier shall be of the infrared type consisting of high intensity quartz lamps mounted above and out of the water supply. The

evaporator pan shall be stainless steel and arranged to be serviceable without disconnecting high voltage electrical connections. The complete humidifier section shall be pre-piped ready for final connection. The infrared humidification system shall use bypass air to prevent over-humidification of the computer room. The humidifier shall have a capacity as indicated on the drawings and shall be equipped with an automatic water supply system. The system shall have an adjustable water-overfeed to prevent mineral precipitation.

2. Steam generating humidifier: The environmental control system shall be equipped with a steam generating humidifier that is controlled by the microprocessor control system. It shall be complete with disposable canister, all supply and drain valves, steam distributor, and electronic controls. The need to change canister shall be annunciated on the microprocessor control panel. The humidifier shall be designed to operate with water conductivity from 200-500 micromhos.

E. Reheat Provisions:

Select from following options; edit as needed for Project.

1. Electric reheat: The electric reheat coils shall be low watt density, 304/304 stainless steel fin tubular construction, protected by thermal safety switches, shall be rated as shown on the drawings and controlled in three stages.
2. Hot water reheat: The hot water reheat coil shall have copper tubes and aluminum fins with a capacity as shown on the drawings when supplied with entering water temperature indicated. The control system shall be factory pre-piped with a 2-way modulating control valve and cleanable Y-strainer.

F. Control processor:

Select this "Standard" system of the "Advanced" type system described in the following Article; edit as needed for Project.

1. Standard control processor: The control system shall be microprocessor based. The system shall be provided with two 0.43 inch high, seven-segment LED numerical displays to allow observation of room temperature and humidity and each settable function. Normal Operating Modes (Heating, Cooling, Humidification, Dehumidification) shall be indicated by colored LEDs on the unit-mounted display panel.
 - a. Control: The control system shall allow programming of the following room conditions:
 - 1) Temperature Setpoint: 65-85 degrees F.
 - 2) Temperature Sensitivity: 1 to 5 degrees F.
 - 3) Humidity Setpoint: 40-60% R.H.
 - 4) Humidity Sensitivity: 1% to 10% R.H.
 - 5) Humidifier Flush Rate.
 - b. Compressor Short-Cycle Control: The control system shall prevent compressor short-cycling by a 3-minute timer from compressor stop to the next start.

- c. Alarms: The control system shall monitor unit operation and activate an audible and visual alarm in the event of the following factory preset alarm conditions:

- 1) High Temperature.
- 2) Low Temperature.
- 3) High Humidity.
- 4) Low Humidity.
- 5) Restricted Air Filters.
- 6) Loss of Air.
- 7) High Head Pressure.
- 8) Local Alarm.

G. Advanced Microprocessor Control w/Graphics

1. The advanced control processor shall be microprocessor based with a front monitor dot matrix display panel and control keys for user inputs. The controls shall be menu driven with on-screen prompts for easy user operation. The system shall allow user review and programming of temperature and humidity setpoints, alarm parameters, and setup selections including choice of control type. A password shall be required to make system changes. For all user selections, the range of acceptable input (temperature, humidity, or time delay) shall be displayed on the monitor screen. The system shall provide monitoring of room conditions, operational status in percentage of each function, component run times, date and time, and four analog inputs from sensors provided by others.
 - a. Control: The control system shall allow programming of the following room conditions:
 - 1) Temperature Setpoint 65-85 degrees F.
 - 2) Temperature Sensitivity +/-1 to +/- 9.9 degrees F in 0.1 degree F increments.
 - 3) Humidity Setpoint 20-80% R.H.
 - 4) Humidity Sensitivity +/-1% to +/-30% R.H.
 - b. All setpoints shall be adjustable from the individual unit front monitor panel. Temperature and humidity sensors shall be capable of being calibrated using the front monitor panel controls to coordinate with other temperature and humidity sensors in the room.
 - c. Predictive humidity control: The microprocessor shall calculate the moisture content in the room and prevent unnecessary humidification and dehumidification cycles by responding to changes in dewpoint temperature. In addition, the system shall provide the following internal controls:
 - d. Compressor Short-Cycle Control: The control system shall prevent compressor short-cycling by a 3-minute timer from compressor stop to the next start.
 - e. Automatic compressor sequencing: The microprocessor shall automatically change the lead/lag sequence of the compressors after each start to lengthen compressor-on cycles and even compressor wear.

- f. System auto-restart: For start-up after power failure, the system shall provide automatic restart with a programmable (up to 9.9 minutes in 6-second increments) time delay. Programming can be performed either at the unit or from the central site monitoring system.
 - g. Sequential load activation: During start-up, or after power failure, the microprocessor shall sequence operational load activation to minimize inrush current. Systems allowing multiple loads to start simultaneously are unacceptable.
 - h. Hot water/econ-o-coil flush cycles: Hot water coils and Econ-o-coils shall be automatically flushed to prevent the buildup of contaminants. Systems without this feature shall include the necessary devices to bypass fluid into the coil on a programmed basis.
2. Front monitor display panel: The microprocessor shall provide a front monitor 240 x 128 dot matrix graphics display panel with backlighting. This display (along with five front mounted control keys) shall be the only operator interface required to obtain all available system information such as room conditions, operational status, graphical data, alarms, control and alarm set-points, and all user selections including alarm delays, sensor calibration, DIP switch selections, and diagnostics. All indicators shall be in language form. No symbols or codes shall be acceptable.
 3. Alarms: The microprocessor shall activate an audible and visual alarm in event of any of the following conditions:

Select from following options based on applicability; edit as needed.

- a. High Temperature.
 - b. Low Temperature.
 - c. High Humidity.
 - d. Low Humidity.
 - e. Short Cycle.
 - f. Compressor: Overload #1 and #2.
 - g. Main Fan Overload.
 - h. Humidifier Problem.
 - i. High Head Pressure (#1 and #2),
 - j. Change Filters.
 - k. Loss of Air Flow.
 - l. Low Suction Pressure.
 - m. Loss of Power.
 - n. Custom Alarm (#1 to #4)
4. Custom alarms are four customer accessible alarm inputs to be indicated on the front panel. Custom alarms can be identified with prepared (programmed) labels for the following frequently used inputs:
 - a. Water Under Floor.
 - b. Smoke Detected.
 - c. Standby GC Pump On.
 - d. Loss of Water Flow.
 - e. Standby Unit On.

5. User customized text can be entered for all four custom alarms. Each alarm (unit and custom) can be separately enabled or disabled, selected to activate the common alarm, and programmed for a time delay of 0 to 255 seconds.
 - a. Audible Alarm: The audible alarm shall annunciate any alarm that is enabled by the operator.
 - b. Common Alarm: A programmable common alarm shall be provided to interface user selected alarms with a remote alarm device.
 - c. Remote Monitoring: All alarms shall be communicated to the Liebert site monitoring system with the following information:
 - 1) Date and time of occurrence, unit number, and present temperature and humidity.
6. Control type: The user shall be able to select the type of control the advanced microprocessor will use. Selections available shall be intelligent, proportional, and tunable PID (proportional, integral, and derivative gains). The intelligent control shall incorporate control logic that uses artificial intelligence techniques including "fuzzy logic" and "expert systems" methods to maintain precise, stable control. If tunable PID is selected, the user shall be able to program each of the three gains.
7. Analog Inputs: The system shall include four customer accessible analog inputs for sensors provided by others. The analog inputs shall accept a 4 to 20 mA or 0 to 10 vdc signal. The user shall be able to change the input to 0 to 5 vdc if desired. The gains for each analog input shall be programmable from the front panel. The analog inputs shall be able to be monitored from the front panel.
8. Diagnostics: The control system and electronic circuitry shall be provided with self-diagnostics to aid in troubleshooting. The microcontroller board shall be diagnosed and reported as pass/not pass. Control inputs shall be indicated as on or off at the front monitor panel. Control outputs shall be able to be turned on or off from the front monitor panel without using jumpers or a service terminal.
9. Data collection: The control system shall maintain accumulative operating hours of compressors, reheats, humidifier, fan motor, Econ-o-coil, and heat rejection. The sixty most recent alarms shall also be retained.
10. Graphing: The control shall display the following graphical data:
 - a. Temperature, humidity, analog inputs.
 - b. Component operating status by hour.
 - c. Leak detection floor plan.
 - d. Operating status.
11. Communications: The microprocessor shall be compatible with all Liebert remote monitoring and control devices.

H. Compressorized Systems

1. Dual refrigeration systems: Each refrigeration circuit shall include hot gas mufflers, liquid line filter dryers, refrigerant sight glass with moisture indicator adjustable, externally equalized expansion valves, and liquid line solenoid valves.

2. Semi-hermetic compressors: The compressors shall be located in a separate compartment so they may be serviced during operation of the equipment. The compressor shall be semi-hermetic with a suction gas cooled motor, vibration isolators, thermal overloads, oil sight glass, manual reset high pressure switch, pump down low pressure switch, suction line strainer, reversible oil pumps for forced feed lubrication, and a maximum operating speed of 1750 RPM.
3. Four-step refrigeration system: The environmental control system shall include cylinder unloaders on the semi-hermetic compressors. The unloaders shall be activated by solenoid valves, which are controlled from the microprocessor control. In response to the return air temperature, the microprocessor control shall activate the unloader solenoids and the liquid line solenoids such that four stages of refrigeration cooling are obtained. The stages shall be as follows:
 - a. One compressor, partially loaded,
 - b. Two compressors partially loaded,
 - c. One compressor partially loaded, one compressor fully loaded,
 - d. Two compressors fully loaded.

Select this optional four step system if warranted; edit as needed.

- 1) On a call for dehumidification, the microprocessor control shall insure that at least one compressor is on full for proper humidity control.
4. A-Frame DX coil: The evaporator coil shall be an A-Frame design and shall be constructed of copper tubes and aluminum fins. Refrigerant of each system shall be distributed throughout the entire coil face area. A stainless steel condensate drain pan shall be provided.
5. Air cooled systems: The Liebert manufactured air cooled condenser shall be the low profile, show speed, multiple direct drive, propeller fan type. The condenser shall balance the heat rejection of the compressor at applicable ambient temperature. The condenser shall be constructed of aluminum and contain a copper tube, aluminum fin coil arranged for (horizontal) (vertical) air discharge. Provide hail protection on condensing units exposed to outdoors.
 - a. Fan speed control condenser: The winter control system for the air cooled condenser shall be Liebert Fan Speed Control. The variable speed motor shall operate from 0 to 230 volts single phase, 10 to 1050 RPM. It shall be designed with ball bearings, permanent lubrication, internal overload protection, 40 degrees Celsius rise at full speed, 65 degrees Celsius rise at 10 RPM. The control system shall be complete with transducers, thermostats and electrical control circuit, factory pre-packaged in the integral condenser control box. The transducer shall automatically sense the highest head pressure of either operating compressor and control the variable speed fan on the air cooled condenser to properly maintain the head pressure. The fan speed control system shall provide positive start-up and operation in ambient temperature as low as -20 degrees F.
 - b. Lee-temp winter control system: The winter control system for the air cooled condenser shall be Lee-Temp. The Lee-Temp system shall allow start-up and positive head pressure control with ambient temperatures as

- low as -30 degrees F. The Lee-Temp package shall include the following components for each refrigeration circuit: insulated receiver, pressure relief valve, head pressure three-way control valve, and rotoloc valve for isolating the refrigerant charge. The Lee-Temp receiver shall be factory insulated and mounted ready for the field connection to the air cooled condenser. The Lee-Temp heater shall require a separate power supply.
- c. Quiet-line condenser: Fan motors shall be 12-pole, 570 RPM, equipped with rain shields and permanently sealed ball bearings. Motors shall include built-in overload protection. Motors shall be rigidly mounted on die-formed galvanized steel supports. Disconnect switch shall be a standard feature.
 - d. Air cooled condenser: Provide a disconnect switch factory mounted and wired to the condenser control panel, accessible from the exterior.

6. Water Cooled Systems:

- a. Condenser: The water cooled condensers for each circuit shall be clean-able, shell-and-tube, counter flow with removable heads. Condensers shall be A.S.M.E. stamped for a maximum refrigerant pressure of 400 PSI at 200 degrees F.

Select from options following this subparagraph; edit as needed.

- b. Water regulating valve: The condenser shall be pre-piped with a 2-way regulating valve which is head pressure actuated.

Select one below.

- c. Regulating valves: The water regulating valve shall be pre-piped with head pressure actuated **[3 way] [2 way with bypass]** regulating valve.

Select one below.

- d. Pressure rating: The condenser water circuit shall be designed for a pressure of **[150] [300]**PSI.
- e. Hot gas reheat: The complete hot gas reheat system shall include a copper tube, aluminum fin coil, three-way solenoid valve, refrigeration check valve, and one stage of electric reheat.

7. Glycol cooled:

- a. Condenser: The glycol cooled condenser for each circuit shall be counterflow, shell-and-tube. It shall be cleanable, with removable heads. The condensers shall be A.S.M.E. stamped for a maximum refrigerant pressure of 400 PSI at 200 degrees F.

Select from options following this subparagraph; edit as needed.

- b. Glycol regulating valve: Each condenser shall be pre-piped with head pressure activated regulating valve and parallel bypass valve.
- c. Three-way glycol- regulating valve: Each condenser shall be pre-piped with a head pressure activated three-way regulating valve.

Select one below.

- d. Pressure rating: The condenser glycol circuit shall be designed for a

- pressure of [150] [300] PSI.
- e. Dry cooler: The dry cooler shall be the low profile, slow speed, multiple direct drive, propeller fan type. The dry cooler shall be constructed of aluminum and contain a copper tube aluminum fin coil with an integral electric control panel and disconnect switch.
 - f. Glycol pump package: This system shall be provided with a centrifugal pump mounted in a weatherproof and vented enclosure. The pump shall be rated as shown on the drawings.
 - g. Dual pump package: The dual pump package shall include pumps, enclosure, field mounted flow switch, and a separate factory wired control box (including a lead/lag switch for the pumps). The standby pump shall automatically start upon failure of the lead pump.
 - h. Hot gas reheat: The complete hot gas reheat system shall include a copper tube, aluminum fin coil, three-way solenoid valve, and refrigerant check valve.

8. Glycool:

"Glycool" may be selected as condensing system to provide economy cooling in cold weather. Select from options described in subparagraphs 4 through 8; edit as needed.

- a. Condenser: The glycol cooled condenser for each circuit shall be counterflow, shell-and-tube. It shall be cleanable, with removable heads. The condensers shall be A.S.M.E. stamped for a maximum refrigerant pressure of 400 PSI at 200 degrees F.
 - b. Glycol regulating valve: Each condenser shall be pre-piped with a head pressure activated three-way regulating valve.
 - c. Dry cooler: The dry cooler shall be the low profile, slow speed, multiple direct drive, propeller fan type. The dry cooler shall be constructed of aluminum and contain a copper tube aluminum fin coil with an integral electric control panel and disconnect switch.
 - d. Glycol pump package: This system shall be provided with a centrifugal pump mounted in a weatherproof and vented enclosure.
 - e. Dual pump package: The dual pump package shall include pumps, enclosure, field mounted flow switch, and a separate factory wired control box (including a lead/lag switch for the pumps). The standby pump shall automatically start upon failure of the lead pump.
 - f. Glycool three-way control valve: The glycool coil shall be equipped with a fully proportional 3-way control valve. This motorized control valve shall control the amount of flow to the glycool cooling coil and maintain constant temperature and relative humidity.
 - g. Glycool coil: Free cooling Glycool coil shall be copper tube, aluminum fin coil located in the return air before the A-Frame evaporator coil.
 - h. Pressure rating: The condenser/GLYCOOL coil circuit shall be designed for a pressure of [150] [300] PSI.
9. Dual Cooling Source Systems: The dual cooling source system shall consist of an air or water cooled compressorized system with the addition of a chilled water coil, a modulating control valve, and a comparative temperature sensor. The system shall be able to function either as a modulating chilled water system or

as a compressorized system, or a combination of both. The primary mode of cooling shall be chilled water. Switchover between the two cooling modes shall be performed automatically by the microprocessor control.

- a. Dual cooling source three-way control valve: The water circuit shall include a 3-way modulating valve. The microprocessor positions the valve in response to room conditions. Cooling capacity will be controlled by bypassing chilled water around the coil. The modulating valve travel for dehumidification shall be proportional.
- b. Dual cooling source coil: The dual-cooling source coil shall be constructed with copper tubes and aluminum fins. It shall be located in the return air, before the A-Frame evaporator coil.

I. Equipment Components:

Select from following options; edit as needed.

1. Disconnect switch:
 - a. Disconnect switch (non-locking type): The manual disconnect switch shall be mounted in the high voltage section of the electrical panel. The switch shall be accessible with the door closed.
 - b. Disconnect switch (locking type): The manual disconnect switch shall be mounted in the high voltage section of the electrical panel. The switch shall be accessible from the outside of the unit with the door closed, and prevent access to the high voltage electrical components until switched to the "OFF" position.
2. Firestat: The firestat shall immediately shut down the environmental control system when activated. The firestat shall be mounted in the electrical panel with the sensing element in the return air.
3. Condensate pump: The condensate pump shall have a minimum capacity of 100 GPH at 20 ft head. It shall be complete with integral float switch, pump and motor assembly, and reservoir.
4. LiquiTect sensors (max. of two per unit): Provide <Insert quantity> solid state water sensors under the raised floor.
5. Floor stand: The floor stand shall be constructed of a heliarc welded tubular steel frame. The floor stand shall have adjustable legs with vibration isolation pads. The floor stand shall be of height matching raised floor system.
6. Floor stand turning vane: A factory supplied, field mounted turning vane shall be provided.
7. Temperature and humidity recorder: Provide a 7-day/24 hour temperature and humidity recorder of the full scope, two pen, surface mounted type with 100 recording charts, one red and one blue bottle of recording ink.
8. Smoke detector: The smoke detector shall immediately shut down the environmental control system and activate the alarm system when activated. The smoke detector shall be mounted in the electrical panel with the sensing element in the return air compartment.
9. SiteScan site monitoring system: Provide a SiteScan monitor system with the Deluxe System/3. The SiteScan shall have the capability to monitor and change

(at the user direction) the temperature and humidity setpoints and sensitivities of each unit. The printer shall provide the user with chronological alarm information. It shall also be capable of being programmed to print out environmental conditions or operating modes at each unit.

Hail guards are required on all condensing units that are located outdoors or in areas where apron workers have access to them.

10. Air cooled DX-condensing coils shall be provided with steel hail guard. Hail guard shall be constructed to prevent the passage of one-half inch diameter hail.

2.3 CEILING-MOUNTED UNITS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Liebert
 2. Mitsubishi
 3. Daikin
 4. York International.
 5. <Insert manufacturer>
 6. or approved equal.
- B. Standard Features:
 1. Cabinet construction for ceiling mounted units: The cabinet and chassis shall be constructed of heavy gauge galvanized steel. Mounting brackets shall be factory attached to the cabinet.
 - a. For units of 1-1/2 ton capacity or less, service access is from front and bottom of unit only (water cooled units require right end access).
 - b. For units of 2-ton and larger capacity, evaporator cabinet service shall require access from one side only.
 2. Air distribution:
 - a. Systems larger than 1-1/2 ton capacity: The air distribution system shall be constructed with a quiet, direct-drive fan assembly equipped with double-inlet blower, self-aligning ball bearings, and lifetime lubrication. Fan motor shall be permanent-split capacitor, high efficiency type, equipped with two speeds for air flow modulation. Dehumidification shall utilize the lower fan speed. For systems 5 tons and larger, drive package shall be equipped with an adjustable motor sheave and fan/motor assembly shall be mounted on vibration isolators. Refer to drawings for ratings.
 - b. Systems 1-1/2 ton and smaller: The air distribution system shall be constructed with a quiet, direct-drive fan assembly equipped with double-inlet blower, self-aligning ball bearings, and lifetime lubrication. Fan motor shall be permanent-split capacitor, high efficiency type, equipped

with two speeds for air flow modulation. Dehumidification shall utilize the lower fan speed. System shall be suitable for plenum or ducted air distribution. Refer to drawings for ratings.

3. Microprocessor control: The control system shall be microprocessor based. The wall-mounted control enclosure shall include a 2-line by 16 character LCD display providing continuous display of operating status and alarm condition. An 8-key membrane keypad for setpoint/program control, unit on/off, and fan speed shall be located below the display. Temperature and humidity sensors shall be located in the wall box which shall be capable of being located up to 300 ft. from the evaporator/air handling unit, via field supplied and wired thermostat-type wire.
 - a. For 8-ton capacity systems, the microprocessor shall provide 3 stages of cooling by cycling the 3-ton compressor, 5-ton compressor and then both compressors. The microprocessor shall determine the optimal stage to run based on historical run data.

Delete this paragraph if not applicable.

4. Monitoring: The LCD display shall provide an on/off indication, fan speed indication, operating mode indication (cooling, heating, humidifying, dehumidifying) and current day, time, temperature and humidity (if applicable) indication. The monitoring system shall be capable of relaying unit operating parameters and alarms to the Liebert SiteScan, or approved substitute, monitoring system.
5. Control setpoint parameters:
 - a. Temp. setpoint: 65-85 degrees F.
 - b. Temp. sensitivity: 1 to 5 degrees F (1 to 9.9 degrees F for units larger than 3-ton capacity).
 - c. Humidity setpoint: 20-80% RH.
 - d. Humidity sensitivity: 1 to 10% RH (1 to 30% RH for units larger than 3-ton capacity).
 - e. Unit controls:
 - 1) Compressor short-cycle control: The control system shall prevent compressor short-cycling by a 3 minute timer from compressor stop to the next start.
 - 2) Common alarm and remote on/off: A common alarm relay shall provide a contact closure to a remote alarm device. Two (2) terminals shall also be provided for remote on/off control. Individual alarms shall be "enabled" or "disabled" from reporting to the common alarm.
 - 3) Temperature calibration: The control shall include the capabilities to calibrate the temperature and humidity sensors and adjust the sensor response delay time from 1 to 90 seconds. The control shall be capable of displaying temperature values in degrees F.
 - 4) System auto restart: For start-up after power failure, the system shall provide automatic restart with a programmable (up to 9.9 minutes in 6-second increments) time delay. Programming can be performed either at the unit or from the central site monitoring system.

f. Alarms:

1) Unit alarm: The control system shall monitor unit operation and activate an audible and visual alarm in the event of the following factory preset alarm conditions:

- a) High Temperature.
- b) Low Temperature.
- c) High Humidity.
- d) Low Humidity.
- e) High Water Alarm - Lockout Unit Operation.
- f) High Head Pressure.
- g) Loss of Power.
- h) Compressor Short Cycle.

2) Custom alarms (2x): (User customized text can be entered for the two (2) custom alarms):

- a) Humidifier Problem.
- b) Filter Clog.
- c) Water Detected.
- d) Smoke Detected.

- 6. Alarm controls: Each alarm (unit and custom) shall be separately enabled or disabled, selected to activate the common alarm (except for high head pressure).
- 7. Audible alarm: The audible alarm shall annunciate any alarm that is enabled by the operator.
- 8. Common alarm: A programmable common alarm shall be provided to interface user selected alarms with a remote alarm device.
- 9. Remote monitoring: All alarms shall be communicated to the site monitoring system with the following information: date and time of occurrence, unit number, and preset temperature and humidity.
- 10. Radiated noise shall not exceed:
 - a. NC 35 - In Office.
 - b. NC 40 - Terminal/Concourse.
 - c. NC 45 - Maintenance Facilities.

C. Direct expansion system evaporator components:

- 1. Direct expansion coil: The evaporator section shall include evaporator coil, thermostatic expansion valve, and filter drier.
- 2. The evaporator coil shall be constructed of copper tubes and aluminum fins. The coil shall be provided with a stainless steel drain pan. Refrigerant flow shall be controlled by an externally equalized thermostatic expansion valve.
- 3. Refrigeration system (DX systems 1-1/2 Ton Capacity or Smaller): The refrigeration system shall consist of a scroll or rotary compressor with vibration isolating grommets, high pressure safety switch, filter drier, and externally equalized expansion valve.

D. Chilled Water System Components:

1. Chilled water control valve: The control solenoid valve shall be motorized slow-acting type to reduce water hammer. Design pressure shall be 300 psig static pressure, with a maximum close-off pressure of 30 psi.
2. Chilled water coil: The cooling coil shall be constructed of copper tubes and aluminum fins and have a maximum face velocity of 500 ft. per minute at rated CFM. The coil shall be supplied with 45 degree F entering water temperature. The coil assembly shall be mounted in a stainless steel condensate drain pan.

E. Air-cooled centrifugal fan condensing unit (systems 2 tons or larger):

Select the desired type of condensing systems from this Article 2.4 or following Articles 2.5 through 2.7.

1. The condenser coil shall be constructed of copper tubes and aluminum fins. The condensing unit shall be factory charged with refrigerant, sealed, and shall be capable of being connected to the evaporator section directly. The condensing unit can be mounted directly to the evaporator or can be mounted remote to the evaporator; refer to drawings for arrangement.
 - a. The condensing unit shall be designed for 95 degrees F ambient and be capable of operation to -20 degrees F ambient. The fan and motor assembly shall be direct drive for systems of 3 tons capacity or less; and belt driven for larger systems.
 - b. A hot gas bypass circuit shall be provided to ensure operation under low load conditions.
 - c. Provide hail protection on condensing units exposed to outdoors.

Sound testing and sound performance shall not be waived. Review the table below for compliance with NC-40 criteria.

2. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

F. Self-Contained Systems (1-1/2 ton or smaller):

1. Air-cooled self-contained systems: The condenser section shall contain a factory mounted and piped condenser coil constructed of copper tubes and aluminum fins. No piping, brazing, dehydration or charging shall be required. The condenser coil shall be factory mounted within the evaporator cabinet. A factory supplied condenser fan shall be field mounted to the end of the evaporator cabinet.
 - a. Condenser electrical connection to the cooling chassis shall be by a factory provided harness. Fan shall be sized to provide full rated cooling capacity at 95 degrees F entering air from plenum space. The system shall be

provided with a fan speed control system to permit operation at -20 degrees F ambient temperature.

2. Water or glycol cooled self-contained systems: The water/glycol system shall be equipped with a coaxial condenser having ratings as indicated on the drawings. The condenser circuit shall be pre-piped with a **[2-way] [3-way]** regulating valve which is head-pressure actuated. The condenser water/glycol circuit shall be designed for a pressure of 150 PSI.

G. Air-Cooled Propeller Fan Condensing Unit:

1. The condenser coil shall be constructed of copper tubes and aluminum fins with a direct-drive propeller-type fan, and shall include a scroll compressor, high pressure switch, and Lee-temp receiver. All components shall be factory assembled, charged with refrigerant, sealed, and be capable of being connected to the evaporator section using pre-charged refrigerant line sets. No internal piping, brazing, dehydration, or charging shall be required. Condensing unit shall be designed for 95 degrees F ambient and be capable of operation to -30 degrees F.
 - a. The condensing unit shall be designed to operate at a sound level less than 58 dba.
 - b. A hot gas bypass circuit shall be provided to ensure operation under low load conditions.
 - c. The outdoor condensing unit shall be designed for design ambient operation of 105 degrees F.

Sound testing and sound performance shall not be waived. review the table below for compliance with NC-40 criteria.

2. Sound Ratings: ARI 260. Sound power levels from discharge and inlet openings of the unit shall not exceed the following:

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Discharge	64	57	51	47	42	39	38	37
Inlet	64	57	51	47	42	39	38	37

H. Water/Glycol Cooled Condensing Unit:

1. The water/glycol condensing unit shall be equipped with a coaxial condenser, scroll compressor, and high-pressure switch. The condensing unit shall be factory charged with R-22 refrigerant. The condenser circuit shall be pre-piped with a **[2-way] [3-way]** regulating valve which is head-pressure actuated. The condenser water/glycol circuit shall be designed for a static operating pressure of 150 PSI.
 - a. A hot gas bypass circuit shall be provided to reduce compressor cycling and improve operation under low load conditions.

I. Factory-Installed Accessories:

Select desired accessories from the following.

1. Steam Generating Humidifier: The environmental control system shall be equipped with a steam generating humidifier that is controlled by the microprocessor control system. It shall be complete with disposable canister, all supply and drain valves, steam distributor, and electronic controls. The need to change canister shall be annunciated on the microprocessor wallbox control panel. The humidifier shall have a capacity as indicated on the drawings. An LED light on the humidifier assembly shall indicate cylinder full, over-current detection, fill system fault, and end of cylinder life conditions.
2. Electric Reheat: The electric reheat shall be low-watt density, 304/304 stainless steel, finned-tubular. The reheat section shall include an NRTL approved safety switch to protect the system from overheating. The capacity of the reheat coils shall be as shown on the drawings, controlled in one stage.
3. Hot Water Reheat: The hot water reheat coil shall have copper tubes and aluminum fins with a capacity as shown on the drawings. The control system shall be factory prepiped with a 2-way solenoid valve and cleanable Y-strainer.
 - a. SCR Electric Reheat: The electric reheat shall be low-watt density, 304/304 stainless steel, finned-tubular and shall be capable of maintaining room dry bulb conditions when the system is calling for dehumidification. The reheat section shall include an NRTL approved safety switch to protect the system from overheating.
4. The SCR (Silicon Controlled Rectifier) controller shall proportionally control the reheat elements to maintain the selected room temperature. The unit microprocessor control shall operate the SCR controller, while cooling is locked on. The capacity of the reheat coils shall be as shown on the drawings.
5. Disconnect switch, Non-Locking: The non-automatic, non-locking, molded case circuit breaker shall be factory mounted in the high voltage section of the electrical panel. The switch shall be accessible from the front of the unit.
6. Firestat: The firestat shall immediately shut down the system when high temperatures are detected. The firestat shall be mounted with the sensing element in the return air.
7. Smoke detector: The smoke detector shall immediately shut down the environmental control system and activate the alarm system when activated. The sensing element shall be located in the return air compartment.
8. Free-cooling/dual cooling source: A free-cooling coil shall be integral to the evaporator cabinet, and shall be constructed of copper tubes and aluminum fins. The coil shall be rated as shown on the drawings. Free-cooling shall be activated by a temperature stat, and shall include factory piped three-way valve and separate supply and return piping.

J. Field Installed Accessories:

Select desired field-installed accessories from the following.

1. Remote sensors: The unit shall be supplied with remote temperature and humidity sensors. The sensors shall be connected to the unit by a shielded cable.
2. Accessories for 1-ton and 1-1/2-ton Systems:

- a. Supply and return grill: A factory supplied supply and return grill kit, with 20% ASHRAE 52-76 filter, shall be provided for supply and return air delivery through a 2' x 4' ceiling grid.
 - b. Filter box and duct kit: A return air filter box shall be provided with hinged filter access, and 1" duct flange. A 1" duct flange shall also be provided for air discharge. Filters shall be 35% efficiency based on ASHRAE 52-76.
 - c. Duct collar kit: A 1" Duct Flange shall be provided for the discharge and return air openings. Filters to be field supplied.
3. Air distribution plenum (2-ton through 8-ton systems): The evaporator section shall be supplied with an air distribution plenum with integral filter. The plenum shall provide 4-way air distribution, for installation into a standard 29 x 49 ceiling grid. Filter size shall be 4" deep pleated type with minimum efficiency of 20%, based on ASHRAE 52-76.
 4. High static blower assembly (2-ton through 8-ton systems): A blower box shall be field attached to the evaporator to provide up to 2.00 of external static pressure on the discharge side of the evaporator. The blower box shall contain a centrifugal type, double inlet blower, with belt drive and single speed motor, mounted to an adjustable motor base.
 5. Air filter box (2-ton through 8-ton systems): The evaporator section shall be supplied with an air filter box for use with ducted installations. The filter shall be 4" deep, pleated type, with a minimum efficiency of 20%, based on ASHRAE 52-76.
 6. Condensate pump: The condensate pump shall have the minimum capacity of 30 GPH at 20 ft. head, and shall be complete with integral float switch, pump, motor assembly, and reservoir.
 7. Refrigerant line sets: Pre-charged refrigerant line sets shall be provided in proper lengths for application. Line set lengths shall be as shown on the drawings.
 8. Refrigerant line sweat adapter Kit: Provide a sweat adapter kit to permit field brazing of refrigerant line connections.
 9. Single point power kit: A single point power kit shall be provided for a close-coupled system to allow a single electrical feed to supply power to both the evaporator and condensing unit.
 10. Liebert SiteScan Site Monitoring System: A Liebert SiteScan Site Monitoring System shall be provided for remote monitoring of the Mini-Mate2 unit and monitoring of other Liebert support equipment. The SiteScan shall have the capability to monitor and change (at the user direction) the temperature and humidity setpoints and sensitivities of each unit. The printer shall provide the user with chronological alarm information. It shall also be capable of being programmed to print out environmental conditions or operating modes at each unit.
 11. Dry cooler: The dry cooler shall be the low-profile, slow speed, multiple direct drive propeller fan type. The dry cooler shall be constructed of aluminum and contain a copper type, aluminum fin coil with an integral electric control panel. The dry cooler shall be designed for 105 degrees ambient.
 12. Glycol pump package: The system shall include a centrifugal pump mounted in a weatherproof and vented enclosure. The pump shall be rated as shown on the drawings.

K. Electrical Characteristics and Components:

1. Electrical characteristics: As indicated on the Drawings.

Select one below.

2. Disconnect Switch: Factory mount disconnect switch [in control panel.] [on equipment under provisions of Division 26 Sections.]

L. Supplemental Condensate Drain Pans:

1. Wherever units equipped for cooling service are installed above facilities such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment.
 - a. Supplemental drain pans to be constructed of 20 gauge (minimum) galvanized steel, minimum depth 2 inches, fabricated, braced, and supported so as to ensure stability.
 - b. Provide drain piping conforming to provisions 15410 or 15510, as applicable, minimum size 3/4 inch, terminating as a visible sight drain discharging to a floor drain or service sink if feasible, or as may otherwise be directed or approved by the DEN Project Manager.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for hydronic piping systems to verify actual locations of piping connections before equipment installation.
- C. Examine walls, floors, and roofs for suitable conditions where computer-room air conditioners will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances. [**Install according to ARI Guideline B.**]

Retain one or more of five paragraphs below. Coordinate with Drawings and Sections specifying vibration and seismic controls. Retain or insert amount of required deflection.

- B. Computer-Room Air-Conditioner Mounting: Install using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."]
1. Minimum Deflection: [1/4 inch (6 mm)] [1 inch (25 mm)] <Insert dimension>.
- C. Suspended Computer-Room Air Conditioners: Install using continuous-thread hanger rods and [elastomeric hangers] [spring hangers] [spring hangers with vertical-limit stop] of size required to support weight of computer-room air conditioner.
1. Comply with requirements for vibration isolation devices specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."] Fabricate brackets or supports as required.
 2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- D. Air-Cooled Refrigerant Condenser Mounting: Install using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."]
1. Minimum Deflection: [1/4 inch (6 mm)] [1 inch (25 mm)] <Insert dimension>.
- E. Remote, Air-Cooled, Glycol-Solution Cooler Mounting: Install using [elastomeric pads] [elastomeric mounts] [restrained spring isolators] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."]
1. Minimum Deflection: [1/4 inch (6 mm)] [1 inch (25 mm)] <Insert dimension>.
- F. Glycol-Solution Pump Package Mounting: Install using [elastomeric pads] [elastomeric mounts] <Insert device>. Comply with requirements for vibration isolation devices specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."]

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other heating, ventilating, and air-conditioning Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

- B. Install piping adjacent to machine to allow service and maintenance.
- C. Water and Drainage Connections: Comply with applicable requirements in Section 221116 "Domestic Water Piping." Provide adequate connections for water-cooled units, condensate drain, and humidifier flushing system.

Retain first paragraph below for units with hot-water coils.

- D. Hot-Water Heating Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Provide shutoff valves in inlet and outlet piping to heating coils.

Retain first paragraph below for units with steam coils.

- E. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Provide shutoff valves in steam inlet and steam trap in condensate outlet piping to heating coils.
- F. Condenser-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Provide shutoff valves in water inlet and outlet piping on water-cooled units.
- G. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Provide shutoff valves and piping.
- H. Electrical System Connections: Comply with applicable requirements in Division 26 for power wiring, switches, and motor controls.
- I. Ground equipment according to Division 26.
- J. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Retain first paragraph below to require a factory-authorized service representative to perform inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

C. Tests and Inspections:

1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
2. After installing computer-room air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- D. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
- B. Verify that computer-room air-conditioning units are installed and connected according to manufacturer's written instructions and the Contract Documents.
- C. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements in Division 26.
- D. Complete installation and startup checks according to manufacturer's written instructions.
- E. After startup service and performance test, change filters and flush humidifier.

3.6 ADJUSTING

- A. Adjust initial temperature[**and humidity**] set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number>

months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain computer-room air conditioners.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238123

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SECTION 238126 - SPLIT-SYSTEM AIR-CONDITIONERS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify with manufacturers that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include split-system air conditioners may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes split-system air-conditioning and heat-pump units consisting of separate evaporator-fan and compressor-condenser components.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT

PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.

1. Include data substantiating that materials comply with requirements.

- B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

- C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

Retain subparagraph below if equipment includes wiring.

2. Wiring Diagrams: For power, signal, and control wiring.

Coordinate sample requirements with DEN Project Manager.

- D. Samples for Initial Selection: For units with factory-applied color finishes.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
B. Warranty: Sample of special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For split-system air-conditioning units to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: **[One (1)] <Insert number>** set(s) for each air-handling unit.
 - 2. Gaskets: **[One (1)] <Insert number>** set(s) for each access door.
 - 3. Fan Belts: **[One (1)] <Insert number>** set(s) for each air-handling unit fan.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE Compliance:
 - 1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

"ASHRAE Compliance" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1. In addition to establishing minimum ventilation rates, ASHRAE 62.1 includes requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain-pan construction and connection, finned-tube coil selection and cleaning, and equipment access. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- 2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Procedures," and Section 7 - "Construction and System Start-up."

"ASHRAE/IESNA" Compliance Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1. See "LEED Rating System" Article in the Evaluations for discussion on this prerequisite.

- C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

1.8 COORDINATION

Retain first paragraph below if remote condensing units are located on grade; retain second paragraph if they are located on roof.

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Section 033000 "Cast-in-Place Concrete."
- B. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.9 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of split-system air-conditioning units that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components with manufacturers listed in Part 2.

1. Warranty Period:

- a. For Compressor: Minimum **[one (1)] [five (5)] <Insert number>** year(s) from date of Substantial Completion.
- b. For Parts: Minimum **[one (1)] [five (5)] <Insert number>** year(s) from date of Substantial Completion.
- c. For Labor: Minimum **[one (1)] [five (5)] <Insert number>** year(s) from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- B. Factory-packaged and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.
- C. Radiated noise shall not exceed:
 - 1. NC 35 – In Office.
 - 2. NC 40 – Terminal/Concourse.
 - 3. NC 45 – Maintenance Facilities.

2.2 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain one paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

Verify that manufacturers retained in the list below make combination of unit components retained.

- 1. Carrier Corporation; Home Comfort and HVAC Building & Industrial Systems.
- 2. Coleman Company Inc. (The).
- 3. First Operations LP.
- 4. Friedrich Air Conditioning Company.
- 5. Koldwave, Inc.; a Mestek company.
- 6. Lennox International Inc.
- 7. Mitsubishi Electric & Electronics USA, Inc.; HVAC Advanced Products Division.
- 8. Mitsubishi Electric Sales Canada Inc.
- 9. Mitsubishi Heavy Industries America, Inc.
- 10. SANYO North America Corporation; SANYO Fisher Company.
- 11. Trane; a business of American Standard companies.
- 12. YORK; a Johnson Controls company.
- 13. **<Insert manufacturer's name>.**
- 14. or approved equal.

2.3 INDOOR UNITS (5 TONS (18 kW) OR LESS)

- A. Concealed Evaporator-Fan Components:
 - 1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
 - 2. Insulation: Faced, glass-fiber duct liner.
 - 3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.

Retain one of first two subparagraphs below if heating coil is required.

- 4. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch (2.5 mm)**; leak tested to **300 psig (2070 kPa)** underwater; with a two-position control valve.

5. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
6. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
7. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
 - c. Wiring Terminations: Connect motor to chassis wiring with plug connection.

ASHRAE compliance in "Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph below to comply with LEED Prerequisite IEQ 1.

8. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
9. Filters: Permanent, cleanable.
10. Condensate Drain Pans:

First option in first subparagraph below is minimum slope in ASHRAE 62.1.

- a. Fabricated with **[one]** **[two]** percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.

ASHRAE compliance option in "Length" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option in first subparagraph to comply with LEED Prerequisite IEQ 1; otherwise, insert distance.

- 1) Length: Extend drain pan downstream from leaving face **[to comply with ASHRAE 62.1]** **<Insert distance>**.
- 2) Depth: A minimum of **[2 inches (50 mm)]** **<Insert depth>** deep.

Retain one of first two subparagraphs below. Retain second subparagraph if drain-pan temperature is expected to fall below surrounding dew point temperature.

- b. Single-wall, **[galvanized]** **[stainless]**-steel sheet.
- c. Double-wall, **[galvanized]** **[stainless]**-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
- d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on **[one end]** **[both ends]** of pan.
 - 1) Minimum Connection Size: **[NPS 1 (DN 25)]** **[NPS 2 (DN 50)]** **<Insert size>**.

Retain first subparagraph below for galvanized-steel drain pans; delete for stainless-steel drain pans.

- e. Pan-Top Surface Coating: Asphaltic waterproofing compound.
- f. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

B. Floor-Mounted, Evaporator-Fan Components:

- 1. Cabinet: Enameled steel with removable panels on front and ends in color selected by DEN Project Manager.
 - a. Discharge Grille: **[Steel with surface-mounted frame] [Welded steel bars forming a linear grille and welded into supporting panel].**
 - b. Insulation: Faced, glass-fiber duct liner.
 - c. Drain Pans: Galvanized steel, with connection for drain; insulated.
- 2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.

Retain one of first two subparagraphs below if heating coil is required.

- 3. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch (2.5 mm)**; leak tested to **300 psig (2070 kPa)** underwater; with a two-position control valve.
- 4. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
- 5. Fan: Direct drive, centrifugal, **with power-induced outside air**].
- 6. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
- 7. Air Filtration Section:

See Evaluations for discussion on filter characteristics and applications. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

- a. General Requirements for Air Filtration Section:
 - 1) Comply with NFPA 90A.
 - 2) Minimum Arrestance: According to ASHRAE 52.1 and MERV according to ASHRAE 52.2.
 - 3) Filter-Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
- b. Disposable Panel Filters:

Retain one or more of first seven subparagraphs below, as applicable. If Project has more than one filter type, indicate filter type for each unit on Drawings.

- 1) Factory-fabricated, viscous-coated, flat-panel type.
- 2) Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
- 3) Dust-Holding Capacity: <Insert lb (kg)>.
- 4) Initial Resistance: <Insert inches wg (Pa)>.
- 5) Recommended Final Resistance: <Insert inches wg (Pa)>.
- 6) Arrestance according to ASHRAE 52.1: [80] <Insert value>.
- 7) Merv according to ASHRAE 52.2: [5] <Insert value>.
- 8) Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
- 9) Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, and hinged; with pull and retaining handles.

c. Extended-Surface, Disposable Panel Filters:

- 1) Factory-fabricated, dry, extended-surface type.
- 2) Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
- 3) Dust-Holding Capacity: <Insert lb (kg)>.
- 4) Initial Resistance: <Insert inches wg (Pa)>.
- 5) Recommended Final Resistance: <Insert inches wg (Pa)>.
- 6) Arrestance according to ASHRAE 52.1: [90] <Insert value>.
- 7) Merv according to ASHRAE 52.2: [7] <Insert value>.
- 8) Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
- 9) Media-Grid Frame: [**Nonflammable cardboard**] [**Galvanized steel**] [**Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets**].
- 10) Mounting Frames: Welded, galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

C. Wall-Mounted, Evaporator-Fan Components:

1. Cabinet: Enameled steel with removable panels on front and ends in color selected by DEN Project Manager, and discharge drain pans with drain connection.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.

Retain "Electric Coil" Subparagraph below for heat-pump units and supplemental electric heat.

3. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
4. Fan: Direct drive, centrifugal.
5. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

- b. Multitapped, multispeed with internal thermal protection and permanent lubrication.

Retain first subparagraph below if enclosure is not open-dripproof type. Retain second subparagraph for premium efficiency.

- c. Enclosure Type: Totally enclosed, fan cooled.
- d. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
- e. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

Retain first subparagraph below to require that disconnect switches be supplied with unit.

- f. Mount unit-mounted disconnect switches on **[exterior]** **[interior]** of unit.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

- g. **<Insert unique motor characteristics>**.

ASHRAE compliance in "Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph to comply with LEED Prerequisite IEQ 1.

- 6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- 7. Condensate Drain Pans:

First option in first subparagraph below is minimum slope in ASHRAE 62.1.

- a. Fabricated with **[one]** **[two]** percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.

ASHRAE compliance option in "Length" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option in first subparagraph to comply with LEED Prerequisite IEQ 1; otherwise, insert distance.

- 1) Length: Extend drain pan downstream from leaving face **[to comply with ASHRAE 62.1]** **<Insert distance>**.
- 2) Depth: A minimum of **[1 inch (25 mm)]** **<Insert depth>** deep.

Retain one of first two subparagraphs below.

- b. Single-wall, **[galvanized]** **[stainless]**-steel sheet.
- c. Double-wall, **[galvanized]** **[stainless]**-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
- d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on **[one end]** **[both ends]** of pan.
 - 1) Minimum Connection Size: **[NPS 1 (DN 25)]** **[NPS 2 (DN 50)]** **<Insert size>**.

Retain first subparagraph below for galvanized-steel drain pans; delete for stainless-steel drain pans.

e. Pan-Top Surface Coating: Asphaltic waterproofing compound.

8. Air Filtration Section:

See Evaluations for discussion on filter characteristics and applications. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

a. General Requirements for Air Filtration Section:

- 1) Comply with NFPA 90A.
- 2) Minimum Arrestance: According to ASHRAE 52.1 and MERV according to ASHRAE 52.2.
- 3) Filter-Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

b. Disposable Panel Filters:

Retain one or more of first seven subparagraphs below, as applicable. If Project has more than one filter type, indicate filter type for each unit on Drawings.

- 1) Factory-fabricated, viscous-coated, flat-panel type.
- 2) Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
- 3) Dust-Holding Capacity: <Insert lb (kg)>.
- 4) Initial Resistance: <Insert inches wg (Pa)>.
- 5) Recommended Final Resistance: <Insert inches wg (Pa)>.
- 6) Arrestance according to ASHRAE 52.1: [80] <Insert value>.
- 7) Merv according to ASHRAE 52.2: [5] <Insert value>.
- 8) Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
- 9) Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, and hinged; with pull and retaining handles.

c. Extended-Surface, Disposable Panel Filters:

- 1) Factory-fabricated, dry, extended-surface type.
- 2) Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
- 3) Dust-Holding Capacity: <Insert lb (kg)>.
- 4) Initial Resistance: <Insert inches wg (Pa)>.
- 5) Recommended Final Resistance: <Insert inches wg (Pa)>.
- 6) Arrestance according to ASHRAE 52.1: [90] <Insert value>.
- 7) Merv according to ASHRAE 52.2: [7] <Insert value>.
- 8) Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
- 9) Media-Grid Frame: [Nonflammable cardboard] [Galvanized steel] [Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets].
- 10) Mounting Frames: Welded, galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

2.4 INDOOR UNITS (6 TONS (21 kW) OR MORE)

A. Concealed Evaporator-Fan Components:

1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
2. Insulation: Faced, glass-fiber duct liner.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.

Retain one of first two subparagraphs below if heating coil is required.

4. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm); leak tested to 300 psig (2070 kPa) underwater; with a two-position control valve.
5. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
6. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
7. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
 - c. Three-phase, permanently lubricated, ball-bearing motors with built-in thermal-overload protection.
 - d. Wiring Terminations: Connect motor to chassis wiring with plug connection.

ASHRAE compliance in "Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph to comply with LEED Prerequisite IEQ 1.

8. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

The smaller casings of these units do not typically permit extensive filtration choices.

9. Filters: [1 inch (25 mm) thick, in fiberboard frames] [Permanent, cleanable].
10. Condensate Drain Pans:

First option in first subparagraph below is minimum slope in ASHRAE 62.1.

- a. Fabricated with [one] [two] percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.

ASHRAE compliance option in "Length" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option in first subparagraph to comply with LEED Prerequisite IEQ 1; otherwise, insert distance.

- 1) Length: Extend drain pan downstream from leaving face [**to comply with ASHRAE 62.1**] <Insert distance>.
- 2) Depth: A minimum of [2 inches (50 mm)] <Insert depth> deep.

Retain one of first two subparagraphs below. Retain second subparagraph if drain-pan temperature is expected to fall below surrounding dew point temperature.

- b. Single-wall, [**galvanized**] [**stainless**]-steel sheet.
- c. Double-wall, [**galvanized**] [**stainless**]-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
- d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on [**one end**] [**both ends**] of pan.
 - 1) Minimum Connection Size: [NPS 1 (DN 25)] [NPS 2 (DN 50)] <Insert size>.

Retain first subparagraph below for galvanized-steel drain pans; delete for stainless-steel drain pans.

- e. Pan-Top Surface Coating: Asphaltic waterproofing compound.
- f. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

B. Floor-Mounted, Evaporator-Fan Components:

1. Cabinet: Enameled steel with removable panels on front and ends in color selected by DEN Project Manager.
 - a. Discharge Grille: [**Steel with surface-mounted frame**] [**Welded steel bars forming a linear grille and welded into supporting panel**].
 - b. Insulation: Faced, glass-fiber duct liner.
2. Condensate Drain Pans:

First option in first subparagraph below is minimum slope in ASHRAE 62.1.

- a. Fabricated with [**one**] [**two**] percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.

ASHRAE compliance option in "Length" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option in first subparagraph to comply with LEED Prerequisite IEQ 1; otherwise, insert distance.

- 1) Length: Extend drain pan downstream from leaving face [**to comply with ASHRAE 62.1**] <Insert distance>.
- 2) Depth: A minimum of [2 inches (50 mm)] <Insert depth> deep.

Retain one of first two subparagraphs below. Retain second subparagraph if drain-pan temperature is expected to fall below surrounding dew point temperature.

- b. Single-wall, **[galvanized]** **[stainless]**-steel sheet.
- c. Double-wall, **[galvanized]** **[stainless]**-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
- d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on **[one end]** **[both ends]** of pan.
 - 1) Minimum Connection Size: **[NPS 1 (DN 25)]** **[NPS 2 (DN 50)]** **<Insert size>**.

Retain first subparagraph below for galvanized-steel drain pans; delete for stainless-steel drain pans.

- e. Pan-Top Surface Coating: Asphaltic waterproofing compound.
 - f. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.

Retain one of first two subparagraphs below if heating coil is required.

- 4. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch (2.5 mm)**; leak tested to **300 psig (2070 kPa)** underwater; with a two-position control valve.
- 5. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
- 6. Fan: Direct drive, centrifugal, **with power-induced outside air**].
- 7. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Multitapped, multispeed with internal thermal protection and permanent lubrication.

Retain first subparagraph below if enclosure is not open-dripproof type. Retain second subparagraph for premium efficiency.

- c. Enclosure Type: Totally enclosed, fan cooled.
- d. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
- e. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

Retain first subparagraph below to require that disconnect switches be supplied with unit.

- f. Mount unit-mounted disconnect switches on **[exterior]** **[interior]** of unit.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

- g. **<Insert unique motor characteristics>**.

8. Air Filtration Section:

See Evaluations for discussion on filter characteristics and applications. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

a. General Requirements for Air Filtration Section:

- 1) Comply with NFPA 90A.
- 2) Minimum Arrestance: According to ASHRAE 52.1 and a MERV according to ASHRAE 52.2.
- 3) Filter-Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

b. Disposable Panel Filters:

Retain one or more of first seven subparagraphs below, as applicable. If Project has more than one filter type, indicate filter type for each unit on Drawings.

- 1) Factory-fabricated, viscous-coated, flat-panel type.
- 2) Thickness: [1 inch (25 mm)] [2 inches (50 mm)].
- 3) Dust-Holding Capacity: <Insert lb (kg)>.
- 4) Initial Resistance: <Insert inches wg (Pa)>.
- 5) Recommended Final Resistance: <Insert inches wg (Pa)>.
- 6) Arrestance according to ASHRAE 52.1: [80] <Insert value>.
- 7) Merv according to ASHRAE 52.2: [5] <Insert value>.
- 8) Media: Interlaced glass fibers sprayed with nonflammable adhesive[**and antimicrobial agent**].
- 9) Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, and hinged; with pull and retaining handles.

c. Extended-Surface, Disposable Panel Filters:

- 1) Factory-fabricated, dry, extended-surface type.
- 2) Thickness: [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)].
- 3) Dust-Holding Capacity: <Insert lb (kg)>.
- 4) Initial Resistance: <Insert inches wg (Pa)>.
- 5) Recommended Final Resistance: <Insert inches wg (Pa)>.
- 6) Arrestance according to ASHRAE 52.1: [90] <Insert value>.
- 7) Merv according to ASHRAE 52.2: [7] <Insert value>.
- 8) Media: Fibrous material formed into deep-V-shaped pleats[**with antimicrobial agent**] and held by self-supporting wire grid.
- 9) Media-Grid Frame: [Nonflammable cardboard] [Galvanized steel] [Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets].
- 10) Mounting Frames: Welded, galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

Paragraph below is an example of variable-frequency controllers. Retain features and attributes to suit Project, and verify their availability with listed manufacturers.

C. Variable-Frequency Controllers:

1. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, three-phase induction motor by adjusting output voltage and frequency.
2. Output Rating: Three-phase; 6 to **[60 Hz, with voltage proportional to frequency throughout voltage range] [66 Hz, with torque constant as speed changes] [120 Hz, with horsepower constant throughout speed range]**.
3. Unit Operating Requirements:
 - a. Input ac voltage tolerance of **[208 V, plus or minus 5] [380 to 500 V, plus or minus 10] [525 to 575 V, plus or minus 10]** percent.
 - b. Input-frequency tolerance of 06/11 Hz, plus or minus 6 percent.
 - c. Minimum Efficiency: 96 percent at 60 Hz, full load.
 - d. Minimum Displacement Primary-Side Power Factor: 96 percent.
 - e. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
 - f. Starting Torque: 100 percent of rated torque or as indicated.
 - g. Speed Regulation: Plus or minus 1 percent.
4. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
5. Internal Adjustability Capabilities:
 - a. Minimum Speed: 5 to 25 percent of maximum rpm.
 - b. Maximum Speed: 80 to 100 percent of maximum rpm.
 - c. Acceleration: 2 seconds to a minimum of 22 seconds.
 - d. Deceleration: 2 seconds to a minimum of 22 seconds.
 - e. Current Limit: 50 percent to a minimum of 110 percent of maximum rating.
6. Self-Protection and Reliability Features:

Retain one or more of first nine subparagraphs below.

- a. Input transient protection by means of surge suppressors.
- b. Undervoltage and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
- c. Adjustable motor overload relays capable of NEMA ICS 2, **[Class 10] [Class 20] [Class 30]** performance.
- d. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
- e. Instantaneous line-to-line and line-to-ground overcurrent trips.
- f. Loss-of-phase protection.
- g. Reverse-phase protection.
- h. Short-circuit protection.
- i. Motor overtemperature fault.

Revise first four subparagraphs below to suit Project; delete if not applicable.

7. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into

- rotating loads, spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.
8. Power-Interruption Protection: Prevents motor from re-energizing after a power interruption until motor has stopped.
 9. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
 10. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back, based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
 11. Door-mounted, digital status lights shall indicate the following conditions:
 - a. Power on.
 - b. Run.
 - c. Overvoltage.
 - d. Line fault.
 - e. Overcurrent.
 - f. External fault.
 12. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual-speed-control potentiometer and elapsed-time meter.
 13. Meters or digital readout devices and selector switch, mounted flush in controller door and connected, to indicate the following controller parameters:
 - a. Output frequency (Hertz).
 - b. Motor speed (rpm).
 - c. Motor status (running, stop, fault).
 - d. Motor current (amperes).
 - e. Motor torque (percent).
 - f. Fault or alarming status (code).
 - g. Proportional-integral-derivative feedback signal (percent).
 - h. DC-link voltage (volts dc).
 - i. Set-point frequency (Hertz).
 - j. Motor output voltage (volts).
 14. Control Signal Interface:
 - a. Electric Input Signal Interface: A minimum of two analog inputs (0 to 10 V or 0/4-20 mA) and six programmable digital inputs.
 - b. Remote signal inputs capable of accepting any of the following speed-setting input signals from the control system:
 - 1) 0 to 10-V dc.
 - 2) 0-20 or 4-20 mA.
 - 3) Potentiometer using up/down digital inputs.
 - 4) Fixed frequencies using digital inputs.
 - 5) RS485.
 - 6) Keypad display for local hand operation.

- c. Output signal interface with a minimum of one analog output signal (0/4-20 mA), which can be programmed to any of the following:
 - 1) Output frequency (Hertz).
 - 2) Output current (load).
 - 3) DC-link voltage (volts dc).
 - 4) Motor torque (percent).
 - 5) Motor speed (rpm).
 - 6) Set-point frequency (Hertz).
- d. Remote indication interface with a minimum of two dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
 - 1) Motor running.
 - 2) Set-point speed reached.
 - 3) Fault and warning indication (overtemperature or overcurrent).
 - 4) High- or low-speed limits reached.
15. Communications: RS485 interface allows VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.

Coordinate both subparagraphs below with manufacturers; not all manufacturers offer all optional features below.

16. Integral Disconnecting Means: [**NEMA AB 1, instantaneous-trip circuit breaker**] [**NEMA AB 1, molded-case switch**] [**NEMA KS 1, nonfusible switch**] [**NEMA KS 1, fusible switch**] with lockable handle.
17. Accessories:
 - a. Devices shall be factory installed in controller enclosure unless otherwise indicated.
 - b. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
 - c. Standard Displays:
 - 1) Output frequency (Hertz).
 - 2) Set-point frequency (Hertz).
 - 3) Motor current (amperes).
 - 4) DC-link voltage (volts dc).
 - 5) Motor torque (percent).
 - 6) Motor speed (rpm).
 - 7) Motor output voltage (volts).

2.5 OUTDOOR UNITS (5 TONS (18 kW) OR LESS)

A. Air-Cooled, Compressor-Condenser Components:

1. Casing: Steel, finished with baked enamel in color selected by DEN Project Manager, with removable panels for access to controls, weep holes for water

- drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - a. Compressor Type: Scroll.

Feature in first subparagraph below is not available from all manufacturers.

- b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.

LEED Credit EA 4 awards a single point if all HVAC&R equipment has HCFC-free refrigerants. R-407C and R-410A are HCFC-free refrigerants.

- c. Refrigerant Charge: [R-22] [R-407C] [R-410A] <Insert type>.
 - d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 206/110.

Retain first subparagraph below for heat-pump units.

3. Heat-Pump Components: Reversing valve and low-temperature-air cutoff thermostat.
4. Fan: Aluminum-propeller type, directly connected to motor.
5. Motor: Permanently lubricated, with integral thermal-overload protection.
6. Low Ambient Kit: Permits operation down to 45 deg F (7 deg C).
7. Mounting Base: Polyethylene.

2.6 OUTDOOR UNITS (6 TONS (21 kW) OR MORE)

A. Air-Cooled, Compressor-Condenser Components:

1. Casing: Steel, finished with baked enamel in color selected by DEN Project Manager, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - a. Compressor Type: Scroll.

Feature in first subparagraph below is not available from all manufacturers.

- b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.

LEED Credit EA 4 awards a single point if all HVAC&R equipment has HCFC-free refrigerants. R-407C and R-410A are HCFC-free refrigerants.

- c. Refrigerant Charge: [R-22] [R-407C] [R-410A] <Insert type>.
 - d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 206/110.

Retain first subparagraph below for heat-pump units.

3. Heat-Pump Components: Reversing valve and low-temperature-air cutoff thermostat.
4. Fan: Aluminum-propeller type, directly connected to motor.
5. Motor: Permanently lubricated, with integral thermal-overload protection.
6. Low Ambient Kit: Permits operation down to 45 deg F (7 deg C).
7. Mounting Base: Polyethylene.

B. Water-Cooled, Compressor-Condenser Components:

1. Casing: Steel, finished with baked enamel in color selected by DEN Project Manager, with removable panels for access to controls and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - a. Compressor Type: Scroll.

Feature in first subparagraph below is not available from all manufacturers.

- b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.

LEED Credit EA 4 awards a single point if all HVAC&R equipment has HCFC-free refrigerants. R-407C and R-410A are HCFC-free refrigerants.

- c. Refrigerant Charge: [R-22] [R-407C] [R-410A] <Insert type>.

Retain first subparagraph below for heat-pump units.

3. Heat-Pump Components: Reversing valve.
4. Heat Exchanger: Copper tubes in copper tube or in steel shell, with water-temperature-actuated, water-regulating valve.

2.7 ACCESSORIES

Retain one of first three paragraphs below. Retain first paragraph if controls are part of overall temperature control system.

- A. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Thermostat: Low voltage with subbase to control compressor and evaporator fan.
- C. Thermostat: Wireless infrared functioning to remotely control compressor and evaporator fan, with the following features:
 1. Compressor time delay.
 2. 24-hour time control of system stop and start.

3. Liquid-crystal display indicating temperature, set-point temperature, time setting, operating mode, and fan speed.
 4. Fan-speed selection including auto setting.
- D. Automatic-reset timer to prevent rapid cycling of compressor.
- E. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.
- F. Drain Hose: For condensate.

LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1 require continuous metering equipment for monitoring building energy consumption performance over time. Retain paragraph below if required to comply with requirements for this credit. Verify availability of control features with unit manufacturers or if required by Project requirements or authorities having jurisdiction.

- G. Additional Monitoring:
1. Monitor constant and variable motor loads.
 2. Monitor variable-frequency-drive operation.
 3. Monitor economizer cycle.
 4. Monitor cooling load.
 5. Monitor air distribution static pressure and ventilation air volumes.

2.8 CAPACITIES AND CHARACTERISTICS

A. Cooling Capacity:

1. Total: <Insert value> Btu/h (kW).
2. Sensible: <Insert value> Btu/h (kW).

Retain "SEER" Subparagraph below for units with capacities 5 tons (18 kW) and less.

3. SEER: [10.0] [12.0] [13.0] [14.0] [16.0] <Insert ratio>.

Retain "EER" Subparagraph below for units with capacities 6 tons (21 kW) or more.

4. EER: [10.0] [12.0] [13.0] [14.0] [16.0] <Insert ratio>.
5. Moisture Removal: <Insert pints/h (L/h)>.
6. Entering-Air Temperature:

- a. Dry Bulb: <Insert deg F (deg C)>.
- b. Wet Bulb: <Insert deg F (deg C)>.

7. Leaving-Air Temperature:

- a. Dry Bulb: <Insert deg F (deg C)>.
- b. Wet Bulb: <Insert deg F (deg C)>.

B. Heating Capacity:

1. Type: **[Electric]** **[Natural gas]**.
2. Total Capacity: **<Insert value>** Btu/h (kW).
3. Air-Temperature Rise: **<Insert deg F (deg C)>**.

Retain one or both of first two subparagraphs below for heat pumps.

4. Coefficient of Performance: **<Insert value>**.
5. Heating Season Performance Factor: **[7.7] [8.0] <Insert value>**.

Retain first subparagraph below for hydronic heating coil.

6. Hot Water:
 - a. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - b. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
 - c. Water Flow: **<Insert gpm (L/s)>**.
 - d. Water Pressure Drop: **<Insert feet of head (kPa)>**.

Retain first subparagraph below for electric heating coil.

7. Electric Heating Coil:
 - a. Total Capacity: **<Insert value>** kW.
 - b. Volts: **[120] [208] [230] [460] <Insert value>**.
 - c. Phase: **[Single] [Poly]**.
 - d. Hertz: 60.
 - e. Steps: **[One] [Two] [Three] <Insert number>**.

Retain subparagraph below for natural or propane gas heat.

8. Gas Heating Section:
 - a. Input: **<Insert cfh (mL/s)>**.
 - b. Output: **<Insert cfh (mL/s)>**.

C. Auxiliary Heating Capacity:

Retain first six subparagraphs below for heat pumps with auxiliary electric heat.

1. Type: **[Electric]** **[Natural gas]** **[Propane]**.
2. Total Capacity: **<Insert value>** Btu/h (kW).
3. Volts: **[120] [208] [230] [460] <Insert value>**.
4. Phase: **[Single] [Poly]**.
5. Hertz: 60.
6. Steps: **[One] [Two] [Three] <Insert number>**.

Retain two subparagraphs below for auxiliary gas heat.

7. Input: **<Insert cfh (mL/s)>**.
8. Output: **<Insert cfh (mL/s)>**.

D. Indoor Unit:

1. Fan Motor Electrical Characteristics:

- a. Volts: [120] [208] [230] [460] <Insert value>.
 - b. Phase: [Single] [Poly].
 - c. Hertz: 60.
2. Airflow: <Insert value> cfm (L/s).
- E. Outdoor Unit:
1. Type: [Air cooled] [Water cooled].
 2. Electrical Characteristics:
 - a. Volts: [120] [208] [230] [460] <Insert value>.
 - b. Phase: [Single] [Poly].
 - c. Hertz: 60.
 - d. Minimum Circuit Ampacity: <Insert value>.
 - e. Maximum Overcurrent Protection: <Insert amperage>.
 - f. Fan Motor Full-Load Amperes: <Insert value>.
 - g. Compressor Full-Load Amperes: <Insert value>.
 - h. Compressor Locked-Rotor Amperes: <Insert value>.
 3. Sound-Pressure Level: <Insert value> dBa.
- Retain subparagraph below for water-cooled outdoor units.
4. Water:
 - a. Entering-Water Temperature: <Insert deg F (deg C)>.
 - b. Water Flow: <Insert gpm (L/s)>.
 - c. Water Pressure Drop: <Insert feet of head (kPa)>.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install units level and plumb.
- D. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- E. Protection: Provide finished cabinet units with protective covers during balance of construction.
- F. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure.

- G. Install roof-mounted, compressor-condenser components on equipment supports specified in Section 077200 "Roof Accessories." Anchor units to supports with removable, cadmium-plated fasteners.
- H. Equipment Mounting:

Retain first subparagraph below to require ground-mounted units to be installed on cast-in-place concrete equipment bases.

1. Install ground-mounted, compressor-condenser components on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
2. Install ground-mounted, compressor-condenser components on polyethylene mounting base.

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

3. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 4. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- I. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.

3.2 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

Retain first subparagraph below for units with hot-water coils.

1. Water Coil Connections: Comply with requirements specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Connect hydronic piping to supply and return coil connections with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.

Retain subparagraph below for units with remote water-cooled condenser.

2. Remote, Water-Cooled Condenser Connections: Comply with requirements specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Connect hydronic piping to supply and return connections with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.

- B. Where piping is installed adjacent to unit, allow space for service and maintenance of unit.

Retain paragraph below for units connected to ducts. Coordinate duct installation requirements with schematics on Drawings and with requirements specified for duct systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- C. Duct Connections: Duct installation requirements are specified in Section 233113 "Metal Ducts." Drawings indicate the general arrangement of ducts. Connect supply[**and return**] ducts to split-system air-conditioning units with flexible duct connectors. Flexible duct connectors are specified in Section 233300 "Air Duct Accessories."
- D. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.3 FIELD QUALITY CONTROL

Retain first paragraph below to require a factory-authorized service representative to perform inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- C. Tests and Inspections:
 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Remove and replace malfunctioning units and retest as specified above.

- E. Prepare test and inspection reports.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. **<Insert startup steps if any>**.

3.5 CLEANING

- A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets.
- B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.
- C. Install new filters.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist contractor and train owner's maintenance personnel to adjust, operate, and maintain units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238126

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SECTION 238146 - WATER-SOURCE UNITARY HEAT PUMPS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes unitary heat pumps with refrigerant-to-water heat exchangers, refrigeration circuits, and refrigerant compressor(s).

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each water-source unitary heat pump.
2. Include rated capacities, operating characteristics, furnished specialties, and accessories.
3. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

1. Product Data for Credit EA 2: Documentation indicating that equipment complies with minimum efficiency.

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

2. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

C. Shop Drawings:

1. Include plans, elevations, sections, and mounting and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC" or Section 230548.13 "Vibration Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

A. Seismic Qualification Certificates: For water-source unitary heat pumps, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Product Certificates" Paragraph below to require submittal of product certificates from manufacturers.

B. Product Certificates: For each type of water-source unitary heat pump, signed by product manufacturer.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

Coordinate sample requirements with DEN Project Manager.

- D. Sample Warranty: For manufacturer's warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For water-source unitary heat pumps to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Revise subparagraph below to suit Project.

1. **[One (1)] <Insert number>** spare heat-pump unit(s) of each size and model furnished.

1.7 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace components of water-source unitary heat pumps that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, refrigeration components.

Verify available warranties and warranty periods for refrigerant components.

2. Warranty Period: Minimum **[four (4)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance:
1. ASHRAE 15.
- B. Comply with NFPA 70.
- C. Comply with safety requirements in UL 484 for assembly of free-delivery, water-source heat pumps.

2.2 WATER-SOURCE UNITARY HEAT PUMPS, 6 TONS (21 kW) AND SMALLER

Many optional features are available for this product, and some optional features are mutually exclusive from each other. Specify all those required for Project.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carrier Corporation; a unit of United Technologies Corp.
 2. ClimateMaster, Inc.
 3. FHP Manufacturing Inc.
 4. Hydro-Temp Corporation, Inc.
 5. Mammoth Inc.
 6. McQuay International; Daikin Industries.
 7. Trane Inc.
 8. Water Furnace International, Inc.
 9. **<Insert manufacturer's name>.**
 10. or approved equal.

- B. Description: Packaged water-source unitary heat pump with temperature controls; factory assembled, piped, wired, tested, and rated according to ASHRAE/ARI/ISO-13256-1.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Cabinet and Chassis: Galvanized-steel casing with the following features:
1. Access panel for access and maintenance of internal components.
 2. Knockouts for electrical and piping connections.
 3. Cabinet Insulation: Glass-fiber liner, minimum [1/2 inch (13 mm)], [3/4 inch (19 mm)] thick, complying with UL 181, ASTM C 1071, and ASTM G 21.
- D. Water Circuits:
1. Refrigerant-to-Water Heat Exchangers:

Retain one of first two subparagraphs below.

- a. Source-side coaxial heat exchangers with **[copper] [cupronickel] [internal vented double wall]** water tube, with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side.
- b. Load-side coaxial heat exchangers with **[copper] [cupronickel]** water tube, with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side.
- c. Stainless-steel, brazed-plate heat exchanger is leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
- d. Hot-water generator, **[copper water tube] [vented double wall copper tube]** with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side, pump, circuit breaker, high water temperature and low water refrigerant cutoffs, and tank connection.

Verify availability of water-regulating valves and motorized water valves.

- E. Refrigerant Circuit Components:
1. Sealed Refrigerant Circuit: Charge with R-410A refrigerant.

Filter-dryers are unavailable from some manufacturers.

2. Filter-Dryer: Factory installed to clean and dehydrate the refrigerant circuit.
3. Charging Connections: Service fittings on suction and liquid for charging and testing on each circuit.
4. Reversing Valve: Four-way, solenoid-activated valve designed to be fail-safe in heating position with replaceable magnetic coil.

Options in "Compressor" Subparagraph below depend on unit size. Verify with manufacturers. Delete if these features are not specific selection criteria.

5. Compressor:
 - a. ~~[Scroll]~~ **[Reciprocating]**.
 - b. **[Single stage]** ~~[Two stage]~~ **[Variable speed]**.
 - c. Installed on vibration isolators and mounted on a structural steel base plate and full-length channel stiffeners.
 - d. Exterior of compressor shall be wrapped with a high-density sound-attenuating blanket and housed in an acoustically treated enclosure.
 - e. Factory-Installed Safeties:
 - 1) Antirecycle timer.
 - 2) High-pressure cutout.
 - 3) Low-pressure cutout or loss of charge switch.
 - 4) Internal thermal-overload protection.

Retain first two subparagraphs below for compressor safety switches.

- 5) Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below **[35 deg F (2 deg C)]** **<Insert temperature>**.
 - 6) Water-coil, low-temperature switch.
6. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
7. Pipe Insulation: Refrigerant minimum **3/8-inch- (10-mm-)** thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-developed indexes according to ASTM E 84.

Retain one of two "Refrigerant Metering Device" subparagraphs below.

8. Refrigerant Metering Device: Thermal-expansion valve.
9. Refrigerant Metering Device: Dual-port, thermal-expansion valve to allow specified operation with entering-water temperatures from **[25 to 125 deg F (minus 4 to plus 52 deg C)]** **<Insert temperature range>**.

Retain one of the two "Controls" paragraphs below. Retain first paragraph if controls are part of a DDC temperature-control system.

- F. Controls: Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- G. Controls:
 1. Basic Unit Control Modes and Devices:
 - a. Unit shutdown on high or low refrigerant pressures.
 - b. Unit shutdown on low water temperature.
 - c. Low- and high-voltage protection.
 - d. Overcurrent protection for compressor.
 - e. Random time delay, three to 10 seconds, start on power-up.

- f. Time delay override for servicing.
 - g. Control voltage transformer.
 - h. Water-coil freeze protection (selectable for water or antifreeze).
 - i. Automatic intelligent reset. Unit shall automatically reset five minutes after trip if the fault has cleared. Should a fault reoccur three times sequentially, lockout requiring manual reset occurs.
 - j. Ability to defeat time delays for servicing.
 - k. Digital display to indicate high pressure, low pressure, low voltage, and high voltage.
 - l. The low-pressure switch shall not be monitored for the first 90 seconds after a compressor start command to prevent nuisance safety trips.
 - m. Remote fault-type indication at thermostat.
 - n. Selectable 24-V dc or pilot duty dry contact alarm output.
 - o. 24-V dc output to cycle a motorized water valve with compressor contactor.
 - p. Service test mode for troubleshooting and service.
 - q. Unit-performance sentinel warns when heat pump is running inefficiently.
 - r. Compressor soft start.
2. Thermostat:
- a. Wall-Mounted Thermostat:
 - 1) Heat-cool-off switch.
 - 2) **[Five day] [Seven day]**, programmable.
 - 3) **[Manual] [Automatic]** changeover.
 - 4) **[Concealed] [Exposed]** temperature set point.
 - 5) **[Concealed] [Exposed]** temperature indication.
 - 6) Deg **[F] [C]** indication.
 - b. Wall-mounted temperature sensor.
 - c. Duct-mounted temperature sensor
 - d. Unoccupied period override push button.
 - e. Digital display to indicate fault condition at heat pump.
 - f. Data entry and access port.
 - 1) Input data include room temperature and humidity set points for occupied and unoccupied periods.
 - 2) Output data include room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.
3. Terminal Controller:
- a. Scheduled operation for occupied and unoccupied periods on **[seven] [365]**-day clock with minimum of four programmable periods per day.
 - b. **[Two] <Insert number>**-hour unoccupied override period.
 - c. Remote-control panel to contain programmable timer and digital display for fault condition.
 - d. Compressor-disable relay to stop compressor operation for demand limiting or switch to unoccupied operation.

- e. Automatic restart after five minutes if fault clears. Lockout after three attempts to restart following fault. Indicate fault for service technician.
 - f. Backup for volatile memory.
4. DDC interface requirements as further described in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- a. Interface relay for scheduled operation.
 - b. Interface relay to provide indication of fault at central workstation.
 - c. Provide [**BAC-net**] [**or**] [**Lonworks**] interface for central DDC workstation for the following functions:
 - 1) Set-point adjustment.
 - 2) Start/stop and operating status of heat-pump unit.
 - 3) Data inquiry to include supply-air and room-air temperature and humidity, and entering-water temperature.
 - 4) Occupied and unoccupied schedules.

H. Electrical Connection: Single electrical connection [**with fused disconnect**].

If Project has more than one of this type of heat pump, delete "Capacities and Characteristics" Paragraph below and schedule heat pumps on Drawings.

I. Capacities and Characteristics:

1. Source-Side Water Supply:

- a. Water Flow: <Insert gpm (L/s)>.
- b. Pressure Loss: <Insert feet wg (kPa)>.
- c. Entering-Water Temperature (Cooling): <Insert deg F (deg C)>.
- d. Entering-Water Temperature (Heating): <Insert deg F (deg C)>.
- e. Antifreeze Protection Chemical: <Insert chemical name>.
- f. Antifreeze Concentration: <Insert percentage>.

2. Load-Side Water Supply:

- a. Water Flow: <Insert gpm (L/s)>.
- b. Pressure Loss: <Insert feet wg (kPa)>.
- c. Entering-Water Temperature (Cooling): <Insert deg F (deg C)>.
- d. Entering-Water Temperature (Heating): <Insert deg F (deg C)>.
- e. Antifreeze Protection Chemical: <Insert chemical name>.
- f. Antifreeze Concentration: <Insert percentage>.

3. Cooling:

- a. Total Capacity: <Insert Btu/h (kW)>.
- b. Sensible Capacity: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- c. Minimum Energy-Efficiency Ratio (EER): **<Insert value>**.
4. Heating:
 - a. Capacity: **<Insert Btu/h (kW)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- b. Minimum Coefficient of Performance (COP): **<Insert value>**.
5. Electrical Characteristics for Single Connection:
 - a. Volts: **[120] [208] [230] <Insert number> V.**
 - b. Phase: **[Single] [Three].**
 - c. Hertz: 60.
 - d. Full-Load Amperes (FLA): **<Insert number> A.**
 - e. Maximum Circuit Amperage (MCA): **<Insert number> A.**
 - f. Maximum Overcurrent Protection (MOCP): **<Insert number> A.**

2.3 WATER-SOURCE UNITARY HEAT PUMPS LARGER THAN 6 TONS (21 kW)

Many optional features are available for this product, and some are mutually exclusive. Specify all those required for Project.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Carrier Corporation; a unit of United Technologies Corp.
 2. ClimateMaster, Inc.
 3. FHP Manufacturing Inc.
 4. Hydro-Temp Corporation, Inc.
 5. Mammoth Inc.
 6. McQuay International; Daikin Industries.
 7. Trane Inc.
 8. Water Furnace International, Inc.
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Description: Packaged water-source unitary heat pump with temperature controls; factory assembled, piped, wired, tested, and rated according to ASHRAE/ARI/ISO-13256-1.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency and marked for intended location and application.
- C. Cabinet and Chassis: Galvanized-steel casing with the following features:
1. Access panel for access and maintenance of internal components.
 2. Knockouts for electrical and piping connections.
 3. Cabinet Insulation: Glass-fiber liner, minimum [1/2 inch (13 mm)], [3/4 inch (19 mm)] thick, complying with UL 181, ASTM C 1071, and ASTM G 21.
- D. Water Circuits:
1. Refrigerant-to-Water Heat Exchangers:

Retain one of first two subparagraphs below.

- a. Source-side coaxial heat exchangers with [**copper**] [**cupronickel**] [**internal vented double wall**] water tube, with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to 450 psig (3102 kPa) on refrigerant side and 400 psig (2758 kPa) on water side.
- b. Load-side coaxial heat exchangers with [**copper**] [**cupronickel**] water tube, with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to 450 psig (3102 kPa) on refrigerant side and 400 psig (2758 kPa) on water side.
- c. Stainless-steel, brazed-plate heat exchanger is leak tested to 450 psig (3102 kPa) on refrigerant side and 400 psig (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
- d. Hot-water generator, [**copper water tube**] [**vented double wall copper tube**] with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to 450 psig (3102 kPa) on refrigerant side and 400 psig (2758 kPa) on water side, pump, circuit breaker, high water temperature and low water refrigerant cutoffs, and tank connection.

Verify availability of water-regulating valves and motorized water valves.

- E. Refrigerant Circuit Components:
1. Sealed Refrigerant Circuit: Charge with R-410A refrigerant.

Filter-dryers are unavailable from some manufacturers.

2. Filter-Dryer: Factory installed to clean and dehydrate the refrigerant circuit.
3. Charging Connections: Service fittings on suction and liquid for charging and testing on each circuit.
4. Reversing Valve: Four-way, solenoid-activated valve designed to be fail-safe in heating position with replaceable magnetic coil.

Options in "Compressor" Subparagraph below depend on unit size. Verify with manufacturers. Delete if these features are not specific selection criteria.

5. Compressor:

- a. **[Scroll] [Reciprocating].**
- b. **[Single stage] [Two stage] [Variable speed].**
- c. Installed on vibration isolators and mounted on a structural steel base plate and full-length channel stiffeners.
- d. Exterior of compressor shall be wrapped with a high-density sound-attenuating blanket and housed in an acoustically treated enclosure.
- e. Factory-Installed Safeties:
 - 1) Antirecycle timer.
 - 2) High-pressure cutout.
 - 3) Low-pressure cutout or loss of charge switch.
 - 4) Internal thermal-overload protection.

Retain first two subparagraphs below for compressor safety switches.

- 5) Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below [35 deg F (2 deg C)] **<Insert temperature>**.
 - 6) Water-coil, low-temperature switch.
6. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
 7. Pipe Insulation: Refrigerant minimum **3/8-inch- (10-mm-)** thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-developed indexes according to ASTM E 84.

Retain one of two "Refrigerant Metering Device" subparagraphs below.

8. Refrigerant Metering Device: Thermal-expansion valve.
9. Refrigerant Metering Device: Dual-port, thermal-expansion valve to allow specified operation with entering-water temperatures from [25 to 125 deg F (minus 4 to plus 52 deg C)] **<Insert temperature range>**.

Retain first "Controls" Paragraph below if controls are part of a DDC temperature-control system.

- F. Controls: Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

Retain "Controls" Paragraph below if controls are not part of a DDC temperature-control system.

- G. Controls:

1. Basic Unit Control Modes and Devices:
 - a. Unit shutdown on high or low refrigerant pressures.
 - b. Unit shutdown on low water temperature.
 - c. Low- and high-voltage protection.
 - d. Overcurrent protection for compressor.
 - e. Random time delay, three to 10 seconds, start on power-up.
 - f. Time delay override for servicing.
 - g. Control voltage transformer.
 - h. Water-coil freeze protection (selectable for water or antifreeze).

- i. Automatic intelligent reset. Unit shall automatically reset five minutes after trip if the fault has cleared. Should a fault reoccur three times sequentially, lockout requiring manual reset occurs.
 - j. Ability to defeat time delays for servicing.
 - k. Digital display to indicate high pressure, low pressure, low voltage, and high voltage.
 - l. The low-pressure switch shall not be monitored for the first 90 seconds after a compressor start command to prevent nuisance safety trips.
 - m. Remote fault-type indication at thermostat.
 - n. Selectable 24-V dc or pilot duty dry contact alarm output.
 - o. 24-V dc output to cycle a motorized water valve with compressor contactor.
 - p. Service test mode for troubleshooting and service.
 - q. Unit-performance sentinel warns when heat pump is running inefficiently.
 - r. Compressor soft start.
2. Thermostat:
- a. Wall-Mounted Thermostat:
 - 1) Heat-cool-off switch.
 - 2) **[Five day] [Seven day]**, programmable
 - 3) **[Manual] [Automatic]** changeover.
 - 4) **[Concealed] [Exposed]** temperature set point.
 - 5) **[Concealed] [Exposed]** temperature indication.
 - 6) Deg **[F] [C]** indication.
 - b. Wall-mounted temperature sensor.
 - c. Duct-mounted temperature sensor
 - d. Unoccupied period override push button.
 - e. Digital display to indicate fault condition at heat pump.
 - f. Data entry and access port.
 - 1) Input data include room temperature and humidity set points for occupied and unoccupied periods.
 - 2) Output data include room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.
3. Terminal Controller:
- a. Scheduled operation for occupied and unoccupied periods on **[seven] [365]**-day clock with minimum of four programmable periods per day.
 - b. **[Two] <Insert number>**-hour unoccupied override period.
 - c. Remote-control panel to contain programmable timer and digital display for fault condition.
 - d. Compressor-disable relay to stop compressor operation for demand limiting or switch to unoccupied operation.
 - e. Automatic restart after five minutes if fault clears. Lockout after three attempts to restart following fault. Indicate fault for service technician.
 - f. Backup for volatile memory.

4. DDC interface requirements as further described in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
 - a. Interface relay for scheduled operation.
 - b. Interface relay to provide indication of fault at central workstation.
 - c. Provide [**BAC-net**] [**or**] [**Lonworks**] interface for central DDC workstation for the following functions:
 - 1) Set-point adjustment
 - 2) Start/stop and operating status of heat-pump unit.
 - 3) Data inquiry to include supply-air and room-air temperature and humidity, and entering-water temperature.
 - 4) Occupied and unoccupied schedules.

H. Electrical Connection: Single electrical connection[**with fused disconnect**].

If Project has more than one of this type of heat pump, delete "Capacities and Characteristics" Paragraph below and schedule heat pumps on Drawings.

I. Capacities and Characteristics:

1. Source-Side Water Supply:

- a. Water Flow: <Insert gpm (L/s)>.
- b. Pressure Loss: <Insert feet wg (kPa)>.
- c. Entering-Water Temperature (Cooling): <Insert deg F (deg C)>.
- d. Entering-Water Temperature (Heating): <Insert deg F (deg C)>.
- e. Antifreeze Protection Chemical: <Insert chemical name>.
- f. Antifreeze Concentration: <Insert percentage>.

2. Load-Side Water Supply:

- a. Water Flow: <Insert gpm (L/s)>.
- b. Pressure Loss: <Insert feet wg (kPa)>.
- c. Entering-Water Temperature (Cooling): <Insert deg F (deg C)>.
- d. Entering-Water Temperature (Heating): <Insert deg F (deg C)>.
- e. Antifreeze Protection Chemical: <Insert chemical name>.
- f. Antifreeze Concentration: <Insert percentage>.

3. Cooling:

- a. Total Capacity: <Insert Btu/h (kW)>.
- b. Sensible Capacity: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- c. Minimum Energy-Efficiency Ratio (EER): <Insert value>.

4. Heating:

- a. Capacity: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- b. Minimum Coefficient of Performance (COP): <Insert value>.

5. Electrical Characteristics for Single Connection:

- a. Volts: [120] [208] [230] <Insert number> V.
- b. Phase: [Single] [Three].
- c. Hertz: 60.
- d. Full-Load Amperes (FLA): <Insert number> A.
- e. Maximum Circuit Amperage (MCA): <Insert number> A.
- f. Maximum Overcurrent Protection (MOCP): <Insert number> A.

2.4 ACCESSORIES

Retain either "Hose Kits" Paragraph or "Hose Kit Assemblies" Paragraph below. Retain "Hose Kits" Paragraph below if hose kits are furnished with the water-source unitary heat pumps.

A. Hose Kits: Tag hose kits to equipment designations.

1. Minimum Working Pressure: 400 psig (2758 kPa).
2. Operating Temperatures: From 33 to 211 deg F (1 to 100 deg C).
3. Hose Length: [24 inches (600 mm)] [36 inches (900 mm)] <Insert dimension>.
4. Minimum Hose Diameter: Equal to water-source unitary heat-pump piping connection.
5. Hose Material: Braided stainless steel with adapters for pipe connections.
6. Isolation Valves: Two-piece, bronze-body ball valves with stainless-steel ball and stem, standard-port threaded connections, and galvanized-steel lever handle. Valves shall be factory installed on supply and return connections of both load-side and source-side heat exchangers. If balancing valve is combination shutoff type with memory stop, the isolation valve may be omitted on the return.
7. Strainer: Y-pattern with blowdown valve in supply connections of both load and source side of heat exchangers.
8. Balancing Valves: Mount in return connection. Include meter ports to allow flow measurement with differential pressure gage.

Retain one of first three subparagraphs below.

- a. Automatic balancing valve, factory set to operate within 10 percent of design flow rate over a pressure range of 2 to 80 psig (13.8 to 552 kPa).
 - b. Manual, calibrated-orifice balancing valve with memory stop.
 - c. Manual, venturi-type balancing valve with memory stop.
9. Water-Regulating Valve Assemblies: A direct acting valve regulates discharge pressure during the cooling cycle, and a reverse acting valve regulates the suction pressure during the heating cycle. Valves shall close when heat-pump compressor is not running.

10. Motorized Water Valve: Stop water flow through the unit when compressor is off. Slow-acting, 24-V dc valve with threaded connections is installed between isolation valves and heat exchanger.

Retain "Hose Kit Assemblies" Paragraph if hoses kits are not furnished separately from the water-source unitary heat pumps.

B. Hose Kit Assemblies:

1. Minimum Working Pressure: 400-psig (2758-kPa).
2. Operating Temperatures: From 33 to 211 deg F (1 to 100 deg C).
3. Hose Length: [24 inches (600 mm)] [36 inches (900 mm)] <Insert dimension>.
4. Minimum Hose Diameter: Equal to water-source unitary heat-pump piping connection.
5. Hose Material: Braided stainless steel with adapters for pipe connections.

Retain one or more of four subparagraphs below.

6. Supply and return hoses having ball valve with pressure-temperature port.
7. Supply hose having ball valve with pressure-temperature port; return hose having automatic flow regulator valve with pressure-temperature ports and ball valve.
8. Supply hose having Y-pattern strainer with blowdown valve and ball valve with pressure-temperature port; return hose having automatic flow regulator with pressure-temperature ports and ball valve.
9. Supply hose having Y-pattern strainer with blowdown valve and ball valve with pressure-temperature port; return hose having ball valve with pressure-temperature port.

C. Loop Controller: Six stages; two stages for heating and four stages for cooling.

Retain "Pump Module" Paragraph below for individual heat pumps that either stand alone or are secondary to a central circulating water loop.

D. Pump Module:

Values in first subparagraph below are examples only; verify actual values with manufacturer.

1. Minimum [1/6-hp] <Insert motor size>, [230-V] [120-V], single-phase pump, rated for at least [16 gpm (1 L/s)] <Insert value> at [20 feet of head (59 kPa)] <Insert value>.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

2. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
3. Include pump module hose kit with thread to barb fittings, hose, and hose clamps.
4. Three-way brass shut-off/flushing/purging valve.
5. Include controls to operate pump as required to maintain room temperature and ventilation set points.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping and electric installations for water-source unitary heat pumps to verify actual locations of piping connections and electrical conduits before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.

Retain "Equipment Mounting" Paragraph below if units are floor mounted.

- B. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

- 1. Install water-source, unitary heat pumps on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration-isolation and seismic-restraint device type and minimum deflection in supported equipment schedule on Drawings.

- 2. Comply with requirements for vibration-isolation and seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- 3. Comply with requirements for vibration-isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

Retain first paragraph below if units are suspended from structure.

- C. Suspend water-source, unitary heat pumps from structure with all-thread hanger rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stop**]. Hanger rods and attachments to structure are specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment." Vibration hangers are specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]
- D. Install wall-mounting thermostats and switch controls in electrical outlet boxes at heights to match lighting controls or as required in Section 230923 "Direct Digital Control (DDC) System for HVAC."

3.3 CONNECTIONS

Coordinate requirements for piping installation and specialty arrangements with Drawings and with requirements specified in hydronic piping and steam and condensate piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:
 - 1. Connect supply and return hydronic piping to heat pump with **[unions and shutoff valves] [hose kits]**.

Coordinate duct installation requirements with Drawings and with requirements specified for duct systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- B. Install electrical devices furnished by manufacturer but not specified to be factory mounted.
- C. Install piping adjacent to machine to allow space for service and maintenance.

3.4 FIELD QUALITY CONTROL

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following field tests and inspections:
 - 1. After installing water to water heat pumps and after electrical circuitry has been energized, test units for compliance with requirements.
 - 2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Heat pumps will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.5 STARTUP SERVICE

Delete paragraph below if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Inspect for visible damage to unit casing.
 - 3. Inspect for visible damage to compressor and coils.
 - 4. Inspect internal insulation.
 - 5. Verify that labels are clearly visible.
 - 6. Verify that clearances have been provided for servicing.
 - 7. Verify that controls are connected and operable.
 - 8. Adjust vibration isolators.
 - 9. Start unit according to manufacturer's written instructions.
 - 10. Complete startup sheets and attach copy with Contractor's startup report.
 - 11. Inspect and record performance of interlocks and protective devices; verify sequences.
 - 12. Operate unit for an initial period as recommended or required by manufacturer.
 - 13. Verify thermostat calibration.
 - 14. Inspect controls for correct sequencing of heating, refrigeration, and normal and emergency shutdown.

3.6 ADJUSTING

- A. Adjust initial temperature set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two]** <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain water-source unitary heat pumps.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **238146**

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SECTION 238146.13 - WATER-TO-AIR HEAT PUMPS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include water-source unitary heat pumps may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Concealed horizontal or vertical units, **6 tons (21 kW)** and smaller.
 - 2. Concealed horizontal or vertical units larger than **6 tons (21 kW)**.
 - 3. Vertical-stack units.
 - 4. Exposed, floor-mounted console units.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
1. Include rated capacities, furnished specialties, and accessories for each model.
 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
1. Include diagrams for power, signal, and control wiring.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- D. Samples: For each exposed product and for each color and texture specified.
- E. Samples for Initial Selection: For units with factory-applied color finishes.
- F. Samples for Verification: For each type of unit indicated.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

Revise subparagraphs below to suit Project.

1. Suspended ceiling components.
2. Structural members to which heat pumps are attached.
3. Method of attaching hangers to building structure.
4. Size and location of initial access modules for acoustical tile.
5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. <Insert item>.

Retain "Product Certificates" Paragraph below to require submittal of product certificates from manufacturers.

- B. Product Certificates: For each type of water-source unitary heat pump, signed by product manufacturer.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Seismic Qualification Certificates: Submit certification that water-source heat pumps, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified, and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity, and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Field quality-control reports.

E. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For water-to-air heat pumps to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Revise subparagraphs below to suit Project.

1. **[One (1)]** <Insert number>set(s) of matched fan belts for each belt-driven fan.
2. **[One (1)]** <Insert number>set(s) of filters for each unit.
3. **[One (1)]** <Insert number> spare heat-pump unit(s) of each size and model furnished.

1.7 QUALITY ASSURANCE

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

A. ASHRAE Compliance:

1. ASHRAE 15.
2. Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IESNA Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1.

- B. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- C. Comply with NFPA 70.
- D. Comply with safety requirements in UL 484 for assembly of free-delivery, water-source heat pumps.
- E. Comply with safety requirements in UL 1995 for duct-system connections.

1.8 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace components of water-source heat pumps that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, refrigeration components.

Verify available warranties and warranty periods for refrigerant components.

- 2. Warranty Period: Minimum [four (4)] <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 CONCEALED WATER-SOURCE HEAT PUMPS, 6 TONS (21 kW) AND SMALLER

Concealed water-source heat pumps, 6 tons (21 kW) and smaller, are characterized by direct-drive fan and absence of mixing box including outdoor-air dampers.

Many optional features are available for this product, and some are mutually exclusive. Specify all those required for Project. Identify optional features for specific units in the schedule or on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation](#).
 2. [ClimateMaster, Inc.](#)
 3. [FHP Manufacturing Inc.](#)
 4. [Hydro-Temp Corporation, Inc.](#)
 5. [Mammoth Inc.](#)
 6. [McQuay International.](#)
 7. [Trane Inc.](#)
 8. [WaterFurnace International, Inc.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ASHRAE/ARI/ISO-13256-1.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.
- C. Cabinet and Chassis: Galvanized-steel casing with the following features:
1. Access panel for access and maintenance of internal components.
 2. Knockouts for electrical and piping connections.
 3. Flanged duct connections.
 4. Cabinet Insulation: Glass-fiber liner, minimum **1/2 inch (13 mm)** thick, complying with UL 181, ASTM C 1071, and ASTM G 21.
 5. Units field convertible for various discharge configurations.

ASHRAE compliance option in "Condensate Drainage" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option in subparagraph to comply with LEED Prerequisite IEQ 1.

6. Condensate Drainage: High-density polyethylene plastic or stainless-steel drain pan with condensate drain piping projecting through unit cabinet[**and complying with ASHRAE 62.1**].
 - a. Condensate Overflow Protection Switch: Solid state electronic; mechanical float switch not permitted.

ASHRAE compliance in "Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Sound Attenuation Package" Subparagraph below for sound attenuation package. Verify, with manufacturer, availability of method selected.

8. Sound Attenuation Package: Provide one or more of the following:
 - a. Minimum **0.598-inch-** (1.5-mm-) thick compressor enclosure and front panel. Minimum **0.0937-inch-** (2.38-mm-) thick foam gasket around the compressor and perimeter of end panel.
 - b. Sound attenuating blanket over compressor.
 - c. Hot-gas muffler.
 - d. **<Insert method>**.

- D. Fan: Direct driven, centrifugal, with multispeed motor resiliently mounted in fan inlet and with inlet rings to allow wheel removal from one side without removing housing.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

1. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Motor: Multispeed, permanently lubricated, [**permanent split capacitor**] [**ECM**] motor.

- E. Water Circuit:

1. Refrigerant-to-Water Heat Exchangers:

Retain one of first two subparagraphs below.

- a. Coaxial heat exchangers with [**copper**] [**cupronickel**] water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
- b. Stainless-steel, brazed-plate heat exchanger is leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.

Verify availability of water-regulating valves and motorized water valves.

2. Water-Regulating Valves: Limit water flow through refrigerant-to-water heat exchanger, and control head pressure on compressor during cooling and heating. Valves shall close when heat-pump compressor is not running.
3. Motorized Water Valve: Stop water flow through the unit when compressor is off.

"Refrigerant-to-Air Coils" Paragraph below describes both heating/cooling and reheat coils.

- F. Refrigerant-to-Air Coils: Copper tubes with aluminum fins, leak tested to 450 psig (3102 kPa).
- G. Refrigerant Circuit Components:
 - 1. Sealed Refrigerant Circuit: Charge with R-410A refrigerant.

Filter-dryer is unavailable from some manufacturers.

- 2. Filter-Dryer: Factory installed to clean and dehydrate the refrigerant circuit.
- 3. Charging Connections: Service fittings on suction and liquid for charging and testing on each circuit.
- 4. Reversing Valve: Four-way, solenoid-activated valve designed to be fail-safe in heating position with replaceable magnetic coil.

Options in "Compressor" Subparagraph below depend on unit size. Verify with manufacturers. Delete if these features are not specific selection criteria.

- 5. Compressor: Hermetic [rotary] [reciprocating] [scroll], [single-stage] [two-stage] compressor installed on vibration isolators and housed in an acoustically treated enclosure with factory-installed safeties as follows:
 - a. Antirecycle timer.
 - b. High-pressure cutout.
 - c. Low-pressure cutout or loss of charge switch.
 - d. Internal thermal-overload protection.

Retain first two subparagraphs below for compressor safety switches.

- e. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below [35 deg F (2 deg C)] <Insert temperature>.
 - f. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.
 - g. Water-coil, low-temperature switch.
 - h. Air-coil, low-temperature switch.
- 6. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
 - 7. Pipe Insulation: Refrigerant minimum 3/8-inch- (10-mm-) thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-developed indexes according to ASTM E 84.

Retain one of two "Refrigerant Metering Device" subparagraphs below.

- 8. Refrigerant Metering Device: Thermal-expansion valve.
- 9. Refrigerant Metering Device: Dual-port, thermal-expansion valve to allow specified operation with entering-water temperatures from [25 to 125 deg F (minus 4 to plus 52 deg C)] <Insert temperature range>.

Retain "Hot-Gas Reheat Valve" Subparagraph below for hot-gas reheat.

- 10. Hot-Gas Reheat Valve: Pilot-operated, sliding-type valve with replaceable magnetic coil.

Electric heating coil is an optional feature for "boilerless" system. Some features are mutually exclusive. Verify availability with manufacturer. Temperature set point is adjustable and varies with system type.

- H. Electric Heating Coil: Helix-wound, nickel-chromium, wire-heating elements in ceramic insulators mounted on steel supports. Energize on call for heating when entering-water-loop temperature is less than [25 deg F (minus 4 deg C)] [40 deg F (5 deg C)] [60 deg F (15 deg C)] <Insert temperature>.

Retain "Hot-Gas Reheat" Paragraph below for hot-gas reheat for humidity control; water-regulating valves may be required.

- I. Hot-Gas Reheat: Reheat valve diverts refrigerant hot gas to reheat coil when remote humidistat calls for dehumidification.

Retain one of five "Filters" paragraphs below. Verify availability of filter options in first paragraph with manufacturers. Retain second, fourth, or fifth paragraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

- J. Filters: Disposable, glass-fiber, flat type, [1 inch (25 mm)] <Insert dimension> thick, treated with adhesive, and having a minimum efficiency reporting value of 5 according to ASHRAE 52.2.
- K. Filters: Disposable, pleated type, [1 inch (25 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 7 according to ASHRAE 52.2.
- L. Filters: Electronic air cleaner type; 1 inch (25 mm); cleanable.
- M. Filters: Disposable, pleated type, [4 inches (100 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 13 according to ASHRAE 52.2.
- N. Filters: Disposable, pleated type, [2 inches (50 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 11 according to ASHRAE 52.2.
- O. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

Retain last paragraph above and delete "Controls" Paragraph below if controls are part of overall temperature-control system.

- P. Controls:
 - 1. Basic Unit Control Modes and Devices:
 - a. Dehumidification mode.
 - b. Unit shutdown on high or low refrigerant pressures.
 - c. Unit shutdown on low water temperature.
 - d. Low- and high-voltage protection.
 - e. Overcurrent protection for compressor and fan motor.
 - f. Random time delay, three to ten seconds, start on power-up.
 - g. Time delay override for servicing.

- h. Control voltage transformer.
- i. Water-coil freeze protection (selectable for water or antifreeze).
- j. Air-coil freeze protection (check filter switch).
- k. Condensate overflow shutdown switch.
- l. Option to reset unit at thermostat or disconnect.
- m. Fault type shall be retained in memory if reset at thermostat.
- n. Automatic intelligent reset. Unit shall automatically reset five minutes after trip if the fault has cleared. Should a fault reoccur three times sequentially, lockout requiring manual reset occurs.
- o. Ability to defeat time delays for servicing.
- p. Light-emitting diodes (LED) to indicate high pressure, low pressure, low voltage, and high voltage.
- q. The low-pressure switch SHALL NOT be monitored for the first 90 seconds after a compressor start command to prevent nuisance safety trips.
- r. Remote fault-type indication at thermostat.
- s. Selectable 24-V dc or pilot duty dry contact alarm output.
- t. 24-V dc output to cycle a motorized water valve with compressor contactor.
- u. Electric heat output to control two stages of electric heat (emergency heat).
- v. Service test mode for troubleshooting and service.
- w. Unit-performance sentinel warns when the heat pump is running inefficiently.

2. Thermostat:

a. Wall-Mounted Thermostat:

- 1) Heat-cool-off switch.
- 2) Fan on-auto switch.
- 3) **[Manual]** **[Automatic]** changeover.
- 4) **[Concealed]** **[Exposed]** temperature set point.
- 5) **[Concealed]** **[Exposed]** temperature indication.
- 6) Deg **[F]** **[C]** indication.

b. Wall-Mounted Humidistat: **[Concealed]** **[Exposed]**.

- 1) Temperature set point.
- 2) Temperature indication.

c. Wall-mounted temperature sensor.

- d. Unoccupied period override push button.
- e. LED to indicate fault condition at heat pump.
- f. Data entry and access port.

- 1) Input data include room temperature and humidity set points for occupied and unoccupied periods.
- 2) Output data include room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

3. Terminal Controller:

- a. Scheduled operation for occupied and unoccupied periods on **[seven]** **[365]**-day clock with minimum of four programmable periods per day.
 - b. **[Two]** **<Insert number>**-hour unoccupied override period.
 - c. Remote-control panel to contain programmable timer and LED for fault condition.
 - d. Compressor disable relay to stop compressor operation for demand limiting or switch to unoccupied operation.
 - e. Automatic restart after five minutes if fault clears. Lockout after three attempts to restart following fault. Indicate fault for service technician.
 - f. Return-air temperature high-limit (firestat). Stop unit on high temperature.
 - g. Backup for volatile memory.
 - h. Differential pressure switch to indicate fan status. Fan failure alarm.
 - i. Differential pressure switch to indicate filter status. Dirty filter alarm.
4. Interface with DDC system for HVAC requirements as further described in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- a. Interface relay for scheduled operation.
 - b. Interface relay to provide indication of fault at central workstation.
 - c. Provide **[BAC-net]** **[or]** **[Lonworks]** interface for central DDC system for HVAC workstation for the following functions:
 - 1) Set-point adjustment for set points identified in this Section.
 - 2) Start/stop and operating status of heat-pump unit.
 - 3) Data inquiry to include supply air, room air temperature and humidity, and entering-water temperature.
 - 4) Occupied and unoccupied schedules.

Q. Electrical Connection: Single electrical connection[**with fused disconnect**].

If Project has more than one of this type of heat pump, delete "Capacities and Characteristics" Paragraph below and schedule heat pumps on Drawings.

R. Capacities and Characteristics:

1. Fan:
 - a. Airflow: **<Insert cfm (L/s)>**.
 - b. External Static Pressure: **<Insert inches wg (kPa)>**.
 - c. Fan Speed: **<Insert rpm>**.
 - d. Motor Speed: **<Insert rpm>**.
 - e. Motor Horsepower: **<Insert value>**.
2. Water Supply:
 - a. Water Flow: **<Insert gpm (L/s)>**.
 - b. Pressure Loss: **<Insert feet wg (kPa)>**.
 - c. Entering-Water Temperature (Cooling): **<Insert deg F (deg C)>**.
 - d. Entering-Water Temperature (Heating): **<Insert deg F (deg C)>**.
 - e. Antifreeze Protection Chemical: **<Insert chemical name>**.

- f. Antifreeze Concentration: **<Insert percentage>**.
3. Cooling:
- a. Total Capacity: **<Insert Btu/h (kW)>**.
 - b. Sensible Capacity: **<Insert Btu/h (kW)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- c. Minimum Energy-Efficiency Ratio (EER): **<Insert value>**.
 - d. Entering-Air Temperature Dry Bulb: **<Insert deg F (deg C)>**.
 - e. Entering-Air Temperature Wet Bulb: **<Insert deg F (deg C)>**.
4. Heating:
- a. Capacity: **<Insert Btu/h (kW)>**.
 - b. Entering-Air Temperature: **<Insert deg F (deg C)>**.
 - c. Air Temperature Rise: **<Insert deg F (deg C)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- d. Minimum Coefficient of Performance (COP): **<Insert value>**.
5. Electric Heating Coil (Optional Feature):
- a. Capacity: **<Insert Btu/h (kW)>**.
 - b. Number of Steps: **<Insert number>**.

6. Filters:
- a. Face Area: **<Insert sq. ft. (sq. m)>**.
 - b. Maximum Face Velocity: **<Insert fpm (m/s)>**.

7. Electrical Characteristics for Single Connection:
- a. Volts: **[120] [208] [230] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes (F.L.A.): **<Insert value>**.
 - e. Maximum Circuit Amperage (MCA): **<Insert value>**.
 - f. Maximum Overcurrent Protection (MOCP): **<Insert amperes>**.

2.2 CONCEALED WATER-SOURCE HEAT PUMPS LARGER THAN 6 TONS (21 kW)

Concealed water-source heat pumps larger than 6 tons (21 kW) are characterized by belt-drive fan and absence of mixing box including outdoor-air dampers.

Many optional features are available for this product, and some are mutually exclusive. Specify all those required for Project. Identify optional features for specific units in the schedule or on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation](#).
 2. [ClimateMaster, Inc.](#)
 3. [FHP Manufacturing Inc.](#)
 4. [Hydro-Temp Corporation, Inc.](#)
 5. [Mammoth Inc.](#)
 6. [McQuay International](#).
 7. [Trane Inc.](#)
 8. [WaterFurnace International, Inc.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ASHRAE/ARI/ISO-13256-1.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.
- C. Cabinet and Chassis: Galvanized-steel casing with the following features:
1. Access panel for access and maintenance of internal components.
 2. Knockouts for electrical and piping connections.
 3. Flanged duct connections.
 4. Cabinet Insulation: Glass-fiber liner, minimum **1/2 inch (13 mm)** thick, complying with UL 181, ASTM C 1071, and ASTM G 21.
 5. Units field convertible for various discharge configurations.

Retain option in "Condensate Drainage" Subparagraph below to comply with LEED Prerequisite IEQ 1.

6. Condensate Drainage: High-density polyethylene plastic or stainless-steel drain pan with condensate drain piping projecting through unit cabinet[**and complying with ASHRAE 62.1**].
 - a. Condensate Overflow Protection Switch: Solid state electronic; mechanical float switch not permitted.

ASHRAE compliance in "Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

7. Airstream Surfaces: Surfaces lined with one-half-thick, foil-backed fiber insulation in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Sound Attenuation Package" Subparagraph below for sound attenuation package. Verify, with manufacturer, availability of method selected.

8. Sound Attenuation Package: Provide one or more of the following:

- a. Minimum **0.598-inch**- (1.5-mm-) thick compressor enclosure and front panel. Minimum **0.0937-inch**- (2.38-mm-) thick foam gasket around the compressor and perimeter of end panel.
 - b. Sound attenuating blanket over compressor.
 - c. Hot-gas muffler.
 - d. **<Insert method>**.
- D. Fan: Belt driven, centrifugal, with motor installed on an adjustable fan base resiliently mounted in chassis and with inlet rings to allow wheel removal from one side without removing housing.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project. Permanently lubricated ball bearings are available for motors up to and including 5 hp. Larger motors have grease-lubricated ball bearings.

1. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 2. Motor: Single-speed, permanently lubricated, ECM motor.
- E. Water Circuit:
1. Refrigerant-to-Water Heat Exchanger:

Retain one or both of first two subparagraphs below.

- a. **[Coaxial] [Coil-in-shell] [Shell-and-tube]** heat exchanger with **[copper] [cupronickel]** water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
- b. Stainless-steel, brazed-plate heat exchanger is leak tested to **450 psig** (3102 kPa) on refrigerant side and **400 psig** (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.

Verify availability of water-regulating valves and motorized water valves.

2. Water-Regulating Valves: Limit water flow through refrigerant-to-water heat exchanger, and control head pressure on compressor during cooling and heating. Valves shall close when heat-pump compressor is not running.
3. Motorized Water Valve: Stop water flow through the unit when compressor is off.

"Refrigerant-to-Air Coils" Paragraph below describes both heating/cooling and reheat coils.

- F. Refrigerant-to-Air Coils: Copper tubes with aluminum fins, leak tested to **450 psig** (3102 kPa).
- G. Refrigerant Circuit Components:

1. Sealed Refrigerant Circuit: Minimum of two circuits required for units [10 tons (35 kW)] <Insert value> and larger. Intertwine circuits in refrigerant to air coil.
 - a. Charge with R-410A refrigerant.

Filter-dryer is unavailable from some manufacturers.

2. Filter-Dryer: Factory installed to clean and dehydrate each refrigerant circuit.
3. Charging Connections: Service fittings on suction and liquid for charging and testing on each circuit.
4. Reversing Valve: Four-way, solenoid-activated valve designed to be fail-safe in heating position with replaceable magnetic coil.

Options in "Compressor" Subparagraph below depend on unit size. Verify with manufacturers. Delete if these features are not specific selection criteria.

5. Compressor: [Hermetic reciprocating] [Scroll] [Single-stage] [Two-stage] compressor installed on vibration isolators housed in an acoustically treated enclosure with factory-installed safeties as follows:
 - a. Antirecycle timer.
 - b. High-pressure cutout.
 - c. Low-pressure cutout or loss of charge switch.
 - d. Internal thermal-overload protection.

Retain first subparagraph below for compressor safety switches.

- e. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below [35 deg F (2 deg C)] <Insert temperature>.
 - f. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.
 - g. Water-coil, low-temperature switch.
 - h. Air-coil, low-temperature switch.
6. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
7. Pipe Insulation: Refrigerant minimum 3/8-inch- (10-mm-) thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-developed indexes per ASTM E 84.
8. Refrigerant Metering Device: Dual-port, thermal-expansion valve to allow specified operation with entering-water temperatures from 25 to 125 deg F (minus 4 to plus 52 deg C).

Retain "Hot-Gas Reheat Valve" Subparagraph below for hot-gas reheat.

9. Hot-Gas Reheat Valve: Pilot-operated, sliding-type valve with replaceable magnetic coil.

Electric heating coil is an optional feature for "boilerless" system. Some features are mutually exclusive. Verify availability with manufacturer. Temperature set point is adjustable and varies with system type.

- H. Electric Heating Coil: Helix-wound, nickel-chromium, wire-heating elements in ceramic insulators mounted on steel supports. Energize on call for heating when

entering-water-loop temperature is less than [25 deg F (minus 4 deg C)] [40 deg F (5 deg C)] [60 deg F (15 deg C)] <Insert temperature>.

Retain "Hot-Gas Reheat" Paragraph below for hot-gas reheat for humidity control; water-regulating valves may be required.

- I. Hot-Gas Reheat: Reheat valve diverts refrigerant hot gas to reheat coil when remote humidistat calls for dehumidification.

Retain "Hot-Gas Bypass" Paragraph below for hot-gas bypass for capacity control; water-regulating valves may be required.

- J. Hot-Gas Bypass: Include constant pressure expansion valve, solenoid valve, and controls to maintain continuous refrigeration system operation at 10 percent of full load on lead compressor.

Retain one of four "Filters" paragraphs below. Verify availability of filter options in first paragraph with manufacturers. Retain second, third, or fourth paragraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

- K. Filters: Disposable, glass-fiber, flat type, [1 inch (25 mm)] [2 inches (50 mm)] [4 inches (100 mm)] <Insert dimension> thick, treated with adhesive, and having a minimum efficiency reporting value of 5 according to ASHRAE 52.2.
- L. Filters: Disposable, pleated type, [1 inch (25 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 7 according to ASHRAE 52.2.
- M. Filters: Disposable, pleated type, [2 inches (50 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 11 according to ASHRAE 52.2.
- N. Filters: Disposable, pleated type, [4 inches (100 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 13 according to ASHRAE 52.2.
- O. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

Retain last paragraph above and delete "Controls" Paragraph below if controls are part of overall temperature-control system.

- P. Controls:
 1. Basic Unit Control Modes and Devices:
 - a. Dehumidification mode.
 - b. Unit shutdown on high or low refrigerant pressures.
 - c. Unit shutdown on low water temperature.
 - d. Low- and high-voltage protection.
 - e. Overcurrent protection for compressor and fan motor.
 - f. Random time delay, three to ten seconds, start on power-up.
 - g. Time delay override for servicing.

- h. Control voltage transformer.
- i. Water-coil freeze protection (selectable for water or antifreeze).
- j. Air-coil freeze protection (check filter switch).
- k. Condensate overflow shutdown switch.
- l. Option to reset unit at thermostat or disconnect.
- m. Fault type shall be retained in memory if reset at thermostat.
- n. Automatic intelligent reset. Unit shall automatically reset five minutes after trip if the fault has cleared. Should a fault reoccur three times sequentially, lockout requiring manual reset occurs.
- o. Ability to defeat time delays for servicing.
- p. Light-emitting diodes (LED) to indicate high pressure, low pressure, low voltage, and high voltage.
- q. The low-pressure switch SHALL NOT be monitored for the first 90 seconds after a compressor start command to prevent nuisance safety trips.
- r. Remote fault-type indication at thermostat.
- s. Selectable 24-V dc or pilot duty dry contact alarm output.
- t. 24V dc output to cycle a motorized water valve with compressor contactor.
- u. Electric heat output to control two stages of electric heat (emergency heat).
- v. Service test mode for troubleshooting and service.
- w. Unit-performance sentinel warns when the heat pump is running inefficiently.

2. Thermostat:

- a. Wall-Mounted Thermostat:
 - 1) Heat-cool-off switch.
 - 2) Fan on-auto switch.
 - 3) **[Manual]** **[Automatic]** changeover.
 - 4) **[Concealed]** **[Exposed]** temperature set point.
 - 5) **[Concealed]** **[Exposed]** temperature indication.
 - 6) Deg **[F]** **[C]** indication.
 - 7) **[One]** **[Two]**-stage heating.
 - 8) **[One]** **[Two]**-stage cooling.
- b. Wall-Mounted Humidistat: **[Concealed]** **[Exposed]**.
 - 1) Temperature set point.
 - 2) Temperature indication.
- c. Wall-mounted temperature sensor.
- d. Unoccupied period override push button.
- e. LED to indicate fault condition at heat pump.
- f. Data entry and access port.
 - 1) Input data include room temperature and humidity set points for occupied and unoccupied periods.
 - 2) Output data include room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

3. Terminal Controller:
 - a. Scheduled operation for occupied and unoccupied periods on **[seven]** **[365]**-day clock with minimum of four programmable periods per day.
 - b. **[Two]** **<Insert number>**-hour unoccupied override period.
 - c. Remote-control panel to contain programmable timer and LED for fault condition.
 - d. Compressor disable relay to stop compressor operation for demand limiting or switch to unoccupied operation.
 - e. Automatic restart after five minutes if fault clears. Lockout after three attempts to restart following fault. Indicate fault for service technician.
 - f. Return-air temperature high-limit (firestat). Stop unit on high temperature.
 - g. Smoke alarm with smoke detector installed in **[supply]** **[return]** **[supply and return]** air. Stop unit on smoke detection.
 - h. Backup for volatile memory.
 - i. Differential pressure switch to indicate fan status. Fan failure alarm.
 - j. Differential pressure switch to indicate filter status. Dirty filter alarm.

4. Interface with DDC system for HVAC requirements as further described in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
 - a. Interface relay for scheduled operation.
 - b. Interface relay to provide indication of fault at central workstation.
 - c. Provide **[BAC-net]** **[or]** **[Lonworks]** interface for central DDC system for HVAC workstation for the following functions:
 - 1) Set-point adjustment for set points identified in this Section.
 - 2) Start/stop and operating status of heat-pump unit.
 - 3) Data inquiry to include supply air, room air temperature and humidity, and entering-water temperature.
 - 4) Occupied and unoccupied schedules.

- Q. Electrical Connection: Single electrical connection **[with fused disconnect]**.

- R. Capacities and Characteristics:
 1. Fan:
 - a. Airflow: **<Insert cfm (L/s)>**.
 - b. External Static Pressure: **<Insert inches wg (kPa)>**.
 - c. Fan Speed: **<Insert rpm>**.
 - d. Motor Speed: **<Insert rpm>**.
 - e. Motor Horsepower: **<Insert value>**.

 2. Water Supply:
 - a. Water Flow: **<Insert gpm (L/s)>**.
 - b. Pressure Loss: **<Insert feet wg (kPa)>**.
 - c. Entering-Water Temperature (Cooling): **<Insert deg F (deg C)>**.

- d. Entering-Water Temperature (Heating): **<Insert deg F (deg C)>**.
- e. Antifreeze Protection Chemical: **<Insert chemical name>**.
- f. Antifreeze Concentration: **<Insert percentage>**.

3. Cooling:

- a. Total Capacity: **<Insert Btu/h (kW)>**.
- b. Sensible Capacity: **<Insert Btu/h (kW)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- c. Minimum Energy-Efficiency Ratio (EER): **<Insert value>**.
- d. Entering-Air Temperature Dry Bulb: **<Insert deg F (deg C)>**.
- e. Entering-Air Temperature Wet Bulb: **<Insert deg F (deg C)>**.

4. Heating:

- a. Capacity: **<Insert Btu/h (kW)>**.
- b. Entering-Air Temperature: **<Insert deg F (deg C)>**.
- c. Air Temperature Rise: **<Insert deg F (deg C)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- d. Minimum Coefficient of Performance (COP): **<Insert value>**.

5. Electric Heating Coil (Optional Feature):

- a. Capacity: **<Insert Btu/h (kW)>**.
- b. Number of Steps: **<Insert number>**.

6. Filters:

- a. Face Area: **<Insert sq. ft. (sq. m)>**.
- b. Maximum Face Velocity: **<Insert fpm (m/s)>**.

7. Electrical Characteristics for Single Connection:

- a. Volts: **[120] [208] [230] <Insert value>**.
- b. Phase: **[Single] [Three]**.
- c. Hertz: 60.
- d. Full-Load Amperes (F.L.A.): **<Insert value>**.
- e. Maximum Circuit Amperage (MCA): **<Insert value>**.
- f. Maximum Overcurrent Protection (MOCP): **<Insert amperes>**.

2.3 VERTICAL-STACK, WATER-SOURCE HEAT PUMPS

Vertical-stack, water-source heat pumps are distinguished from other types by their approximate cooling capacity of from 1/2 to 3 tons (1.7 to 10.5 kW), direct-drive fans, unfinished cabinet concealed in the occupied space, and absence of outdoor-air dampers.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [ClimateMaster, Inc.](#)
 2. [McQuay International.](#)
 3. [Trane Inc.](#)
 4. **<Insert manufacturer's name>**.
 5. or approved equal.
- B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ASHRAE/ARI/ISO-13256-1.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.
- C. Cabinet and Chassis: Manufacturer's standard galvanized-steel casing with the following features:
1. Return-air opening with access panel for access to internal components.
 2. Knockouts for electrical and piping connections.
 3. Cabinet Insulation: Glass-fiber liner, minimum **1/2 inch (13 mm)** thick, complying with UL 181, ASTM C 1071, and ASTM G 21.

Retain "Sound Attenuation Package" Subparagraph below for sound attenuation package. Verify, with manufacturer, availability of method selected.

4. Sound Attenuation Package: Provide one or more of the following.
 - a. Minimum **0.598-inch- (1.5-mm-)** thick compressor enclosure and front panel. Minimum **0.0937-inch (2.38-mm)** thick foam gasket around the compressor and perimeter of end panel.
 - b. **<Insert method>**.

ASHRAE compliance option in "Condensate Drainage" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option to comply with LEED Prerequisite IEQ 1.

5. Condensate Drainage: High-density polyethylene plastic or stainless-steel drain pan with condensate drain piping projecting to unit exterior[**and complying with ASHRAE 62.1**].

- a. Condensate Overflow Protection: Solid state electronic; mechanical float switch not permitted.
6. Discharge Grille: Double deflection grille for adjustable discharge air pattern.
7. Discharge and Return Grille Color: Selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** color selection.

Retain "Airstream Surfaces" Subparagraph below to comply with LEED Prerequisite IEQ 1.

8. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
9. Fan: Direct driven, centrifugal, with multispeed motor mounted on a removable fan-motor board and with inlet rings to allow wheel removal from one side without removing housing.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

10. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
11. Motor: Multispeed, permanently lubricated, **[permanent split capacitor]** **[ECM]**.

D. Water Circuit:

1. Refrigerant-to-Water Heat Exchanger: **[Coaxial]** **[Coil-in-shell]** heat exchanger with **[copper]** **[cupronickel]** water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to 450 psig (3102 kPa) on refrigerant side and 400 psig (2758 kPa) on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
2. Risers: **[ASTM B 88, Type L (ASTM B 88M, Type B)]** **[ASTM B 88, Type M (ASTM B 88M Type C)]** copper pipe with hose and ball valve for system flushing.

E. Refrigerant-to-Air Coil: Copper tubes with aluminum fins, leak tested to 450 psig (3102 kPa).

F. Refrigerant Circuit Components:

1. Sealed Refrigerant Circuit: Charge with R-410A refrigerant.

Filter-dryer is unavailable from some manufacturers.

2. Filter-Dryer: Factory installed to clean and dehydrate the refrigerant circuit.
3. Charging Connections: Service fittings on suction and liquid for charging and testing.
4. Reversing Valve: Four-way, solenoid-activated valve designed to be fail-safe in heating position with replaceable magnetic coil.

Options in "Compressor" Subparagraph below depend on unit size. Verify with manufacturers. Delete if these features are not specific selection criteria.

5. Compressor: Hermetic **[rotary]** **[scroll]** compressor installed on vibration isolators housed in an acoustically treated enclosure with factory-installed safeties as follows:

- a. Antirecycle timer.
 - b. High-pressure cutout.
 - c. Low-pressure cutout or loss of charge switch.
 - d. Internal thermal-overload protection.
 - e. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below [35 deg F (2 deg C)] <Insert temperature>.
 - f. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.
 - g. Water-coil, low-temperature switch.
 - h. Air-coil, low-temperature switch.
6. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
 7. Pipe Insulation: Refrigerant minimum 3/8-inch- (10-mm-) thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-developed indexes according to ASTM E 84.
 8. Refrigerant Metering Device: Thermal-expansion valve to allow specified operation with entering-water temperatures from [65 to 100 deg F (minus 18 to plus 38 deg C)] <Insert temperature range>.

Retain one of two "Filters" paragraphs below. Verify availability of filter options in first paragraph with manufacturers. Retain second paragraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

- G. Filters: Disposable, glass-fiber, flat type, [1 inch (25 mm)] <Insert dimension> thick, treated with adhesive, and having a minimum efficiency reporting value of 5 according to ASHRAE 52.2.
- H. Filters: Disposable, pleated type, [1 inch (25 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 7 according to ASHRAE 52.2.
- I. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

Retain last paragraph above and delete "Controls" Paragraph below if controls are part of overall temperature-control system.

- J. Controls:
 1. Basic Unit Control Modes and Devices:
 - a. Dehumidification mode.
 - b. Unit shutdown on high or low refrigerant pressures.
 - c. Unit shutdown on low water temperature.
 - d. Low- and high-voltage protection.
 - e. Overcurrent protection for compressor and fan motor.
 - f. Random time delay, three to ten seconds, start on power-up.
 - g. Time delay override for servicing.
 - h. Control voltage transformer.

- i. Water-coil freeze protection (selectable for water or antifreeze).
 - j. Air-coil freeze protection (check filter switch).
 - k. Condensate overflow shutdown switch.
 - l. Option to reset unit at thermostat or disconnect.
 - m. Fault type shall be retained in memory if reset at thermostat.
 - n. Automatic intelligent reset. Unit shall automatically reset five minutes after trip if the fault has cleared. Should a fault reoccur three times sequentially, lockout requiring manual reset occurs.
 - o. Ability to defeat time delays for servicing.
 - p. Light-emitting diodes (LED) to indicate high pressure, low pressure, low voltage, and high voltage.
 - q. The low-pressure switch SHALL NOT be monitored for the first 90 seconds after a compressor start command to prevent nuisance safety trips.
 - r. Remote fault-type indication at thermostat.
 - s. Selectable 24-V dc or pilot duty dry contact alarm output.
 - t. 24-V dc output to cycle a motorized water valve with compressor contactor.
 - u. Electric heat output to control two stages of electric heat (emergency heat).
 - v. Service test mode for troubleshooting and service.
 - w. Unit-performance sentinel warns when the heat pump is running inefficiently.
2. Thermostat:
- a. Wall-Mounted Thermostat:
 - 1) Heat-cool-off switch.
 - 2) Fan on-auto switch.
 - 3) **[Manual]** **[Automatic]** changeover.
 - 4) **[Concealed]** **[Exposed]** temperature set point.
 - 5) **[Concealed]** **[Exposed]** temperature indication.
 - 6) Deg **[F]** **[C]** indication.
3. Terminal Controller:
- a. Scheduled operation for occupied and unoccupied periods on seven-day clock with minimum four periods per day.
 - b. **[Two]** **<Insert number>**-hour unoccupied override period.
 - c. Backup for volatile memory.

K. Electrical Connection: Single electrical connection[**with fused disconnect**].

If Project has more than one of this heat-pump type, delete "Capacities and Characteristics" Paragraph below and schedule heat pumps on Drawings.

L. Capacities and Characteristics:

1. Fan:
 - a. Airflow: **<Insert cfm (L/s)>**.
 - b. External Static Pressure: **<Insert inches wg (kPa)>**.
 - c. Fan Speed: **<Insert rpm>**.

- d. Motor Speed: **<Insert rpm>**.
 - e. Motor Horsepower: **<Insert value>**.
2. Water Supply:
- a. Water Flow: **<Insert gpm (L/s)>**.
 - b. Pressure Loss: **<Insert feet wg (kPa)>**.
 - c. Entering-Water Temperature (Cooling): **<Insert deg F (deg C)>**.
 - d. Entering-Water Temperature (Heating): **<Insert deg F (deg C)>**.
 - e. Antifreeze Protection Chemical: **<Insert chemical name>**.
 - f. Antifreeze Concentration: **<Insert percentage>**.
3. Cooling:
- a. Total Capacity: **<Insert Btu/h (kW)>**.
 - b. Sensible Capacity: **<Insert Btu/h (kW)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- c. Minimum Energy-Efficiency Ratio (EER): **<Insert value>**.
 - d. Entering-Air Temperature Dry Bulb: **<Insert deg F (deg C)>**.
 - e. Entering-Air Temperature Wet Bulb: **<Insert deg F (deg C)>**.
4. Heating:
- a. Capacity: **<Insert Btu/h (kW)>**.
 - b. Entering-Air Temperature: **<Insert deg F (deg C)>**.
 - c. Air Temperature Rise: **<Insert deg F (deg C)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- d. Minimum Coefficient of Performance (COP): **<Insert value>**.
5. Filters:
- a. Face Area: **<Insert sq. ft. (sq. m)>**.
 - b. Maximum Face Velocity: **<Insert fpm (m/s)>**.
6. Electrical Characteristics for Single Connection:
- a. Volts: **[120] [208] [230] <Insert value>**.
 - b. Phase: **[Single] [Three]**.
 - c. Hertz: 60.
 - d. Full-Load Amperes (F.L.A.): **<Insert value>**.
 - e. Maximum Circuit Amperage (MCA): **<Insert value>**.
 - f. Maximum Overcurrent Protection (MOCP): **<Insert amperes>**.

2.4 EXPOSED, CONSOLE WATER-SOURCE HEAT PUMPS

Exposed, console water-source heat pumps are distinguished from other types by their approximate cooling capacity of from 1/2 to 2 tons (1.7 to 7 kW), finished cabinet exposed in the occupied space, hot-gas bypass for capacity control, optional motorized outdoor-air damper, and direct-drive fans.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Carrier Corporation](#).
 2. [ClimateMaster, Inc.](#)
 3. [FHP Manufacturing Inc.](#)
 4. [Hydro-Temp Corporation, Inc.](#)
 5. [Mammoth Inc.](#)
 6. [McQuay International](#).
 7. [Trane Inc.](#)
 8. [WaterFurnace International, Inc.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ASHRAE/ARI/ISO-13256-1.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.
- C. Cabinet and Chassis: Manufacturer's **[standard]** **[low]** **[standard- and low]**-height, **[flat]** **[sloped]**-top, **[extended]** galvanized-steel casing with the following features:
1. Access panel for access and maintenance of internal components.
 2. Knockouts for electrical and piping connections.
 3. Cabinet Insulation: Glass-fiber liner, minimum **1/2 inch** (13 mm) thick, complying with UL 181, ASTM C 1071, and ASTM G 21.
 4. Cabinet Insulation: Glass-fiber liner, minimum **1/2 inch** (13 mm) thick, complying with ASTM C 1071 and NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain "Sound Attenuation Package" Subparagraph below for sound attenuation package. Verify, with manufacturer, availability of method selected.

5. Sound Attenuation Package: Provide one or more of the following:
 - a. Minimum **0.598-inch**- ((1.5-mm-)) thick compressor enclosure and front panel. Minimum **0.0937-inch** ((2.38-mm)) thick foam gasket around the compressor and perimeter of end panel.
 - b. **<Insert method>**.

ASHRAE compliance option in "Condensate Drainage" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option to comply with LEED Prerequisite IEQ 1.

6. Condensate Drainage: High-density polyethylene plastic or stainless-steel drain pan with condensate drain piping projecting to unit exterior[**and complying with ASHRAE 62.1**].
 - a. Condensate Overflow Protection: Solid state electronic; mechanical float switch not permitted.
7. Discharge Grille: Steel, aluminum, or plastic grille for adjustable discharge air pattern.
8. Color: Selected by DEN Project Manager from manufacturer's [**standard**] [**custom**] color selection.

ASHRAE compliance with "Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

9. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Fan: Direct driven, centrifugal, with multispeed motor mounted on a removable fan-motor board.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

1. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Motor: Multispeed, permanently lubricated, [**permanent split capacitor**] [**ECM**].

E. Water Circuit:

1. Refrigerant-to-Water Heat Exchanger: Coaxial heat exchanger with [**copper**] [**cupronickel**] water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube are leak tested to **450 psig** (3102 kPa) for refrigerant side and **400 psig** (2758 kPa) for water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.

"Water-Regulating Valves" Subparagraph below is a feature with some manufacturers.

2. Water-Regulating Valves: Limit water flow through refrigerant-to-water heat exchanger and control head pressure on compressor during cooling and heating. Valves shall close when heat-pump compressor is not running.

"Refrigerant-to-Air Coils" Paragraph below describes both heating/cooling and hot-gas reheat coils.

- F. Refrigerant-to-Air Coils: Copper tubes with aluminum fins, leak tested to **450 psig** (3102 kPa).

G. Refrigerant Circuit Components:

1. Sealed Refrigerant Circuit: Charge with R-410A refrigerant.

Filter-dryer is unavailable from some manufacturers.

2. Filter-Dryer: Factory installed to clean and dehydrate the refrigerant circuit.
3. Charging Connections: Service fittings on suction and liquid for charging and testing.
4. Reversing Valve: Four-way, solenoid-activated valve designed to be fail-safe in heating position with replaceable magnetic coil.
5. Compressor: Hermetic rotary compressor installed on vibration isolators housed in an acoustically treated enclosure with factory-installed safeties as follows:
 - a. Antirecycle timer.
 - b. High-pressure cutout.
 - c. Low-pressure cutout or loss of charge switch.
 - d. Internal thermal-overload protection.

Retain first subparagraph below for compressor safety switches.

- e. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below [35 deg F (2 deg C)] <Insert temperature>.
 - f. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.
 - g. Water-coil, low-temperature switch.
 - h. Air-coil, low-temperature switch.
6. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
 7. Pipe Insulation: Refrigerant minimum 3/8-inch- (10-mm-) thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-developed indexes per ASTM E 84.
 8. Refrigerant Metering Device: Dual-port, thermal-expansion valve to allow specified operation with entering-water temperatures from [25 to 125 deg F (minus 4 to 52 deg C)] <Insert temperature range>.

Retain "Hot-Gas Reheat Valve" Subparagraph below for hot-gas reheat.

9. Hot-Gas Reheat Valve: Pilot-operated, sliding-type valve with replaceable magnetic coil.

Electric heating coil is an optional feature for "boilerless" system. Some features are mutually exclusive. Verify availability with manufacturer. Temperature set point is adjustable and varies with system type.

- H. Electric Heating Coil: Energized on call for heating when entering-water-loop temperature is less than [60 deg F (15 deg C)] <Insert temperature>.

Retain "Hot-Gas Reheat" Paragraph below for hot-gas reheat for humidity control; water-regulating valves may be required.

- I. Hot-Gas Reheat: Reheat valve diverts refrigerant hot gas to reheat coil when [remote] [unit-mounted] humidistat calls for dehumidification.

Retain "Outdoor-Air Damper" Paragraph below for outdoor-air damper.

ASHRAE/IESNA 90.1 sets requirements for dampers. If applying for LEED certification, retain second option in "Outdoor-Air Damper" Paragraph below to comply with ASHRAE/IESNA 90.1.

- J. Outdoor-Air Damper: Two-position, [manual] [motorized] outdoor-air damper for fixed minimum intake up to 25 percent of fan capacity.

Retain one of two "Filters" paragraphs below. Verify availability of filter options in first paragraph with manufacturers. Retain second paragraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

- K. Filters: Disposable, glass-fiber, flat type, [1 inch (25 mm)] <Insert dimension> thick, treated with adhesive, and having a minimum efficiency reporting value of 5 according to ASHRAE 52.2.
- L. Filters: Disposable, pleated type, [1 inch (25 mm)] <Insert dimension> thick and with a minimum efficiency reporting value of 7 according to ASHRAE 52.2.
- M. Control equipment and sequence of operation are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

Retain last paragraph above and delete "Controls" Paragraph below if controls are part of overall temperature-control system.

- N. Controls:
1. Basic Unit Control Modes and Devices:
 - a. Dehumidification mode.
 - b. Unit shutdown on high or low refrigerant pressures.
 - c. Unit shutdown on low water temperature.
 - d. Low- and high-voltage protection.
 - e. Overcurrent protection for compressor and fan motor.
 - f. Random time delay, three to ten seconds, start on power-up.
 - g. Time delay override for servicing.
 - h. Control voltage transformer.
 - i. Water-coil freeze protection (selectable for water or antifreeze).
 - j. Air-coil freeze protection (check filter switch).
 - k. Condensate overflow shutdown switch.
 - l. Option to reset unit at thermostat or disconnect.
 - m. Fault type shall be retained in memory if reset at thermostat.
 - n. Automatic intelligent reset. Unit shall automatically reset five minutes after trip if the fault has cleared. Should a fault reoccur three times sequentially, lockout requiring manual reset occurs.
 - o. Ability to defeat time delays for servicing.
 - p. Light-emitting diodes (LED) to indicate high pressure, low pressure, low voltage, and high voltage.
 - q. The low-pressure switch SHALL NOT be monitored for the first 90 seconds after a compressor start command to prevent nuisance safety trips.
 - r. Remote fault-type indication at thermostat.
 - s. Selectable 24-V dc or pilot duty dry contact alarm output.

- t. 24V dc output to cycle a motorized water valve with compressor contactor.
- u. Electric heat output to control two stages of electric heat (emergency heat).
- v. Service test mode for troubleshooting and service.
- w. Unit-performance sentinel warns when the heat pump is running inefficiently.

Retain subparagraphs below to suit Project; delete those not required. Verify availability with manufacturers.

2. Thermostat:

a. **[Wall] [Unit]**-Mounted Thermostat:

- 1) Heat-cool-off switch.
- 2) Fan on-auto switch.
- 3) **[Manual] [Automatic]** changeover.
- 4) **[Concealed] [Exposed]** temperature set point.
- 5) **[Concealed] [Exposed]** temperature indication.
- 6) Deg **[F] [C]** indication.

b. **[Wall] [Unit]**-Mounted Humidistat: **[Concealed] [Exposed]**.

- 1) Temperature set point.
- 2) Temperature indication.

c. **[Wall] [Unit]**-mounted temperature sensor.

d. Unoccupied period override push button.

e. LED to indicate fault condition at heat pump.

f. Data entry and access port.

- 1) Input data include room temperature and humidity set points for occupied and unoccupied periods.
- 2) Output data include room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

3. Terminal Controller:

- a. Scheduled operation for occupied and unoccupied periods on **[seven] [365]**-day clock with minimum of four programmable periods per day.
- b. **[Two] <Insert number>**-hour unoccupied override period.
- c. Compressor disable relay to stop compressor operation for demand limiting or switch to unoccupied operation.
- d. Automatic restart after five minutes if fault clears. Lockout after three attempts to restart following fault. Indicate fault for service technician.
- e. Backup for volatile memory.

Differential pressure switches for statuses of fan and filter are unavailable from some manufacturers.

- f. Differential pressure switch to indicate fan status. Fan failure alarm.
- g. Differential pressure switch to indicate filter status. Dirty filter alarm.

4. Interface with DDC system for HVAC requirements as further described in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
 - a. Interface relay for scheduled operation.
 - b. Interface relay to provide indication of fault at central workstation.
 - c. Provide [**BAC-net**] [**or**] [**Lonworks**] interface for central DDC system for HVAC workstation for the following functions:
 - 1) Set-point adjustment for set points identified in this Section.
 - 2) Start/stop and operating status of heat-pump unit.
 - 3) Data inquiry to include supply air, room air temperature and humidity, and entering-water temperature.
 - 4) Occupied and unoccupied schedules.
- O. Electrical Connection: Single electrical connection[**with fused disconnect**].

If Project has more than one of this type of heat pump, delete "Capacities and Characteristics" Paragraph below and schedule heat pumps on Drawings.

P. Capacities and Characteristics:

1. Fan:
 - a. Airflow: <Insert cfm (L/s)>.
 - b. External Static Pressure: <Insert inches wg (kPa)>.
 - c. Fan Speed: <Insert rpm>.
 - d. Motor Speed: <Insert rpm>.
 - e. Motor Horsepower: <Insert value>.
2. Water Supply:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Pressure Loss: <Insert feet wg (kPa)>.
 - c. Entering-Water Temperature (Cooling): <Insert deg F (deg C)>.
 - d. Entering-Water Temperature (Heating): <Insert deg F (deg C)>.
 - e. Antifreeze Protection Chemical: <Insert chemical name>.
 - f. Antifreeze Concentration: <Insert percentage>.
3. Cooling:
 - a. Total Capacity: <Insert Btu/h (kW)>.
 - b. Sensible Capacity: <Insert Btu/h (kW)>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- c. Minimum Energy-Efficiency Ratio (EER): <Insert value>.
- d. Entering-Air Temperature Dry Bulb: <Insert deg F (deg C)>.
- e. Entering-Air Temperature Wet Bulb: <Insert deg F (deg C)>.

4. Heating:
 - a. Capacity: **<Insert Btu/h (kW)>**.
 - b. Entering-Air Temperature: **<Insert deg F (deg C)>**.
 - c. Air Temperature Rise: **<Insert deg F (deg C)>**.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1, Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements."

- d. Minimum Coefficient of Performance (COP): **<Insert value>**.
5. Electric Heating Coil (Optional Feature):
 - a. Capacity: **<Insert Btu/h (kW)>**.
 - b. Number of Steps: **<Insert number>**.
6. Filters:
 - a. Face Area: **<Insert sq. ft. (sq. m)>**.
 - b. Maximum Face Velocity: **<Insert fpm (m/s)>**.
7. Electrical Characteristics for Single Connection:
 - a. Volts/Phase/Hertz: **<Insert values>**.
 - b. Full-Load Amperes (F.L.A.): **<Insert value>**.
 - c. Maximum Circuit Amperage (MCA): **<Insert value>**.
 - d. Maximum Overcurrent Protection (MOCP): **<Insert amperes>**.

2.5 HOSE KITS

Retain this article for hose kits furnished with each water-source heat pump. Revise for size and components. Delete this article if retaining "Hose Kit Assemblies" Article.

- A. General: Hose kits shall be designed for minimum **400-psig (2758-kPa)** working pressure and operating temperatures from **33 to 211 deg F (0.5 to 99 deg C)**. Tag hose kits to equipment designations.
- B. Hose: Length [**24 inches (600 mm)**] [**36 inches (900 mm)**] braided stainless steel, complete with adapters, **<Insert dimension>**. Minimum diameter, equal to water-source, heat-pump connection size.
- C. Isolation Valves: Two-piece, bronze-body ball valves with stainless-steel, standard-port ball and stem with normal pipe thread (NPT) connections, and galvanized-steel lever handle. Provide valve for supply and return. If balancing device is combination shutoff type with memory stop, the isolation valve may be omitted on the return.
- D. Strainer: Y-type with blowdown valve in supply connection.
- E. Balancing Device: Mount in return connection. Include meter ports to allow flow measurement with differential pressure gage.

Retain one of three subparagraphs below. Retain more than one if using different balancing valves on different heat-pump types.

1. Automatic balancing valve, factory set to operate within 10 percent of design flow rate over a 40:1 differential pressure range of 2 to 80 psig (13.8 to 552 kPa).
2. Manual, calibrated-orifice balancing valve.
3. Manual, venturi-type balancing valve.

F. Motorized Water Valve: Slow-acting, 24-V dc, with NPT connections.

2.6 HOSE KIT ASSEMBLIES

The assemblies in this article ship with the valves already assembled to the hose described.

- A. Supply and return hoses having ball valve with pressure temperature port.
- B. Supply hose having ball valve with pressure temperature port; return hose having automatic flow regulator valve with pressure temperature ports, and ball valve.
- C. Supply hose having "Y" strainer with blowdown valve, and ball valve with pressure temperature port; return hose having automatic flow regulator with PT ports, and ball valve.
- D. Supply hose having "Y" strainer with blowdown valve, and ball valve with pressure temperature port.
- E. Return hose having ball valve with pressure temperature port.

2.7 PUMP MODULE

Retain this article for individual heat pumps that stand alone from a central circulating water loop. Values in first paragraph below are examples only; verify actual values with manufacturer.

- A. Minimum [1/6] <Insert value>-hp, 230-V, single-phase pump rated to move at least [16 gpm (1 L/s)] <Insert value> at [20-foot wg (59-kPa)] <Insert value> head pressure.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

1. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- B. Include pump module hose kit with thread to barb fittings, hose, and hose clamps.
- C. Three-way brass shut-off/flushing/purging valve.
- D. Include controls to operate pump as required to maintain room temperature and ventilation set points.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping and electric installations for water-source heat pumps to verify actual locations of piping connections and electrical conduits before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

- 1. Install water-source heat pumps on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in **[Section 033000 "Cast-in-Place Concrete."]** **[Section 033053 "Miscellaneous Cast-in-Place Concrete."]**

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

- 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- C. Install wall-mounting thermostats, humidistats, and switch controls in electrical outlet boxes at heights to match lighting controls or as required in Section 230923.27 "Temperature Instruments," Section 230923.19 "Moisture Instruments," and Section 230923 "Direct Digital Control (DDC) System for HVAC."

3.3 CONNECTIONS

Coordinate requirements for piping installation and specialty arrangements with Drawings and with requirements specified in hydronic piping and steam and condensate piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:

1. Connect supply and return hydronic piping to heat pump with [**unions and shutoff valves**] [**hose kits**].
2. Connect heat-pump condensate drain pan to indirect waste connection with condensate trap of adequate depth to seal against fan pressure. Install cleanouts in piping at changes of direction.
3. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
4. Install piping adjacent to machine to allow service and maintenance.

Coordinate duct installation requirements with Drawings and with requirements specified for duct systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- B. Duct installation requirements are specified in other Sections. Drawings indicate general arrangement of ducts. Specific connection requirements are as follows:
1. Connect supply and return ducts to water-source heat pumps with flexible duct connectors specified in Section 233300 "Air Duct Accessories."
- C. Install electrical devices furnished by manufacturer but not specified to be factory mounted.
- D. Install piping adjacent to machine to allow service and maintenance.
- E. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- F. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- G. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following field tests and inspections:

1. After installing water-source heat pumps and after electrical circuitry has been energized, test units for compliance with requirements.
2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Heat pumps will be considered defective if they do not pass tests and inspections.
- D. Retest as specified above after repairs or replacements are made.
- E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

Delete first paragraph below if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
- B. Complete installation and startup checks according to manufacturer's written instructions and do the following:
 1. Inspect for visible damage to unit casing.
 2. Inspect for visible damage to compressor, coils, and fans.
 3. Inspect internal insulation.
 4. Verify that labels are clearly visible.
 5. Verify that clearances have been provided for servicing.
 6. Verify that controls are connected and operable.
 7. Verify that filters are installed.
 8. Adjust vibration isolators.
 9. Inspect operation of barometric dampers.
 10. Verify bearing lubrication on fan.
 11. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
 12. Adjust fan belts to proper alignment and tension.
 13. Start unit according to manufacturer's written instructions.
 14. Complete startup sheets and attach copy with Contractor's startup report.
 15. Inspect and record performance of interlocks and protective devices; verify sequences.
 16. Operate unit for an initial period as recommended or required by manufacturer.
 17. Verify thermostat and humidistat calibration.
 18. Inspect outdoor-air dampers for proper stroke and interlock with return-air dampers.
 19. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.

Retain testing requirements if not using Section 230593 "Testing, Adjusting, and Balancing for HVAC."

20. Start refrigeration system, and measure and record the following:
 - a. Coil leaving-air, dry- and wet-bulb temperatures.
 - b. Coil entering-air, dry- and wet-bulb temperatures.
 - c. Outdoor-air, dry-bulb temperature.
 - d. Outdoor-air-coil, discharge-air, dry-bulb temperature.

21. Measure and record the following minimum and maximum airflows. Plot fan volumes on fan curve.
 - a. Supply-air volume.
 - b. Return-air volume.
 - c. Relief-air volume.
 - d. Outdoor-air intake volume.

3.6 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two (2)] <Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.7 CLEANING

- A. Replace filters used during construction prior to air balance or Substantial Completion.
- B. After completing installation of exposed, factory-finished, water-source heat pumps, inspect exposed finishes and repair damaged finishes.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain water-source heat pumps.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238146.13

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SECTION 238213 - VALANCE HEATING AND COOLING UNITS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Electric radiant heaters.
 - 2. Hydronic heating and cooling panels.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, specialties, and accessories for each product indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, details, and attachments to other work. Detail equipment assemblies and suspension and attachment.
 - 2. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

Retain subparagraph below if equipment includes wiring.

- 3. Include diagrams for power, signal, and control wiring.

Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs below for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- C. Samples for Initial Selection: For units with factory-applied color finishes.
- D. Samples for Verification: For each type of exposed finish required, prepared on Samples of size indicated below.
 - 1. Radiant Heater Finishes: [4 by 4 inches (100 by 100 mm)] <Insert size>.
 - 2. Radiant Panel Finishes: [12 by 12 inches (300 by 300 mm)] <Insert size>.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

- A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

Revise subparagraphs below to suit Project.

- 1. Suspended ceiling components.
- 2. Structural members to which heaters and suspension systems will be attached.
- 3. Size and location of initial access modules for acoustical tile.
- 4. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.

- c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. <Insert item>.
5. Perimeter moldings.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: Submit certification that suspended radiant heaters and panels, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
- 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electric radiant heaters to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 ELECTRIC RADIANT HEATERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Berko Electric Heating; a division of Marley Engineered Products.
 2. Chromalox Inc.; a division of Emerson Electric Company.
 3. Fostoria Industries, Inc.; a division of TPI Corporation.
 4. Markel Products; a division of TPI Corporation.
 5. Omega Engineering, Inc.
 6. QMark Electric Heating; a division of Marley Engineered Products.
 7. **<Insert manufacturer's name>.**
 8. or approved equal.

Retain "Quartz Lamp Heating Elements," "Quartz Tube Heating Elements," or "Metal-Sheathed Heating Elements" Paragraph below. If more than one type of heating element is required, indicate each type in a schedule on Drawings.

- B. Quartz Lamp Heating Elements: Coiled tungsten-wire heating element enclosed in clear quartz tube.
- C. Quartz Tube Heating Elements: Nickel-chromium-wire heating element enclosed in quartz tube.
- D. Metal-Sheathed Heating Elements: Nickel-chromium-wire heating element embedded in magnesium oxide powder enclosed in metal sheath. Comply with UL 1030.

In first paragraph below, retain UL 499 for supplemental heating applications requiring humidity control; retain UL 2021 for comfort heating applications. Retain all three options if both applications are required.

- E. Comply with **[UL 499]** **[and]** **[UL 2021]**.
- F. Enclosures: **[Aluminized]** **[Stainless]** **[Painted]**-steel housing with anodized-aluminum reflector.

Retain "Finish" Subparagraph below for painted enclosures.

1. Finish: Baked-enamel finish in manufacturer's **[standard]** **[custom]** paint color as selected by DEN Project Manager.
- G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain "Unit Controls" Paragraph below for integral control device if control devices are not specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- H. Unit Controls:

Retain one or more of three subparagraphs below. If more than one type of control device is required, indicate each type in a schedule on Drawings.

1. Line-voltage thermostat.
2. Enclosed contactor for remote thermostat.
3. Snow and ice detector with moisture sensor and integral temperature sensor.

If Project has more than one type or size of electric radiant heater, delete "Capacities and Characteristics" Paragraph below and schedule heaters on Drawings.

I. Capacities and Characteristics:

1. Enclosure Length: <Insert inches (mm)>.
2. Mounting Height: <Insert feet (m)>.
3. Heating Capacity: <Insert kilowatts>.
4. Radiation Pattern: [30] [60] [90] <Insert number> [symmetric] [asymmetric]-degree-included angle.
5. Electrical Characteristics for Single-Point Connection:
 - a. Volts: <Insert value>.
 - b. Phase: <Insert value>.
 - c. Hertz: <Insert value>.
 - d. Full-Load Amperes: <Insert value>.
 - e. Minimum Circuit Ampacity: <Insert value>.
 - f. Maximum Overcurrent Protection: <Insert amperage>.

2.2 HYDRONIC HEATING[AND COOLING] PANELS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [AIRTEX Radiant Systems; a division of Engineered Air Ltd.](#)
2. [Rosemex Products.](#)
3. [Sun-EI Corporation.](#)
4. [Twa Panel Systems Inc.](#)
5. <Insert manufacturer's name>.
6. or approved equal.

B. Description: [Modular] [Linear] sheet-metal panel with serpentine water piping, suitable for [lay-in installation flush with T-bar ceiling grid] [surface mounting] [recessed mounting].

1. Panels: Minimum [0.0336-inch- (0.86-mm-) thick, galvanized-steel] [0.0396-inch- (1.0-mm-) thick, aluminum] sheet.
2. Backing Insulation: Minimum [1-inch- (25-mm-)] [2-inch- (50-mm-)] <Insert dimension> thick, mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB with factory-applied jacket.

Retain one of three "Exposed-Side Panel Finish" subparagraphs below. If more than one type of finish is required, indicate each type in a schedule on Drawings.

3. Exposed-Side Panel Finish: Apply silk-screened finish to match appearance of acoustical ceiling tiles selected by DEN Project Manager.
4. Exposed-Side Panel Finish: Factory prime coated, ready for field painting.
5. Exposed-Side Panel Finish: Baked-enamel finish in manufacturer's **[standard]** **[custom]** paint color as selected by DEN Project Manager.
6. Factory Piping: **[ASTM B 88, Type L (ASTM B 88M, Type B)]** **[ASTM B 88, Type M (ASTM B 88M, Type C)]** copper tube with ASME B16.22 wrought-copper fittings and brazed joints. Piping shall be mechanically bonded to panel.

Retain "Surface-Mounted Trim" Subparagraph below for surface-mounted panels.

7. Surface-Mounted Trim: Sheet metal with baked-enamel finish in manufacturer's **[standard]** **[custom]** paint color as selected by DEN Project Manager.

Retain "Accessories" Subparagraph below for linear panels only.

8. Accessories:
 - a. **[5-inch (127-mm)]** **[6-inch (152-mm)]** **[8-inch (203-mm)]** panel with drape track recess.
 - b. **5-inch (127-mm)** male bullnose panel.
 - c. **5-inch (127-mm)** female bullnose panel.
 - d. **4-inch (102-mm)** male corner panel.
 - e. **4-inch (102-mm)** female corner panel.
 - f. Inside corner panel.
 - g. **1/2-inch (13-mm)** filler panel.

If Project has more than one type or size of hydronic heating and cooling panel, delete "Capacities and Characteristics" Paragraph below and schedule panels on Drawings.

C. Capacities and Characteristics:

1. Nominal Panel Size: **[24 by 24 inches (600 by 600 mm)]** **[24 by 36 inches (600 by 900 mm)]** **[24 by 48 inches (600 by 1200 mm)]** **[24 by 60 inches (600 by 1500 mm)]** **<Insert dimensions>**.
2. Piping Inlet and Outlet: **[NPS 1/2 (DN 15)]** **<Insert pipe size>**.
3. Heating:
 - a. Capacity: **<Insert Btu/h (kW)>**.
 - b. Room Temperature: **<Insert deg F (deg C)>**.
 - c. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - d. Average Water Temperature: **<Insert deg F (deg C)>**.
 - e. Water Flow: **<Insert gpm (L/s)>**.
 - f. Water-Side Pressure Loss: **<Insert psig (kPa)>**.
4. Cooling:
 - a. Sensible Capacity: **<Insert Btu/h (kW)>**.
 - b. Dry-Bulb Room Temperature: **<Insert deg F (deg C)>**.
 - c. Wet-Bulb Room Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Water Temperature: **<Insert deg F (deg C)>**.

- e. Average Water Temperature: <Insert deg F (deg C)>.
- f. Water Flow: <Insert gpm (L/s)>.
- g. Water-Side Pressure Loss: <Insert psig (kPa)>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive radiant heating and cooling units for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for [**hydraulic piping**] [**electrical**] connections to verify actual locations before radiant heating and cooling unit installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install radiant heating and cooling units level and plumb.
- D. Suspend radiant heaters from structure.
- E. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- F. Protection: Provide finished units with protective covers during balance of construction.

Revise first paragraph below for other types of construction that penetrate or are supported by ceilings.

- G. Coordinate layout and installation of radiant heaters and suspension-system components with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, communications system, security system, and partition assemblies.
- H. Support for Radiant Heating and Cooling Panels in or on Grid-Type Suspended Ceilings: Use grid as a support element.
 - 1. Install a minimum of four ceiling support-system rods or wires for each panel. Locate not more than **6 inches (150 mm)** from panel corners.
 - 2. Support Clips: Fasten to panel and to ceiling grid members at or near each panel corner with clips designed for the application.

3. Panels of Sizes Less Than Ceiling Grid: Install as indicated on reflected ceiling plans, or center in acoustical panel and support panels independently with at least two 3/4-inch (19-mm) metal channels spanning and secured to ceiling tees.
4. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
5. Install piping adjacent to machine to allow service and maintenance.

Retain subparagraph below if Project is in a seismic area.

6. Install at least one independent support rod or wire from structure to a tab on panel. Wire or rod shall have breaking strength of the weight of panel at a safety factor of three.

To comply with requirements of the Americans with Disabilities Act, verify mounting height in paragraph below with authorities having jurisdiction. Verify locations of thermostats with Drawings and room details before installation.

- I. Install devices [48 inches (1220 mm)] [60 inches (1525 mm)] <Insert dimension> above finished floor.

3.3 CONNECTIONS

Retain first three paragraphs below for hydronic heating and cooling panels. Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
- C. Install piping adjacent to unit to allow service and maintenance.
- D. Ground electric units according to Section 260526 "Grounding and Bonding for Electrical Systems."
- E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- F. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

Retain first subparagraph below if units have electric heat.

1. Operate electric heating elements through each stage to verify proper operation and electrical connections.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and units.
- B. Remove and replace malfunctioning units and retest as specified above.
- C. After installing panels, inspect unit cabinet for damage to finish. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.
- D. Retest as specified above after repairs or replacements are made.
- E. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain radiant heaters and panels. See Section 017900 "Demonstration and Training."
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238213

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SECTION 238216 - AIR COILS

- 1.1 This Section has no Section Text as it has been replaced by the Sections listed below. If e-SPECS Bindings have been associated to this Section, they should be updated to refer to the replacement sections below.
- A. SECTION 238216.11 – HYDRONIC AIR COILS
 - B. SECTION 238216.12 – STEAM AIR COILS
 - C. SECTION 238216.13 – REFRIGERANT AIR COILS
 - D. SECTION 238216.14 – ELECTRIC RESISTANCE AIR COILS

PART 1 - GENERAL (Not Applicable)

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 238216

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SECTION 238216.11 - HYDRONIC AIR COILS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes hydronic heating and cooling air coils.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1.
2. Section 238216.13 "Refrigerant Air Coils."
3. Section 238216.14 "Electric Resistance Air Coils."

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT

PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
1. Include construction details, coil and frame configurations, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
 2. Include rated capacities, operating characteristics, and pressure drops for each air coil.
 3. Include data substantiating that materials comply with requirements.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.
- B. Certificates: Certify that [**coil capacities, pressure drops, and selection procedures**] meet or exceed specified requirements. [**coils are tested and rated in accordance with ARI 410.**]
- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.
- B. Warranty: Submit manufacturer warranty and ensure forms have been completed in DEN Project Manager's name and registered with manufacturer.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in

NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Verify availability of certification. Not all mfrs certify coils. This requirement should not be deleted.

- B. Comply with ARI 410 for components, construction, and rating.
 - 1. Certify coils to ARI 410.
- C. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc., or other testing agency acceptable to the authority having jurisdiction, as suitable for the purpose specified and indicated.

1.7 FIELD CONDITIONS

- A. Altitude above Mean Sea Level: 5,500 feet (1677 m).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 DESCRIPTION

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, humidification and dehumidification, drain-pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 COILS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerofin.
 2. Armstrong-Hunt, Inc.
 3. Carrier Corporation: a UTC company.
 4. Coil Company, LLC.
 5. Colmac Coil Manufacturing, Inc.
 6. Dunham-Bush USA.
 7. Heatcraft Worldwide Refrigeration.
 8. Greenheck Fan Corporation.
 9. Super Radiator Coils.
 10. Technical Systems, Inc.
 11. Temptrol.
 12. Trane.
 13. USA Coil & Air.
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Performance Ratings: Tested and rated according to AHRI 410 and ASHRAE 33.

Pressure/temperature ratings in "Minimum Working-Pressure/Temperature Ratings" Paragraph below are common. Some manufacturers may vary ratings.

- C. Minimum Working-Pressure/Temperature Ratings: 200 psig (1380 kPa), 325 deg F (163 deg C).
- D. Source Quality Control: Factory tested to 300 psig (2070 kPa).
- E. Tubes: ASTM B 743 copper, minimum [0.020 inch (0.508 mm)] [0.035 inch (0.889 mm)] [0.049 inch (1.245 mm)] **<Insert dimension>** thick.
- F. Fins: [Aluminum] [Copper], minimum [0.006 inch (0.152 mm)] [0.010 inch (0.254 mm)] **<Insert dimension>** thick.
- G. Headers: [**Cast iron with drain and air vent tappings**] [**Cast iron with cleaning plugs and drain and air vent tappings**] [**Seamless copper tube with brazed joints, prime coated**] [**Steel with brazed joints, prime coated**].

Retain one of two "Frames" paragraphs below.

- H. Frames: Galvanized-steel channel frame, minimum [0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] thick for [**slip-in**] [**flanged**] mounting.
- I. Frames: ASTM A 666, [**Type 304**] [**Type 316**] stainless steel, minimum 0.0625 inch (1.6 mm) thick for [**slip-in**] [**flanged**] mounting.

Retain "Hot-Water Coil, Face-and-Bypass Dampers" Paragraph below for face-and-bypass heating coils.

- J. Hot-Water Coil, Face-and-Bypass Dampers: Alternating arrangement of coil segments and dampers.

1. Coil Configuration: [**Horizontal**] [**Vertical**] tubes.
2. Dampers: [**Extruded-aluminum**] [**Galvanized-steel**] blades with edge and end seals; full-length drive rod and mount for actuator [**in**] [**outside**] the airstream.

If Project has more than one type or size of hot-water coil, delete "Hot-Water Coil Capacities and Characteristics" Paragraph below and schedule coils on Drawings.

K. Hot-Water Coil Capacities and Characteristics:

1. Coil Face Dimensions:
 - a. Finned Length: <Insert inches (mm)>.
 - b. Finned Width: <Insert inches (mm)>.
2. Minimum Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.81 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.41 mm)] [0.0075 inch (0.19 mm)] <Insert dimension>.
3. Tube Diameter: [0.375 inch (9.5 mm)] [0.50 inch (12.7 mm)] [0.625 inch (15.9 mm)] [0.75 inch (19.0 mm)] [1.0 inch (25.4 mm)] <Insert dimension>.
4. Number of Rows: <Insert number>.
5. Serpentine: [**Single**] [**Half**] [**Full**].
6. Mounting: [**Slip in**] [**Flanged**].
7. Coating: [**Baked phenolic**] [**Cathodic epoxy e-coat**].
8. Air Side:
 - a. Flow Rate: <Insert cfm (L/s)>.
 - b. Finned Area Face Velocity: <Insert fpm (m/s)>.
 - c. Static Pressure Drop: <Insert inches wg (Pa)>.
 - d. Total Capacity: <Insert Btu/h (kW)>.
 - e. Entering Temperature: <Insert deg F (deg C)>.
 - f. Leaving Temperature: <Insert deg F (deg C)>.
9. Water Side:
 - a. Flow Rate: <Insert gpm (L/s)>.
 - b. Tube Velocity: <Insert fpm (m/s)>.
 - c. Glycol Type: [**Ethylene**] [**Propylene**].
 - d. Aqueous Glycol Solution Concentration: <Insert percentage>.
 - e. Pressure Drop: <Insert feet (kPa)>.
 - f. Entering Temperature: <Insert deg F (deg C)>.
 - g. Leaving Temperature: <Insert deg F (deg C)>.

If Project has more than one type or size of chilled-water coil, delete "Chilled-Water Coil Capacities and Characteristics" Paragraph below and schedule coils on Drawings.

L. Chilled-Water Coil Capacities and Characteristics:

1. Coil Face Dimensions:
 - a. Finned Length: <Insert inches (mm)>.
 - b. Finned Width: <Insert inches (mm)>.

2. Minimum Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.81 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.41 mm)] [0.0075 inch (0.19 mm)] **<Insert dimension>**.
3. Tube Diameter: [0.375 inch (9.5 mm)] [0.50 inch (12.7 mm)] [0.625 inch (15.9 mm)] [0.75 inch (19.0 mm)] [1.0 inch (25.4 mm)] **<Insert dimension>**.
4. Number of Rows: **<Insert number>**.
5. Serpentine: [Half] [Single] [Double].
6. Mounting: [Slip in] [Flanged].
7. Coating: [Baked phenolic] [Cathodic epoxy e-coat].
8. Air Side:
 - a. Flow Rate: **<Insert cfm (L/s)>**.
 - b. Finned Area Face Velocity: **<Insert fpm (m/s)>**.
 - c. Static Pressure Drop: **<Insert inches wg (Pa)>**.
 - d. Total Capacity: **<Insert Btu/h (kW)>**.
 - e. Sensible Capacity: **<Insert Btu/h (kW)>**.
 - f. Entering Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - g. Entering Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 - h. Leaving Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - i. Leaving Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
9. Water Side:
 - a. Flow Rate: **<Insert gpm (L/s)>**.
 - b. Tube Velocity: **<Insert fpm (m/s)>**.
 - c. Glycol Type: [Ethylene] [Propylene].
 - d. Aqueous Glycol Solution Concentration: **<Insert percentage>**.
 - e. Pressure Drop: **<Insert feet (Pa)>**.
 - f. Entering Temperature: **<Insert deg F (deg C)>**.
 - g. Leaving Temperature: **<Insert deg F (deg C)>**.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before coil installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturers written instructions.

- B. Install coils level and plumb.
- C. Make connections to coils with unions and flanges.
- D. Install coils level. [**Install cleanable tube coils with 1:50 pitch.**]
- E. Connect water supply to leaving air side of coil (counterflow arrangement).
- F. Provide shut-off valve on supply line and lockshield balancing valve [**with memory stop**] on return line.
- G. Locate water supply at bottom of supply header and return water connection at top.

Select one below.

- H. Provide [**manual**] [**float operated automatic**] air vents at high points complete with stop valve.
- I. Ensure water coils are drainable and provide drain connection at low points.
- J. Refer to Section 232116 "Hydronic Piping Specialties".
- K. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
 - 1. Support coil sections independent of piping on steel channel or double angle frames and secure to casings.
 - 2. Provide frames for maximum three coil sections.
 - 3. Arrange supports to avoid piercing drain pans.
 - 4. Install coil to assure access for cleaning and maintenance.
 - 5. Provide airtight seal between coil and duct or casing.
- L. Install [**galvanized**] [**stainless**]-steel drain pan under each cooling coil.

Option in first subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option to comply with LEED Prerequisite IEQ 1.

- 1. Construct drain pans with connection for drain; insulated[**and complying with ASHRAE 62.1**].
 - 2. Construct drain pans to extend beyond coil length and width and to connect to condensate trap and drainage.
 - 3. Extend drain pan upstream and downstream from coil face.
 - 4. Extend drain pan under coil headers and exposed supply piping.
- M. Install moisture eliminators for cooling coils. Extend drain pan under moisture eliminator.
- N. Provide protection for coils to prevent damage to fins and flanges. Comb out and straighten bent fins on air coils.

- O. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified for hydronic piping systems.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to coils to allow service and maintenance.
- C. Connect water piping with unions and shutoff valves to allow coils to be disconnected without draining piping. Control valves are specified in Section 230923.11 "Control Valves," and other piping specialties are specified in Section 232116 "Hydronic Piping Specialties."
- D. Ground equipment.
 - 1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Straighten bent fins on each air coil.

3.5 CLEANING

- A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.
- B. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238216.11

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SECTION 238216.12 - STEAM AIR COILS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes steam heating air coils.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 238216.11 "Hydronic Air Coils."
- 2. Section 238216.13 "Refrigerant Air Coils."
- 3. Section 238216.14 "Electric Resistance Air Coils."

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
 - 2. Include rated capacities, operating characteristics, and pressure drops for each air coil.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

1.6 FIELD CONDITIONS

- A. Altitude above Mean Sea Level: <Insert feet (m)>.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 DESCRIPTION

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, humidification and dehumidification, drain-pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 COILS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

Retain "Basis-of-Design Product" Paragraph and list of manufacturers below to identify a specific product or a comparable product from manufacturers listed. Retain option and delete insert note if manufacturer's name and model number are indicated on Drawings.

B. Basis-of-Design Product: Subject to compliance with requirements, provide [product indicated on Drawings] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. Aerofin Corporation.
2. Carrier Corporation; a UTC company.
3. Coil Company, LLC.
4. Colmac Coil Manufacturing, Inc.
5. Dunham-Bush, Inc.
6. Greenheck Fan Corporation.
7. Heatcraft Refrigeration Products LLC.
8. Super Radiator Coils.
9. Trane.
10. USA Coil & Air.
11. **<Insert manufacturer's name>.**

C. Performance Ratings: Tested and rated according to AHRI 410 and ASHRAE 33.

Pressure/temperature ratings in "Minimum Working-Pressure/Temperature Ratings" Paragraph below are common. Some manufacturers may vary ratings.

- D. Minimum Working-Pressure/Temperature Ratings: 100 psig (690 kPa), 400 deg F (204 deg C).
- E. Source Quality Control: Factory tested to 300 psig (2070 kPa).
- F. Tubes: ASTM B 743 copper, minimum [0.025 inch (0.635 mm)] [0.035 inch (0.889 mm)] [0.049 inch (1.245 mm)] **<Insert dimension>** thick.
- G. Fins: [Aluminum] [Copper], minimum [0.006 inch (0.152 mm)] [0.010 inch (0.254 mm)] **<Insert dimension>** thick.
- H. Headers: [Cast iron with drain and air vent tappings] [Cast iron with cleaning plugs, and drain and air vent tappings] [Seamless copper tube with brazed joints, prime coated] [Steel with brazed joints, prime coated].

Indicate single- or distributing-tube type in "Capacities and Characteristics" Paragraph or in schedule on Drawings.

I. Tube Type: Single or distributing as indicated.

Retain one of two "Frames" paragraphs below.

J. Frames: Galvanized-steel channel frame, minimum [0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] thick for [slip-in] [flanged] mounting.

- K. Frames: ASTM A 666, [Type 304] [Type 316] stainless steel, minimum 0.0625 inch (1.6 mm) thick for [slip-in] [flanged] mounting.

Retain "Face-and-Bypass Dampers" Paragraph below for face-and-bypass coils.

- L. Face-and-Bypass Dampers: Alternating arrangement of coil segments and dampers.
1. Coil Configuration: [Horizontal] [Vertical] tubes.
 2. Dampers: [Extruded-aluminum] [Galvanized-steel] blades with edge and end seals; full-length drive rod and mount for actuator [in] [outside] the airstream.

If Project has more than one type or size of steam coil, delete "Capacities and Characteristics" Paragraph below and schedule coils on Drawings.

- M. Capacities and Characteristics:

1. Coil Face Dimensions:
 - a. Finned Length: <Insert inches (mm)>.
 - b. Finned Width: <Insert inches (mm)>.
2. Minimum Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.81 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.41 mm)] [0.0075 inch (0.19 mm)] <Insert dimension>.
3. Tube Diameter: [0.375 inch (9.5 mm)] [0.50 inch (12.7 mm)] [0.625 inch (15.9 mm)] [0.75 inch (19.0 mm)] [1.0 inch (25.4 mm)] <Insert dimension>.
4. Number of Rows: <Insert number>.
5. Mounting: [Slip in] [Flanged].
6. Air Side:
 - a. Flow Rate: <Insert cfm (L/s)>.
 - b. Finned Area Face Velocity: <Insert fpm (m/s)>.
 - c. Static Pressure Drop: <Insert inches wg (Pa)>.
 - d. Total Capacity: <Insert Btu/h (kW)>.
 - e. Entering Temperature: <Insert deg F (deg C)>.
 - f. Leaving Temperature: <Insert deg F (deg C)>.
7. Steam Side:
 - a. Inlet Pressure: <Insert psig (kPa)>.
 - b. Tube Type: [Single] [Distributing].
 - c. Condensing Capacity: <Insert lb/h (g/s)>.
 - d. Pressure Drop: <Insert psig (kPa)>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before coil installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install coils level and plumb.
- B. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
- C. Straighten bent fins on air coils.
- D. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified for steam and condensate piping systems.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to coils to allow service and maintenance.
- C. Connect steam piping with gate valve and union and steam condensate piping with union, strainer, trap, and gate valve to allow coils to be disconnected without draining piping. Control valves are specified in Section 230923.11 "Control Valves," and other piping specialties are specified in Section 232213 "Steam and Condensate Heating Piping."

END OF SECTION 238216.12

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SECTION 238216.13 - REFRIGERANT AND GLYCOL AIR COILS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes refrigerant air coils and glycol air coils.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 238216.11 "Hydronic Air Coils."
- 2.
3. Section 238216.14 "Electric Resistance Air Coils."

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, coil and frame configurations, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
 - 2. Include rated capacities, operating characteristics, and pressure drops for each air coil.
 - 3. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

- 1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.
- B. Certificates: Certify that [**coil capacities, pressure drops, and selection procedures**] meet or exceed specified requirements. [**coils are tested and rated in accordance with ARI 410.**]
- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.
- B. Warranty: Submit manufacturer warranty and ensure forms have been completed in DEN Project Manager's name and registered with manufacturer.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300

"Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Verify availability of certification. Not all mfrs certify coils. This requirement should not be deleted.

- B. Comply with ARI 410 for components, construction, and rating.
 - 1. Certify coils to ARI 410.
- C. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc., or other testing agency acceptable to the authority having jurisdiction, as suitable for the purpose specified and indicated.

1.7 FIELD CONDITIONS

- A. Altitude above Mean Sea Level: 5,500 feet (1677 m).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 DESCRIPTION

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, humidification and dehumidification, drain-pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 REFRIGERANT AIR COILS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerofin Corporation.
2. Armstrong-Hunt, Inc.
3. Carrier Corporation; a UTC company.
4. Coil Company, LLC.
5. Colmac Coil Manufacturing, Inc.
6. Dunham-Bush, Inc.
7. Greenheck Fan Corporation.
8. Heatcraft Refrigeration Products LLC.
9. Lennox Industries Inc.
10. Super Radiator Coils.
11. Technical Systems, Inc.
12. Temptrol.
13. Trane.
14. USA Coil & Air.
15. **<Insert manufacturer's name>.**
16. or approved equal.

B. Performance Ratings: Tested and rated according to AHRI 410 and ASHRAE 33.

Pressure rating in "Minimum Working-Pressure Rating" Paragraph below is common. Some manufacturers may vary rating.

C. Minimum Working-Pressure Rating: 300 psig (2070 kPa).

D. Source Quality Control: Factory tested to 450 psig (3105 kPa).

E. Tubes: ASTM B 743 copper, minimum [0.020 inch (0.508 mm)] [0.035 inch (0.889 mm)] [0.049 inch (1.245 mm)] **<Insert dimension>** thick.

F. Fins: [Aluminum] [Copper], minimum [0.006 inch (0.152 mm)] [0.010 inch (0.254 mm)] **<Insert dimension>** thick.

G. Suction and Distributor Piping: ASTM B 88, Type L (ASTM B 88M, Type B) copper tube with brazed joints.

Retain one of two "Frames" paragraphs below.

H. Frames: Galvanized-steel channel frame, minimum [0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] thick for [slip-in] [flanged] mounting.

I. Frames: ASTM A 666, [Type 304] [Type 316] stainless steel, minimum 0.0625 inch (1.6 mm) thick for [slip-in] [flanged] mounting.

If Project has more than one type or size of refrigerant coil, delete "Capacities and Characteristics" Paragraph below and schedule coils on Drawings.

J. Capacities and Characteristics:

1. Coil Face Dimensions:

- a. Finned Length: <Insert inches (mm)>.
- b. Finned Width: <Insert inches (mm)>.

2. Minimum Fin Spacing: [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.81 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.41 mm)] [0.0075 inch (0.19 mm)] <Insert dimension>.

3. Tube Diameter: [0.375 inch (9.5 mm)] [0.50 inch (12.7 mm)] [0.625 inch (15.9 mm)] [0.75 inch (19.0 mm)] [1.0 inch (25.4 mm)] <Insert dimension>.

4. Number of Rows: <Insert number>.

5. Coil Split: [Row] [Face] [Interlaced].

6. Mounting: [Slip in] [Flanged].

7. Coating: [Baked phenolic] [Cathodic epoxy e-coat].

8. Air Side:

- a. Flow Rate: <Insert cfm (L/s)>.
- b. Finned Area Face Velocity: <Insert fpm (m/s)>.
- c. Static Pressure Drop: <Insert inches wg (Pa)>.
- d. Total Capacity: <Insert Btu/h (kW)>.
- e. Sensible Capacity: <Insert Btu/h (kW)>.
- f. Entering Dry-Bulb Temperature: <Insert deg F (deg C)>.
- g. Entering Wet-Bulb Temperature: <Insert deg F (deg C)>.
- h. Leaving Dry-Bulb Temperature: <Insert deg F (deg C)>.
- i. Leaving Wet-Bulb Temperature: <Insert deg F (deg C)>.

9. Refrigerant Side:

Retain one of two "Refrigerant Type" subparagraphs below to require a specific refrigerant type; delete both if any refrigerant type is acceptable. LEED-NC, LEED-CS, and LEED for Schools Credit EA 4 awards a single point if all HVAC&R equipment meets requirements for enhanced refrigerant management.

- a. Refrigerant Type: [R-22] [R-407C] [R-410A] [HFC-134a] [HFC refrigerant] <Insert type>.
- b. Refrigerant Type: R-407C, R-410A, or HFC-134a.
- c. Saturated Suction Temperature: <Insert deg F (deg C)>.

2.3 GLYCOL AIR COILS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerofin Corporation.
2. Armstrong-Hunt, Inc.
3. Carrier Corporation; a UTC company.
4. Coil Company, LLC.
5. Colmac Coil Manufacturing, Inc.
6. Dunham-Bush, Inc.
7. Greenheck Fan Corporation.
8. Heatcraft Refrigeration Products LLC.
9. Lennox Industries Inc.
10. Super Radiator Coils.
11. Technical Systems, Inc.
12. Temptrol.
13. Trane.
14. USA Coil & Air.
15. <Insert manufacturer's name>.
16. or approved equal.

- B. Tubes: 5/8 inch OD seamless copper [**or brass**] arranged in parallel or staggered pattern, expanded into fins, [**silver**] brazed joints.
- C. Fins: Aluminum [**or copper**] [**continuous plate type with full fin collars**] [**or individual helical finned tube type wound under tension**].

Select one or include all of the optional fins; some may only be manufacturer-dependent and not affect performance of the equipment.

Edit paragraph below.

- D. Casing: Die formed channel frame of [**16 gage**] [**14 gage**] [**18 gage**] galvanized steel with [**3/8 inch**] mounting holes on [**3 inch**] [**6 inch**] centers. Provide tube supports for coils longer than [**36 inches**] [**40 inches**] [**48 inches**].
- E. Headers: [**Cast iron with tubes expanded into header**] [**Seamless copper tube with silver brazed joints**] [**Prime coated steel pipe with brazed joints**].

Select one or include all of the optional header systems; some may only be manufacturer-dependent and not affect performance of the equipment.

Select one below.

- F. Testing: Air test under water to [**200 psig**] [**350 psig**] for working pressure of 200 psig and 220 degrees F. Design tested and rated according to ASHRAE 33 and ARI 410.
- G. Configuration: Drainable, with threaded plugs [**in headers**] for drain and vent; threaded plugs in return bends and in headers opposite each tube.

Select one below.

- H. Fin Spacing: [**8 fins per inch**] [**11 fins per inch**].

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before coil installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturers written instructions.
- B. Install coils level and plumb.
- C. Make connections to coils with unions and flanges.
- D. Install coils level. [**Install cleanable tube coils with 1:50 pitch.**]
- E. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
 - 1. Support coil sections independent of piping on steel channel or double angle frames and secure to casings.
 - 2. Provide frames for maximum three coil sections.
 - 3. Arrange supports to avoid piercing drain pans.
 - 4. Install coil to assure access for cleaning and maintenance.
 - 5. Provide airtight seal between coil and duct or casing.
- F. Install [**galvanized**] [**stainless**]-steel drain pan under each cooling coil.

Option in first subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain option to comply with LEED Prerequisite IEQ 1.

- 1. Construct drain pans with connection for drain; insulated[**and complying with ASHRAE 62.1**].
 - 2. Construct drain pans to extend beyond coil length and width and to connect to condensate trap and drainage.
 - 3. Extend drain pan upstream and downstream from coil face.
 - 4. Extend drain pan under coil headers and exposed supply piping.
- G. Install moisture eliminators for cooling coils. Extend drain pan under moisture eliminator.
 - H. Cooling Coils:

Generally, moisture eliminators should be installed on all duct refrigerant cooling coils.

Edit paragraphs 1 and 2 below.

1. Provide [**three break**] [**six break**] moisture eliminators of 24 gage galvanized steel, where air velocity exceeds [**500 ft/min**] [**550 ft/min**] [**<Insert number> ft/min**].
 2. Provide drain pan and drain connection; fabricate from 20 gage galvanized steel, extend 3 inches from face of entering air side, [**6 inches**] [**<Insert number inches**] from face of leaving air side [, and **4 inches from face of eliminators**]. Pipe drain pans individually to floor drain with water seal trap. Drain pan construction shall comply with ASHRAE 62.
- I. Refrigerant Coils: Provide sight glass in liquid line within 12 inches of coil. Refer to Section 232300 "Refrigerant Piping".
 - J. Insulate headers located outside airflow as specified for piping. Refer to Section 230719 "HVAC Piping Insulation" Piping Insulation.
 - K. Electric Duct Heating Coils: Wire in accordance with NFPA 70. Refer to Section 260583 "Electrical Connections for Equipment".
 - L. Straighten bent fins on air coils.
 - M. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified for refrigerant piping systems.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to coils to allow service and maintenance.
- C. Connect refrigerant piping according to Section 232300 "Refrigerant Piping."
- D. Ground equipment.
 1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 ADJUSTING

- A. Adjust initial temperature and humidity set points.

- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Straighten bent fins on each air coil.

3.5 CLEANING

- A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.
- B. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238216.13

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SECTION 238216.14 - ELECTRIC-RESISTANCE AIR COILS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes electric resistance air coils.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 238216.11 "Hydronic Air Coils."
2. Section 238216.13 "Refrigerant and Gycol Air Coils."

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, coil and frame configurations, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
 - 2. Include rated capacities, operating characteristics, and pressure drops for each air coil.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.
- B. Certificates: Certify that coils meet or exceed specified requirements. **[coils are tested and rated in accordance with ARI 410.]**
- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.
- B. Warranty: Submit manufacturer warranty and ensure forms have been completed in DEN Project Manager's name and registered with manufacturer.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Verify availability of certification. Not all mfrs certify coils. This requirement should not be deleted.

- B. Comply with ARI 410 for components, construction, and rating.
 - 1. Certify coils to ARI 410.
- C. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc., or other testing agency acceptable to the authority having jurisdiction, as suitable for the purpose specified and indicated.

1.7 FIELD CONDITIONS

- A. Altitude above Mean Sea Level: 5,500 feet (1677 m).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 DESCRIPTION

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, humidification and dehumidification, drain-pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 COILS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Berko Electric Mfg. Div.
 2. Brasch Manufacturing Co., Inc.
 3. Chromalox.
 4. Dunham-Bush, Inc.
 5. Federal Pacific Electric Co.
 6. INDEECO.
 7. Trane.
 8. **<Insert manufacturer's name>.**
 9. or approved equal.
- B. Testing Agency Listing and Labeling: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Coil Assembly: Comply with UL 1995.

Retain one of two "Heating Elements" paragraphs below.

- D. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
- E. Heating Elements: **[Enclosed copper tube, aluminum finned element of coiled nickel-chrome resistance wire centered in tubes and embedded in refractory material][.] [or]** Open-coil resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, and fastened to supporting brackets.
- F. High-Temperature Coil Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or casing.
1. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
- G. Frames: Galvanized-steel channel frame, minimum [0.052 inch (1.3 mm)] [0.064 inch (1.6 mm)] [0.079 inch (2.0 mm)] thick for **[slip-in] [flanged]** mounting. Provide tube supports for coils longer than **[36 inches] [40 inches] [48 inches]**.
- H. Control Panel: **[Unit] [Remote]** mounted with disconnecting means and overcurrent protection. Include the following controls:
1. Magnetic contactor.
 2. Mercury contactor.

3. Solid-state stepless pulse controller.
4. Toggle switches; one per step.
5. Step controller.
6. Time-delay relay.
7. Pilot lights; one per step.
8. Airflow proving switch.

Retain one of first two paragraphs below.

- I. See Section 230923.27 "Temperature Instruments" for thermostat.

If thermostats are used with step controllers, ensure their compatibility regarding number of steps.

- J. Thermostats: Duct-mounted modulating thermostats, with temperature range from 0 to 100 degrees F, and 2.5 degrees F throttling range; and with 1/2-by-4-1/2-inch sensing bulb and 60-inch capillary.

If Project has more than one type or size of electric coil, delete "Capacities and Characteristics" Paragraph below and schedule coils on Drawings.

- K. Capacities and Characteristics:

1. Coil Face Dimensions:

- a. Length: <Insert inches (mm)>.
- b. Height: <Insert inches (mm)>.

2. Mounting: **[Slip in] [Flanged]**.

3. Air Side:

- a. Flow Rate: <Insert cfm (L/s)>.
- b. Face Velocity: <Insert fpm (m/s)>.
- c. Static Pressure Drop: <Insert inches wg (Pa)>.
- d. Total Capacity: <Insert Btu/h (kW)>.
- e. Entering Temperature: <Insert deg F (deg C)>.
- f. Leaving Temperature: <Insert deg F (deg C)>.

4. Electrical Characteristics:

- a. Capacity: <Insert kilowatts>.
- b. Number of Steps: <Insert number>.
- c. Volts: <Insert value>.
- d. Phase: <Insert value>.
- e. Hertz: <Insert value>.
- f. Full-Load Amperes: <Insert value>.
- g. Minimum Circuit Ampacity: <Insert value>.
- h. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturers written instructions.
- B. Install coils level and plumb.
- C. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
- D. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Ground equipment.
 - 1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 ADJUSTING

- A. Adjust initial temperature and set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.5 CLEANING

- A. After completing system installation, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

- B. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

Delete below if no copper tube with resistance wire and aluminum finned elements.

- C. Straighten bent fins on each air coil.

3.6 FIELD QUALITY CONTROL

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238216.14

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SECTION 238219 - FAN COIL UNITS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include fan coil units may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Ductless fan coil units and accessories.
 - 2. Ducted fan coil units and accessories.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
 2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings:
1. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Include diagrams for power, signal, and control wiring.

Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs below for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- D. Samples for Initial Selection: For units with factory-applied color finishes.
- E. Samples for Verification: For each type of fan coil unit indicated.
- F. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide **<Insert number>** mockup, **<Insert number>** feet long by **<Insert number>** feet wide, of **<typical exterior wall module>** **<one typical bay, under window enclosure assembly complete with induction units>**.
2. Locate **<where directed by DEN Project Manager>** **<Insert location>**.
3. Mockup may **<not>** remain as part of the Work.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
1. Suspended ceiling components.
 2. Structural members to which fan coil units will be attached.
 3. Method of attaching hangers to building structure.
 4. Size and location of initial access modules for acoustical tile.
 5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. <Insert item>.
 6. Perimeter moldings.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC Piping and Equipment." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For fan coil units, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.
- D. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fan coil units to include in emergency, operation, and maintenance manuals.
 - 1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Maintenance schedules and repair part lists for motors, coils, integral controls, and filters.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fan Coil Unit Filters: Furnish <Insert number> spare filters for each filter installed.

Retain "Fan Belts" Subparagraph below only for fan coil units with belt-driven fans.

- 2. Fan Belts: Furnish <Insert number> spare fan belts for each unit installed.

1.7 QUALITY ASSURANCE

- A. Comply with NFPA 70. Listed and labeled by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1.

- C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.8 COORDINATION

Delete this article if fan coil units are wall or floor mounted.

Revise first paragraph below to delete or add types of construction that penetrate or are supported by ceilings.

- A. Coordinate layout and installation of fan coil units and suspension system components with other construction that penetrates or is supported by ceilings, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

Retain paragraph below for units with outdoor air.

- B. Coordinate size and location of wall sleeves for outdoor-air intake.

1.9 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

Warranties vary among manufacturers from covering the whole unit for up to four years, to only the compressor for five to 10 years, or only the condenser coil for five years. Extended special warranties are limited to units in the 1- to 5-ton (3.5- to 17.6-kW) range, and then are usually restricted to residential applications.

- A. Special Warranty: Manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Compressor failure.
 - b. Condenser coil leak.

Verify available warranties and warranty periods for units and components.

- 2. Warranty Period: Minimum **[four (4)] [five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.
- 3. Warranty Period (Compressor Only): Minimum **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Factory-packaged and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.
- C. Radiated noise shall not exceed:
1. NC 35 – In Office.
 2. NC 40 – Terminal/Concourse.
 3. NC 45 – Maintenance Facilities.

2.2 DUCTLESS FAN COIL UNITS

Many additional features, which vary with each manufacturer, are available for this product. Include all features for fan coil units that are required for Project, and identify additional features for specific units in the Fan Coil Unit Schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Airtherm; a Mestek Company.
 2. Carrier Corporation; a UTC company.
 3. DRS Marlo Coil; part of DRS Technologies, Inc.
 4. Dunham-Bush.
 5. Engineered Air.
 6. ENVIRO-TEC; by Johnson Controls, Inc.
 7. First Company Products.
 8. Greenheck Fan Corporation.
 9. IEC; a subsidiary of LSB Industries, Inc.

10. [McQuay International; a member of Daikin Group.](#)
11. [Nailor Industries Inc.](#)
12. [Rosemex.](#)
13. [Superior Rex.](#)
14. [Titus.](#)
15. [Trane Inc.](#)
16. [USA Coil & Air.](#)
17. [YORK; by Johnson Controls, Inc.](#)
18. **<Insert manufacturer's name>.**
19. or approved equal.

Fan coil units come with various coil configurations, the most typical being split coil systems with one heating and three cooling coils. The coils tend to be row split rather than face split, although both configurations are available. Units can also come with either a two-pipe or a four-pipe system, depending on Project design requirements.

B. Fan Coil Unit Configurations: [**Row**] [**Face**] split.

1. Number of Heating Coils: [**One**] **<Insert number>** with two-pipe system.
2. Number of Cooling Coils: [**One**] [**Three**] with [**two**][**four**]-pipe system.

Retain one of two "Coil Section Insulation" paragraphs below for coil section insulation.

Closed-cell insulation with foil or matt facing is provided by some manufacturers to reduce the possibility of fibers from glass-fiber insulation being introduced into the conditioned space.

C. Coil Section Insulation: [**1/2-inch- (13-mm-)**] [**1-inch- (25-mm-)**] **<Insert dimension>** thick, [**coated glass fiber**] [**foil-covered, closed-cell foam**] [**matte-finish, closed-cell foam**] complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Coil Section Insulation: Insulate coil section according to Section 230616 "HVAC Equipment Insulation."

1. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Removable drain pans are an extra feature with some manufacturers.

"(Main and Auxiliary)Drain Pans" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1.

- E. **[Main and Auxiliary]Drain Pans: [Plastic] [Stainless steel] [Insulated galvanized steel with plastic liner].** Fabricate pans and drain connections to comply with ASHRAE 62.1. **[Drain pans shall be removable.]**
- F. Chassis: Galvanized steel where exposed to moisture, **with baked-enamel finish and removable access panel**], **with powder-coat finish and removable access panel**]. Floor-mounting units shall have leveling screws.

Coordinate custom-color requirements in "Cabinet" Paragraph below with sample submittal requirements. Coordinate field painting with Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

- G. Cabinet: Steel with **[factory prime coating, ready for field painting] [baked-enamel finish in manufacturer's standard paint color as selected by DEN Project Manager] [baked-enamel finish in manufacturer's custom paint color as selected by DEN Project Manager]**.
 - 1. Vertical Unit Front Panels: Removable, steel, with **[integral stamped] [polyethylene] [steel]** discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.
 - 2. Horizontal Unit Bottom Panels: Fastened to unit with cam fasteners and hinge and attached with safety chain; with **[integral stamped] [cast-aluminum]** discharge grilles.

Retain "Stack Unit Discharge and Return Grille" Subparagraph below for stack-type fan coil unit.

- 3. Stack Unit Discharge and Return Grille: Aluminum double-deflection discharge grille, and louvered- or panel-type return grille; color as selected by DEN Project Manager from manufacturer's **[standard] [custom]** colors. Return grille shall provide maintenance access to fan coil unit.
- 4. Steel recessing flanges for recessing fan coil units into ceiling or wall.

Retain "Outdoor-Air Wall Box" Paragraph below for fan coil units with outdoor-air intake.

- H. Outdoor-Air Wall Box: Minimum **0.1265-inch- (3.2-mm-)** thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen.
 - 1. Louver Configuration: **[Horizontal] [Vertical]**, rain-resistant louver.
 - 2. Louver Material: **[Aluminum] [Steel]**.
 - 3. Bird Screen: **1/2-inch (13-mm)** mesh screen on interior side of louver.
 - 4. Decorative Grille: On outside of intake.
 - 5. Finish: **[Anodized aluminum] [Baked enamel]**, color as selected by DEN Project Manager from manufacturer's **[standard] [custom]** colors.

Outdoor-air dampers are furnished for wall-mounting, vertical, exposed units only.

- I. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with **[electronic] [pneumatic], [two-position] [modulating]** actuators.

Verify available filter types with manufacturer. Indicate filter thickness in "Capacities and Characteristics" Paragraph or in the Fan Coil Unit Schedule on Drawings.

For further information on air filters and air filter ratings, see Section 234100 "Particulate Air Filtration."

- J. Filters: Easily removed, minimum arrestance and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2 and all addendums.

Retain "MERV Rating" Subparagraph below to require compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher. Also, retain subparagraph for LEED Prerequisite IEQ 1. LEED-NC, LEED-CI, and LEED for Schools Credit IEQ 3.1 and LEED-CS Credit IEQ 3 require that filters have a minimum MERV 13 rating for systems that deliver air to occupied spaces

1. MERV Rating: [6] [13] <Insert number> when tested according to ASHRAE 52.2.

Retain one or more of three subparagraphs below. Indicate filter type in the Fan Coil Unit Schedule on Drawings. 2-inch- (50-mm-) thick washable foam is unavailable. Retain third subparagraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

2. Washable Foam: 70 percent arrestance and MERV[3].
3. Glass Fiber Treated with Adhesive: 80 percent arrestance and MERV[5].
4. Pleated Cotton-Polyester Media: 90 percent arrestance and MERV[7].

- K. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

Retain "Indoor Refrigerant Coils" Paragraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

- L. Indoor Refrigerant Coils: [Copper] [Stainless-steel] tube, with mechanically bonded [aluminum] [stainless-steel] fins spaced no closer than 0.1 inch (2.5 mm) and brazed joints at fittings. Comply with AHRI 210/240, and leak test to minimum 450 psig (3105 kPa) for a minimum 300-psig (2070-kPa) working pressure. Include thermal expansion valve.
- M. Steam Coils: Copper[distributing] tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 75 psig (517 kPa).

Some manufacturers limit air-to-air heat pumps to electric supplemental heating coils.

- N. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.
- O. Fan and Motor Board: Removable.

1. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

2. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
3. Wiring Termination: Connect motor to chassis wiring with plug connection.

Retain "Factory, Hydronic Piping Package" Paragraph below to suit Project. Delete if factory piping package is not required.

- P. Factory, Hydronic Piping Package: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M Type C)] copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.

Retain one or more of first four subparagraphs below.

1. [Two][Three]-way, [two-position] [modulating] control valve for dual-temperature coil.
2. [Two][Three]-way, [two-position] [modulating] control valve for chilled-water coil.
3. [Two][Three]-way, [two-position] [modulating] control valve for hot-water heating coil.
4. [Two][Three]-way [two-position] [modulating] control valve for hot-water reheat coil.
5. Hose Kits: Minimum 400-psig (2758-kPa) working pressure and operating temperatures from 33 to 211 deg F (0.5 to 99 deg C). Tag hose kits to equipment designations.
 - a. Length: [24 inches (600 mm)] [36 inches (900 mm)] <Insert dimension>.
 - b. Minimum Diameter: Equal to fan coil unit connection size.
6. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig (4140-kPa) minimum CWP rating and blowout-proof stem.
7. Calibrated-Orifice Balancing Valves: Bronze body, ball type; 125-psig (860-kPa) working pressure, 250 deg F (121 deg C) maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and a memory stop to retain set position.
8. Automatic Flow-Control Valve: Brass or ferrous-metal body; 300-psig (2070-kPa) working pressure at 250 deg F (121 deg C); with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig (13.8 to 552 kPa).
9. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig (860-kPa) working pressure; with threaded connections, bolted cover, perforated

- stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 (DN 15) hose-end, full-port, ball-type blowdown valve in drain connection.
10. Wrought-Copper Unions: ASME B16.22.

Retain "Risers" Subparagraph below for stack-type units with hydronic coils.

11. Risers: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M Type C)] copper pipe with hose and ball valve for system flushing.

- Q. Control devices and operational sequences are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

Retain last paragraph above and delete "Basic Unit Controls" Paragraph below if controls are part of overall temperature-control system.

- R. Basic Unit Controls:

1. Control voltage transformer.

Verify control features with manufacturer.

2. [Wall-mounting] [Unit-mounted] thermostat with the following features:
 - a. Heat-cool-off switch.
 - b. Fan on-auto switch.

Retain first subparagraph below if multispeed motors are specified.

- c. Fan-speed switch.
 - d. [Manual] [Automatic] changeover.
 - e. Adjustable deadband.
 - f. [Concealed] [Exposed] set point.
 - g. [Concealed] [Exposed] indication.
 - h. [Degree F] [Degree C] indication.
3. [Wall-mounting] [Unit-mounted] humidistat.
 - a. [Concealed] [Exposed] set point.
 - b. [Concealed] [Exposed] indication.
 4. [Wall-mounting] [Unit-mounted] temperature sensor.
 5. Unoccupied-period-override push button.
 6. Data entry and access port.
 - a. Input data includes room temperature, and humidity set points and occupied and unoccupied periods.
 - b. Output data includes room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

Retain "(DDC)Terminal Controller" Paragraph below and coordinate with "Basic Unit Controls" Paragraph above or with control devices specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

S. **[DDC]** Terminal Controller:

1. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
2. Unoccupied-Period-Override Operation: **[Two]** <Insert number> hours.
3. Unit Supply-Air Fan Operation:
 - a. Occupied Periods: Fan runs continuously.
 - b. Unoccupied Periods: Fan cycles to maintain room setback temperature.
4. Hydronic-Cooling-Coil Operation:
 - a. Occupied Periods: **[Open]** **[Modulate]** control valve to maintain room temperature.
 - b. Unoccupied Periods: Close control valve.

Retain "Refrigerant-Coil Operation" Subparagraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

5. Refrigerant-Coil Operation:
 - a. Occupied Periods: Start compressor to maintain room temperature or humidistat set point.
 - b. Unoccupied Periods: Stop compressor cooling and cycle compressor for heating to maintain setback temperature.
6. **[Supplemental]** Heating-Coil Operation:
 - a. Occupied Periods: **[Open control valve]** **[Modulate control valve]** **[Energize electric-resistance coil]** to provide heating if room temperature falls below thermostat set point.
 - b. Unoccupied Periods: Start fan and **[open control valve]** **[modulate control valve]** **[energize electric-resistance coil]** if room temperature falls below setback temperature.

Retain first subparagraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

- c. Switch refrigerant-reversing valve to operate supplemental coil for heating when outdoor temperature is below **[25 deg F (4 deg C)]** <Insert temperature>.
7. Dual-Temperature Hydronic-Coil Operation:
 - a. Occupied Periods: When chilled water is available, **[open]** **[modulate]** control valve if room temperature exceeds thermostat set point. When hot water is available, open control valve if temperature falls below thermostat set point.

- b. Unoccupied Periods: When chilled water is available, close control valve. When hot water is available, **[open] [modulate]** control valve if room temperature falls below thermostat setback temperature.

8. Reheat-Coil Operation:

Retain "Humidity Control for Occupied Periods" and "Humidity Control for Unoccupied Periods" subparagraphs below if reheat coil provides reheating only.

- a. Humidity Control for Occupied Periods:
 - 1) Humidistat **[opens control valve] [modulates control valve] [energizes electric-resistance coil]** to provide heating. As space temperature rises above set point, cooling-coil valve **[opens] [modulates]** to maintain room temperature.
- b. Humidity Control for Unoccupied Periods: **[Close control valve] [De-energize]**.

Retain "Occupied Periods" and "Unoccupied Periods" subparagraphs below if reheat coil provides heating and reheating.

- c. Occupied Periods:
 - 1) Heating Operations: **[Open control valve] [Modulate control valve] [Energize electric-resistance coil]** to provide heating if room temperature falls below thermostat set point.
 - 2) Humidity-Control Operations: Humidistat **[opens control valve] [modulates control valve] [energizes electric-resistance coil]** to provide heating. As space temperature rises above set point, cooling-coil valve **[opens] [modulates]** to maintain room temperature.
- d. Unoccupied Periods: Start fan and **[open control valve] [modulate control valve] [energize electric-resistance coil]** if room temperature falls below setback temperature. Humidity control is not available.

Retain first "Outdoor-Air Damper Operation" Subparagraph below for fixed, minimum outdoor-air intake.

9. Outdoor-Air Damper Operation:

- a. Occupied Periods: Open damper to fixed position for **[25] <Insert number>** percent outdoor air.
- b. Unoccupied periods: Close damper.

Retain "Outdoor-Air Damper Operation" Subparagraph below for outdoor-air economizer cycle.

10. Outdoor-Air Damper Operation:

- a. Occupied Periods:

- 1) Outdoor-Air Temperature below Room Temperature: If room temperature is above thermostat set point, modulate outdoor-air damper to maintain room temperature (outdoor-air economizer). If room temperature is below thermostat set point, position damper to fixed minimum position.
 - 2) Outdoor-Air Temperature above Room Temperature: Position damper to fixed minimum position for [25] <Insert number> percent outdoor air.
- b. Unoccupied Periods: Close damper.

Retain "Outdoor-Air Damper Operation (Enthalpy Based)" Subparagraph below for outdoor-air economizer cycle based on enthalpy.

11. Outdoor-Air Damper Operation (Enthalpy Based):

- a. Occupied Periods:
- 1) Outdoor-Air Enthalpy below Room Enthalpy: If room temperature is above room-temperature set point, modulate outdoor-air damper to maintain room temperature (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum position for [25] <Insert number> percent outdoor air.
 - 2) Outdoor-Air Enthalpy above Room Enthalpy: Position damper to fixed minimum position for [25] <Insert number> percent outdoor air.
- b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

12. Controller shall have volatile-memory backup.

T. Interface with DDC System for HVAC Requirements:

1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at the central workstation.
3. Provide [BACnet] [or] [LonWorks] interface for central DDC system for HVAC workstation for the following functions:
 - a. Adjust set points.
 - b. Fan coil unit start, stop, and operating status.
 - c. Data inquiry, including [outdoor-air damper position,]supply- and room-air temperature[and humidity].
 - d. Occupied and unoccupied schedules.

U. Electrical Connection: Factory wire motors and controls for a single electrical connection.

If Project has more than one type or configuration of fan coil unit, delete "Capacities and Characteristics" Paragraph below and schedule fan coil units on Drawings.

V. Capacities and Characteristics:

1. Fan:
 - a. Airflow: <Insert cfm (L/s)>.
 - b. External Static Pressure: <Insert inches wg (kPa)>.
 - c. Fan Speed: <Insert rpm>.
 - d. Motor Speed: <Insert rpm>.
 - e. Motor Horsepower: <Insert horsepower>.
 - f. Drive: [Direct] [Belt].

2. Cooling Capacity:
 - a. Total: <Insert Btu/h (kW)>.
 - b. Sensible: <Insert Btu/h (kW)>.
 - c. Entering-Air Dry-Bulb Temperature: <Insert deg F (deg C)>.
 - d. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.

3. Chilled-Water Coil:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Water-Side Pressure Loss: <Insert feet wg (kPa)>.
 - c. Entering-Water Temperature: <Insert deg F (deg C)>.
 - d. Air-Side Pressure Drop: <Insert inches wg (kPa)>.

Retain "Refrigerant Coil" Subparagraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

4. Refrigerant Coil:
 - a. Air-Side Pressure Loss: <Insert inches wg (kPa)>.
 - b. Suction Temperature: <Insert deg F (deg C)>.

5. Heating Capacity:
 - a. Output: <Insert Btu/h (kW)>.
 - b. Entering-Air Temperature: <Insert deg F (deg C)>.
 - c. Air-Temperature Rise: <Insert deg F (deg C)>.

6. Hot-Water Heating Coil:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Water-Side Pressure Loss: <Insert feet wg (kPa)>.
 - c. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
 - d. Entering-Water Temperature: <Insert deg F (deg C)>.

7. Steam Heating Coil:
 - a. Inlet Steam Pressure: <Insert psig (kPa)>.
 - b. Condensing Capacity: <Insert lb/h (g/s)>.
 - c. Air-Side Pressure Drop: <Insert inches wg (kPa)>.

8. Electric-Resistance Heating Coil:
 - a. Capacity: **<Insert kilowatts>**.
 - b. Number of Steps: **<Indicate number>**.
 - c. Air-Side Pressure Drop: **<Insert inches wg (kPa)>**.
9. Reheat Capacity:
 - a. Output: **<Insert Btu/h (kW)>**.
 - b. Entering-Air Temperature: **<Insert deg F (deg C)>**.
 - c. Air-Temperature Rise: **<Insert deg F (deg C)>**.
10. Filters:
 - a. Face Area: **<Insert sq. ft. (sq. m)>**.
 - b. Thickness: **[1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>**.
11. Electrical Characteristics for Single-Point Connection:
 - a. Voltage/Phase/Hertz: **<Insert values>**.
 - b. Full-Load Amperes: **<Insert value>**.
 - c. Maximum Circuit Amperes: **<Insert value>**.
 - d. Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 DUCTED FAN COIL UNITS

Many additional features, which vary with each manufacturer, are available for this product. Include all features for fan coil units that are required for Project, and identify additional features for specific units in the Fan Coil Unit Schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Carrier Corporation; a UTC company.
 2. DRS Marlo Coil; part of DRS Technologies, Inc.
 3. Dunham-Bush.
 4. Engineered Air.
 5. ENVIRO-TEC; by Johnson Controls, Inc.
 6. First Company Products.
 7. Greenheck Fan Corporation.
 8. IEC; a subsidiary of LSB Industries, Inc.
 9. McQuay International; a member of Daikin Group.
 10. Nailor Industries Inc.
 11. Rosemex.
 12. Superior Rex.
 13. Titus.
 14. Trane Inc.

15. [USA Coil & Air.](#)
16. [Williams Comfort Products.](#)
17. [YORK; by Johnson Controls, Inc.](#)
18. **<Insert manufacturer's name>.**
19. or approved equal.

Fan coil units come with various coil configurations, the most typical being split coil systems with one heating and three cooling coils. The coils tend to be row split rather than face split, although both configurations are available. Units can also come with either a two-pipe or a four-pipe system, depending on Project design requirement.

B. Fan Coil Unit Configurations: [**Row**] [**Face**] split.

1. Number of Heating Coils: [**One**] with two-pipe system.
2. Number of Cooling Coils: [**One**] [**Three**] with [**two**][**four**]-pipe system.

Closed-cell insulation with foil or matt facing is provided by some manufacturers to reduce the possibility of fibers from glass-fiber insulation being introduced into the conditioned space. If fan coil unit cabinet is constructed from double-wall insulated panels, then coil unit may not be insulated separately. Retain one of two "Coil Section Insulation" paragraphs below for coil section insulation.

C. Coil Section Insulation: [**1/2-inch- (13-mm-)**] [**1-inch- (25-mm-)**] **<Insert dimension>** thick, [**coated**] [**foil-faced**] glass fiber complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Coil Section Insulation: Insulate coil section according to Section 230616 "HVAC Equipment Insulation."

1. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Removable drain pans are an extra feature with some manufacturers.

"(Main and Auxiliary)Drain Pans" Removable drain pans are an extra feature with some manufacturers. Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1.

- E. **[Main and Auxiliary]**Drain Pans: **[Plastic] [Stainless steel] [Insulated galvanized steel with plastic liner]**. Fabricate pans and drain connections to comply with ASHRAE 62.1.
- F. Chassis: Galvanized steel where exposed to moisture[, **with baked-enamel finish and removable access panel**][, **with powder-coat finish and removable access panel**]. Floor-mounting units shall have leveling screws.
- G. Cabinets: Steel with baked-enamel finish in manufacturer's standard paint color.
1. Supply-Air Plenum: Sheet metal plenum finished and insulated to match the chassis[**with mill-finish, aluminum, double-deflection grille**].

Retain "Return-Air Plenum" or "Mixing Plenum" Subparagraph below.

2. Return-Air Plenum: Sheet metal plenum finished to match the chassis.
3. Mixing Plenum: Sheet metal plenum finished and insulated to match the chassis with outdoor- and return-air, formed-steel dampers.
4. Dampers: Galvanized steel with extruded-vinyl blade seals, flexible-metal jamb seals, and interlocking linkage.

Verify available filters with fan coil unit manufacturer. Indicate filter thickness in "Capacities and Characteristics" Paragraph or in the Fan Coil Unit Schedule on Drawings.

For further information on air filters and air filter ratings, see Section 234100 "Particulate Air Filtration."

- H. Filters: Minimum arrestance and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2 and all addendums.

Retain "MERV Rating" Paragraph below to require compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher. Also, retain paragraph for LEED Prerequisite IEQ 1. LEED-NC, LEED-CI, and LEED for Schools Credit IEQ 3.1 and LEED-CS Credit IEQ 3 require that filters have a minimum MERV 13 rating for systems that deliver air to occupied spaces.

- I. MERV Rating: **[6] [13] <Insert number>** when tested according to ASHRAE 52.2.

Retain one or more of three subparagraphs below. Indicate filter type in the Fan Coil Unit Schedule on Drawings. 2-inch- (50-mm-) thick washable foam is unavailable. Retain third subparagraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

1. Washable Foam: 70 percent arrestance and MERV[**3**].
 2. Glass Fiber Treated with Adhesive: 80 percent arrestance and MERV[**5**].
 3. Pleated Cotton-Polyester Media: 90 percent arrestance and MERV[**7**].
- J. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch (2.5 mm)**, rated for a minimum working pressure of **200 psig (1378 kPa)** and a maximum entering-water temperature of **220 deg F (104 deg C)**. Include manual air vent and drain.

Retain "Indoor Refrigerant Coils" Paragraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

- K. Indoor Refrigerant Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch (2.5 mm)** and brazed joints at fittings. Comply with AHRI 210/240, and leak test to minimum **450 psig (3105 kPa)** for a minimum **300-psig (2070-kPa)** working pressure. Include thermal expansion valve.
- L. Steam Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch (2.5 mm)**, rated for a minimum working pressure of **75 psig (517 kPa)**.
- M. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

Retain "Direct-Driven Fans" or "Belt-Driven Fans" Paragraph below. Retain both if multiple-type units are required. If retaining both, indicate fan type in the Fan Coil Unit Schedule on Drawings.

- N. Direct-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.
- O. Belt-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the cabinet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project. Permanently lubricated ball bearings are available for motors up through 5 hp. Larger motors have grease-lubricated ball bearings.

Retain "Motors" Subparagraph below with "Direct-Driven Fans" or "Belt-Driven Fans" Paragraph above.

1. Motors: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

Retain "Factory, Hydronic Piping Package" Paragraph below to suit Project. Delete if factory piping package is not required.

- P. Factory, Hydronic Piping Package: **[ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M Type C)]** copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.

Retain one or more of first four subparagraphs below.

1. **[Two][Three]-way, [two-position] [modulating]** control valve for chilled-water coil.
2. **[Two][Three]-way, [two-position] [modulating]** control valve for heating coil.
3. **[Two][Three]-way, [two-position] [modulating]** control valve for dual-temperature coil.

4. **[Two][Three]**-way, **[two-position] [modulating]** control valve for reheat coil.
 5. Hose Kits: Minimum **400-psig (2758-kPa)** working pressure and operating temperatures from **33 to 211 deg F (0.5 to 99 deg C)**. Tag hose kits to equipment designations.
 - a. Length: **[24 inches (600 mm)] [36 inches (900 mm)] <Insert dimension>**.
 - b. Minimum Diameter: Equal to fan coil unit connection size.
 6. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and **600-psig (4140-kPa)** minimum CWP rating and blowout-proof stem.
 7. Calibrated-Orifice Balancing Valves: Bronze body, ball type; **125-psig (860-kPa)** working pressure, **250 deg F (121 deg C)** maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and a memory stop to retain set position.
 8. Automatic Flow-Control Valve: Brass or ferrous-metal body; **300-psig (2070-kPa)** working pressure at **250 deg F (121 deg C)**; with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of **2 to 80 psig (13.8 to 552 kPa)**.
 9. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); **125-psig (860-kPa)** working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum **NPS 1/2 (DN 15)** hose-end, full-port, ball-type blowdown valve in drain connection.
 10. Wrought-Copper Unions: ASME B16.22.
- Q. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."
- R. Control devices and operational sequence are specified in Section 230548 "Vibration and Seismic Controls for HVAC Piping and Equipment."

Retain last paragraph above and delete "Basic Unit Controls" Paragraph below if controls are part of overall temperature-control system.

S. Basic Unit Controls:

1. Control voltage transformer.

Verify control features with manufacturer.

2. **[Wall-mounting] [Unit-mounted]** thermostat with the following features.
 - a. Heat-cool-off switch.
 - b. Fan on-auto switch.

Retain first subparagraph below if multispeed motors are specified.

- c. Fan-speed switch.
- d. **[Manual] [Automatic]** changeover.
- e. Adjustable deadband.
- f. **[Concealed] [Exposed]** set point.
- g. **[Concealed] [Exposed]** indication.

- h. **[Degree F] [Degree C]** indication.
- 3. **[Wall-mounting] [Unit-mounted]** humidistat.
 - a. **[Concealed] [Exposed]** set point.
 - b. **[Concealed] [Exposed]** indication.
- 4. **[Wall-mounting] [Unit-mounted]** temperature sensor.
- 5. Unoccupied-period-override push button.
- 6. Data entry and access port.
 - a. Input data includes room temperature, and humidity set points and occupied and unoccupied periods.
 - b. Output data includes room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

Retain "(DDC)Terminal Controller" Paragraph below and coordinate with "Basic Unit Controls" Paragraph above or with control devices specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

T. **[DDC]**Terminal Controller:

- 1. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
- 2. Unoccupied-Period-Override Operation: **[Two] <Insert number>** hours.
- 3. Unit Supply-Air Fan Operation:
 - a. Occupied Periods: Fan runs continuously.
 - b. Unoccupied Periods: Fan cycles to maintain room setback temperature.
- 4. Hydronic-Cooling-Coil Operation:
 - a. Occupied Periods: **[Open] [Modulate]** control valve to maintain room temperature.
 - b. Unoccupied Periods: Close control valve.

Retain "Refrigerant-Coil Operation" Subparagraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

- 5. Refrigerant-Coil Operation:
 - a. Occupied Periods: Start compressor to maintain room temperature or humidistat set point.
 - b. Unoccupied Periods: Stop compressor cooling and cycle compressor for heating to maintain setback temperature.
- 6. **[Supplemental]**Heating-Coil Operation:

- a. Occupied Periods: **[Open control valve] [Modulate control valve] [Energize electric-resistance coil]** to provide heating if room temperature falls below thermostat set point.
- b. Unoccupied Periods: Start fan and **[open control valve] [modulate control valve] [energize electric-resistance coil]** if room temperature falls below setback temperature.

Retain first subparagraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

- c. Switch refrigerant-reversing valve to operate supplemental coil for heating when outdoor temperature is below **[25 deg F (4 deg C)] <Insert temperature>**.

7. Dual-Temperature Hydronic-Coil Operation:

- a. Occupied Periods: When chilled water is available, **[open] [modulate]** control valve if room temperature exceeds thermostat set point. When hot water is available, **[open] [modulate]** control valve if temperature falls below thermostat set point.
- b. Unoccupied Periods: When chilled water is available, close valve. When hot water is available, **[open] [modulate]** control valve if room temperature falls below thermostat setback temperature.

8. Reheat-Coil Operation:

Retain "Humidity Control for Occupied Periods" and "Humidity Control for Unoccupied Periods" subparagraphs below if reheat coil provides reheating only.

- a. Humidity Control for Occupied Periods:
 - 1) Humidistat **[opens control valve] [modulates control valve] [energizes electric-resistance coil]** to provide heating. As room temperature rises above set point, cooling-coil valve **[opens] [modulates]** to maintain room temperature.
- b. Humidity Control for Unoccupied Periods: **[Close control valve] [De-energize]**.

Retain "Occupied Periods" and "Unoccupied Periods" subparagraphs below if reheat coil provides heating and reheating.

- c. Occupied Periods:
 - 1) Heating Operations: **[Open control valve] [Modulate control valve] [Energize electric-resistance coil]** to provide heating if room temperature falls below thermostat set point.
 - 2) Humidity-Control Operations: Humidistat **[opens control valve] [modulates control valve] [energizes electric-resistance coil]** to provide heating. As room temperature rises above set point, cooling-coil valve **[opens] [modulates]** to maintain room temperature.

- d. Unoccupied Periods: Start fan and **[open control valve] [modulate control valve] [energize electric-resistance coil]** if room temperature falls below setback temperature. Humidity control is not available.

Retain first "Outdoor-Air Damper Operation" Subparagraph below for fixed, minimum outdoor-air intake.

9. Outdoor-Air Damper Operation:
 - a. Occupied Periods: Open damper to fixed position for **[25] <Insert number>** percent outdoor air.
 - b. Unoccupied Periods: Close damper.

Retain "Outdoor-Air Damper Operation" Subparagraph below for outdoor-air economizer cycle based on temperature.

10. Outdoor-Air Damper Operation:
 - a. Occupied Periods:
 - 1) Outdoor-Air Temperature below Room Temperature: If room temperature is above room-temperature set point, modulate outdoor- and return-air dampers to maintain room temperature set point (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum setting.
 - 2) Outdoor-Air Temperature above Room Temperature: Position damper to fixed minimum position for **[25] <Insert number>** percent outdoor air.
 - b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

Retain "Outdoor-Air Damper Operation (Enthalpy Based)" Subparagraph below for outdoor-air economizer cycle based on enthalpy.

11. Outdoor-Air Damper Operation (Enthalpy Based):
 - a. Occupied Periods:
 - 1) Outdoor-Air Enthalpy below Room Enthalpy: If room temperature is above room-temperature set point, modulate outdoor-air damper to maintain room temperature (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum position for **[25] <Insert number>** percent outdoor air.
 - 2) Outdoor-Air Enthalpy above Room Enthalpy: Position damper to fixed minimum position for **[25] <Insert number>** percent outdoor air.
 - b. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

12. Controller shall have volatile-memory backup.

- U. Interface with DDC System for HVAC Requirements:
1. Interface relay for scheduled operation.
 2. Interface relay to provide indication of fault at the central workstation.
 3. Provide **[BACnet]** [or] **[LonWorks]** interface for central DDC system for HVAC workstation for the following functions:
 - a. Adjust set points.
 - b. Fan coil unit start, stop, and operating status.
 - c. Data inquiry, including **[outdoor-air damper position,]**supply- and room-air temperature[**and humidity**].
 - d. Occupied and unoccupied schedules.
- V. Electrical Connection: Factory wire motors and controls for a single electrical connection.

If Project has more than one type or configuration of fan coil unit, delete "Capacities and Characteristics" Paragraph below and schedule fan coil units on Drawings.

- W. Capacities and Characteristics:
1. Fan:
 - a. Airflow: **<Insert cfm (L/s)>**.
 - b. Static Pressure: **<Insert inches wg (kPa)>**.
 - c. Fan Speed: **<Insert rpm>**.
 - d. Motor Speed: **<Insert rpm>**.
 - e. Motor Horsepower: **<Insert horsepower>**.
 - f. Drive: **[Direct] [Belt]**.
 2. Cooling Capacity:
 - a. Total: **<Insert Btu/h (kW)>**.
 - b. Sensible: **<Insert Btu/h (kW)>**.
 - c. Entering-Air Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - d. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 3. Chilled-Water Coil:
 - a. Water Flow: **<Insert gpm (L/s)>**.
 - b. Water-Side Pressure Loss: **<Insert feet wg (kPa)>**.
 - c. Air-Side Pressure Drop: **<Insert inches wg (kPa)>**.
 - d. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 4. Refrigerant Coil:
 - a. Air-Side Pressure Loss: **<Insert inches wg (kPa)>**.

Retain "Refrigerant Coil" Subparagraph below only when the fan coil unit includes refrigerant coils working in conjunction with a remote condenser unit. Remote condensing units are specified in Section 236200 "Packaged Compressor and Condenser Units."

- b. Suction Temperature: <Insert deg F (deg C)>.
5. Heating Capacity:
 - a. Output: <Insert Btu/h (kW)>.
 - b. Entering-Air Temperature: <Insert deg F (deg C)>.
 - c. Air-Temperature Rise: <Insert deg F (deg C)>.
6. Hot-Water Heating Coil:
 - a. Water Flow: <Insert gpm (L/s)>.
 - b. Water-Side Pressure Loss: <Insert feet wg (kPa)>.
 - c. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
 - d. Entering-Water Temperature: <Insert deg F (deg C)>.
7. Steam Heating Coil:
 - a. Inlet Steam Pressure: <Insert psig (kPa)>.
 - b. Condensing Capacity: <Insert lb/h (g/s)>.
 - c. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
8. Electric-Resistance Heating Coil:
 - a. Capacity: <Insert kilowatts>.
 - b. Number of Steps: <Insert number>.
 - c. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
9. Reheat Capacity:
 - a. Output: <Insert Btu/h (kW)>.
 - b. Entering-Air Temperature: <Insert deg F (deg C)>.
 - c. Air-Temperature Rise: <Insert deg F (deg C)>.
10. Filters:
 - a. Face Area: <Insert sq. ft. (sq. m)>.
 - b. Thickness: [1 inch (25 mm)] [2 inches (50 mm)] <Insert dimension>.
11. Electrical Characteristics for Single-Point Connection:
 - a. Voltage/Phase/Hertz: <Insert values>.
 - b. Full-Load Amperes: <Insert values>.
 - c. Maximum Circuit Amperes: <Insert values>.
 - d. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas, with Installer present, to receive fan coil units for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping and electrical connections to verify actual locations before fan coil unit installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install fan coil units level and plumb.
- D. Install fan coil units to comply with NFPA 90A.
- E. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- F. Protection: Provide finished cabinet units with protective covers during balance of construction.

Retain first paragraph below for horizontal, suspended units.

- G. Suspend fan coil units from structure with elastomeric hangers. Vibration isolators are specified in Section 230548 "Vibration and Seismic Controls for HVAC Piping and Equipment."

Verify mounting height in first paragraph below with authorities having jurisdiction to comply with requirements of the Americans with Disabilities Act.

- H. Verify locations of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices [48 inches (1220 mm)] [60 inches (1525 mm)] <Insert dimension> above finished floor.
- I. Install new filters in each fan coil unit within two weeks after Substantial Completion.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:
1. Install piping adjacent to machine to allow service and maintenance.
 2. Connect piping to fan coil unit factory hydronic piping package. Install piping package if shipped loose.
 3. Connect condensate drain to indirect waste.
 4. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
 5. Install piping adjacent to machine to allow service and maintenance.

Retain subparagraph below for concealed and ducted fan coil units.

- a. Install condensate trap of adequate depth to seal against fan pressure. Install cleanouts in piping at changes of direction.

Retain first paragraph below for ducted fan coil units. Coordinate duct installation requirements with Drawings and with requirements specified in Section 233113 "Metal Ducts," Section 233116 "Nonmetal Ducts," and Section 233300 "Air Duct Accessories."

- B. Connect supply-air and return-air ducts to fan coil units with flexible duct connectors specified in Section 233300 "Air Duct Accessories." Comply with safety requirements in UL 1995 for duct connections.
- C. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- E. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Retain first subparagraph below if units have electric heat.

2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
 3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Retest as specified above after repairs or replacements are made.
- F. Prepare test and inspection reports.

3.5 ADJUSTING

Retain this article if control devices are specified in this Section; delete if they are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

- A. Adjust initial temperature and humidity set points.
- B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two (2)] <Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.6 CLEANING

- A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets.

- B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.
- C. Install new filters.

3.7 DEMONSTRATION

Delete this article if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain fan coil units.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238219

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SECTION 238223 - UNIT VENTILATORS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include unit ventilators may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes unit ventilators and accessories with the following heating and cooling features:

Some manufacturers can provide both heating and reheat coils in same unit; however, for most applications, retain heating or reheat coil.

1. [Hydronic] [Steam] [Electric] heating coil.
2. [Hydronic] [Steam] [Electric] reheat coil.

3. **[Hydronic] [Direct-expansion refrigerant]** cooling coil.

B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 238146.13 "Water-to-Air Heat Pumps" for ground-loop, water-source heat-pump-type unit ventilators.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product

1. Include rated capacities, operating characteristics, and furnished specialties and accessories for each unit type and configuration.
2. Include data substantiating that materials comply with requirements.

B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Detail anchorages and attachments to structure and to supported equipment.
4. Include diagrams for power, signal, and control wiring.

Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs below for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- D. Samples for Initial Selection: For units with factory-applied color finishes.

- E. Samples for Verification: For each type of unit ventilator[**and auxiliary shelves**] and cabinets indicated.

Delete paragraph (and subparagraphs below) if mockups not required. If retaining, indicate location, size, and other details of mockups on drawings or with inserts.

Verify mockup requirements with DEN Project Manager.

- F. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide **<Insert number>** mockup, **<Insert number>** feet long by **<Insert number>** feet wide, of **<typical exterior wall module> <one typical bay, under window enclosure assembly complete with induction units>**.
2. Locate **<where directed by DEN Project Manager> <Insert location>**.
3. Mockup may **<not>** remain as part of the Work.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

Revise subparagraphs below for ceiling-mounted unit ventilators.

1. Suspended ceiling components.
2. Structural members to which equipment will be attached.
3. Method of attaching hangers to building structure.
4. Size and location of initial access modules for acoustical tile.
5. Size and location of access panels in hard ceilings to provide access to concealed units.
6. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. **<Insert item>**.

7. Perimeter moldings.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC Piping and Equipment." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For unit ventilators, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.
- D. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For unit ventilators to include in emergency, operation, and maintenance manuals.
 - 1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Maintenance schedules and repair part lists for motors, coils, integral controls, and filters.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Unit Ventilator Filters: Furnish <Insert number> spare filter(s) for each filter installed.

Retain "Spare Cooling Chassis" Subparagraph below only for integral cooling chassis unit ventilators.

2. Spare Cooling Chassis: Furnish <Insert number> spare integral cooling chassis for each size unit installed.

1.7 QUALITY ASSURANCE

- A. Comply with NFPA 70. Listed and labeled by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1.

- C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.8 COORDINATION

Delete this article if unit ventilators are wall or floor mounted.

Revise first paragraph below to delete or add types of construction that penetrate or are supported by ceilings.

- A. Coordinate layout and installation of unit ventilators and suspension system components with other construction that penetrates or is supported by ceilings, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

Retain paragraph below for units with outdoor air.

- B. Coordinate size and location of wall sleeves for outdoor-air intake.

1.9 WARRANTY

Delete this article if remote or integral condensing unit is not required.

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

Warranties vary among manufacturers from covering the whole unit for up to four years, to only the compressor for five to 10 years, or only the condenser coil for five years. Extended special warranties are limited to units in the 1- to 5-ton (3.5- to 17.6-kW) range, and then are usually restricted to residential applications.

- A. Special Warranty: Manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Compressor failure.
 - b. Condenser coil leak.

Verify available warranties and warranty periods for units and components.

- 2. Warranty Period: Minimum **[four (4)] [five (5)] [10 (10)] <Insert number>** years from date of Substantial Completion.
- 3. Warranty Period (Compressor Only): Minimum **[five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.
- 4. Warranty Period (Condenser Coil Only): Minimum **[five (5)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Factory-packaged and -tested units rated according to AHRI 840, ASHRAE 33, and UL 1995.

- C. Radiated noise shall not exceed:
1. NC 35 – In Office.
 2. NC 40 – Terminal/Concourse.
 3. NC 45 – Maintenance Facilities.

2.2 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carrier Corporation.
 2. Engineered Air Ltd.
 3. McQuay International.
 4. Nesbitt Aire, Inc.
 5. Trane.
 6. Venmar CES Inc.
 7. **<Insert manufacturer's name>.**
 8. or approved equal.

Many additional features are available for this product. Some are mutually exclusive. Include all features for unit ventilators that are required for Project, and identify additional features for specific units in a Unit Ventilator Schedule on Drawings.

2.3 MANUFACTURED UNITS

- A. Description: Unit ventilators consisting of finished cabinet, filter, cooling coil, drain pan, supply-air fan and motor in [**blow-**] [**or**] [**draw-**]through configuration, and hydronic cooling coil.
1. Unit Ventilator Coil Configurations: [**Row**] [**Face**] split.
 - a. Number of Heating Coils: [**One**] with two-pipe system.
 - b. Number of Cooling Coils: [**One**] [**Three**] with [**two**][**four**]-pipe system.

2.4 CABINETS

Closed-cell insulation with foil or matt facing is provided by some manufacturers to reduce the possibility of fibers from glass-fiber insulation being introduced into the conditioned space. Retain "Insulation" or "Coil Section Insulation" Paragraph below for coil section insulation.

- A. Insulation: Minimum [**1/2-inch-** (13-mm-)] [**1-inch-** (25-mm-)] **<Insert dimension>** thick, [**coated glass fiber**] [**foil-covered, closed-cell foam**] [**matte-finish, closed-cell foam**] complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

- B. Coil Section Insulation: Insulate coil section according to Section 230616 "HVAC Equipment Insulation."

1. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

"Main and Auxiliary Drain Pans" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1. Removable drain pans in paragraph are an extra feature with some manufacturers.

- C. Main and Auxiliary Drain Pans: [**Plastic**] [**Insulated galvanized steel with plastic liner**], formed as required by ASHRAE 62.1. [**Drain pans shall be removable.**]

- D. Cabinet Frame and Access Panels: Welded-steel frame with removable panels fastened with hex-head tamperproof fasteners[**and key-operated control and valve access doors**].

1. Steel components exposed to moisture shall be [**hot-dip galvanized after fabrication**] [**baked-enamel finished**] [**powder-coat finished**].

Retain one of two "Cabinet Finish" paragraphs below to suit Project. Coordinate custom-color requirements with sample submittal requirements. Coordinate field painting with painting Sections.

- E. Cabinet Finish: Baked-on primer ready for field painting.
- F. Cabinet Finish: [**Baked enamel**] [**Powder coat**], in manufacturer's [**standard**] [**custom**] color as selected by Architect.
- G. Indoor-Supply-Air Grille: [**Steel**] [**Aluminum**], [**double deflection, adjustable**] [**adjustable linear bar**].

Note limitations of configurations when retaining an option in "Return-Air Inlet" Paragraph below.

- H. Return-Air Inlet: [**Front toe space**] [**Back inlet with top inlet grille**].

Retain "End Panels" Paragraph below if unit ventilators are freestanding.

- I. End Panels: Matching material and finish of unit ventilator.
- J. Outdoor-Air Wall Box: Minimum **0.1265-inch** (3.2-mm-) thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen.
 - 1. Louver Configuration: [**Horizontal**] [**Vertical**], rain-resistant louver.
 - 2. Louver Material: [**Aluminum**] [**Steel**].
 - 3. Bird Screen: **1/2-inch** (13-mm) mesh screen on interior side of louver.
 - 4. Decorative Grille: On outside of intake.
 - 5. Finish: [**Anodized aluminum**] [**Baked enamel**], color as selected by Architect from manufacturer's [**standard**] [**custom**] colors.

2.5 COILS

- A. Test and rate unit ventilator coils according to ASHRAE 33.
- B. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm), rated for a minimum working pressure of **200 psig** (1378 kPa) and a maximum entering-water temperature of **220 deg F** (104 deg C). Include manual air vent and drain valve.
- C. Steam Coils: Copper[**distributing**] tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm), rated for a minimum working pressure of **75 psig** (517 kPa).

Some manufacturers limit air-to-air heat pumps to electric supplemental heating coils.

- D. Electric-Resistance Heating Coils: Nickel-chromium heating wire or tubular elements in coil fins, free of expansion noise and hum, with fuses in terminal box for overcurrent protection and continuous limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

Retain "Indoor Refrigerant Coils" Paragraph below for integral or remote condensing units.

- E. Indoor Refrigerant Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm), and brazed joints at fittings. Comply with AHRI 210/240, and leak test to minimum **450 psig** (3105 kPa) for a minimum **300-psig** (2070-kPa) working pressure. Include thermal expansion valve.

2.6 INDOOR FAN

- A. Fan and Motor Board: Removable.
 - 1. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.
 - 2. Fan Shaft and Bearings: Hollow-steel shaft with permanently lubricated, resiliently mounted bearings.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project. Permanently lubricated ball bearings are available for motors up through 5 hp.

3. Motor: Permanently lubricated, multispeed, resiliently mounted on motor board. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
4. Wiring Termination: Connect motor to chassis wiring with plug connection.

2.7 DAMPERS

- A. Mixing Dampers: Galvanized-steel blades with edge and end seals and nylon bearings; with **[electric]** **[pneumatic]** actuator.
- B. Outdoor-Air Dampers: Galvanized-steel blades with edge and end seals and nylon bearings; with **[electric]** **[pneumatic]** actuator.

Face and bypass dampers in "Face and Bypass Dampers" Paragraph below are optional.

- C. Face and Bypass Dampers: Galvanized-steel damper blades with edge and end seals and nylon bearings; with factory-mounted **[electric]** **[pneumatic]** actuator.

Retain paragraph below to comply with LEED Prerequisite EA 2.

- D. Comply with ASHRAE/IES 90.1.

2.8 ACCESSORIES

Verify availability of additional features for unit ventilators specified.

- A. Exhaust Shutter: **[Barometric]** **[Motorized, modulating]** type designed to limit room pressure to maximum **0.10-inch wg** (25 kPa) with **[steel]** **[aluminum]** **[fabric]** damper blades, including edge and end seals, in galvanized-steel frame with **[outdoor]** **[and]** **[interior]** wall grille.
- B. Subbase: Sheet metal floor-mounting base with leveling screws and black enamel finish.
- C. Insulated false back with gasket seals on wall and outdoor-air plenum.
 1. Insulation: Minimum **[1/2-inch- (13-mm-)]** **[1-inch- (25-mm-)]** **<Insert dimension>** thick, **[coated glass fiber]** **[foil-covered, closed-cell foam]** **[matte-finish, closed-cell foam]** complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.
 - a. Surface-Burning Characteristics: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84 by a qualified testing agency.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

- b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

- D. Return-air plenum, 6 inches (150 mm) thick, designed to take return air from top inlet grilles in cabinets on both sides of unit ventilator with gasket seals on wall and outdoor-air plenum extension.

Retain first paragraph below for concealed unit ventilators.

- E. Duct flanges for supply-, return-, and outdoor-air connections.
- F. Radiation Grille: [Steel] [Aluminum], [linear-bar] [stamped] grille with finish to match discharge-air grille.

Verify available filters with unit ventilator manufacturer.

For further information on air filters and air filter ratings, see Section 234100 "Particulate Air Filtration."

- G. Filters: Minimum arrestance and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2 and all addendums.

Retain "MERV Rating" Subparagraph below to require compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher. Also, retain subparagraph for LEED Prerequisite IEQ 1. LEED-NC, LEED-CI, and LEED for Schools Credit IEQ 3.1 and LEED-CS Credit IEQ 3 require that filters have a minimum MERV 13 rating for systems that deliver air to occupied spaces.

1. MERV Rating: [6] [13] <Insert number> when tested according to ASHRAE 52.2.

Retain one of three subparagraphs below. Retain third subparagraph if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

2. Washable Foam: 70 percent arrestance and MERV[3].
3. Glass Fiber Treated with Adhesive: 80 percent arrestance and MERV[5].
4. Pleated Cotton-Polyester Media: 90 percent arrestance and MERV[7].

- H. Energy Recovery Wheel:

1. Casing: Steel with manufacturer's standard paint coating and with the following:
 - a. Integral purge section.
 - b. Casing seals on periphery of rotor, on duct divider, and on purge section.
 - c. Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.
2. Rotor: Corrugated-aluminum, segmented wheel strengthened with radial spokes, and having nontoxic, noncorrosive silica-gel desiccant coating. Construct media for passing maximum 800-micrometer solids and maximum 0.04 percent cross contamination by volume of exhaust air. Drive rotor with belt around outside of rotor.

3. Defrost Coils: Electric defrost coil in the exhaust airstream.
4. Drive: Fractional horsepower motor and gear reducer, with speed changed by adjustable variable frequency controller.
5. Inlet and Discharge Fans: Forward curved, centrifugal; resiliently mounted with flexible duct connections.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

- a. Motor and Drive: Permanently lubricated, direct driven. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Filters: 1-inch- (25-mm-) thick, disposable type, mounted in galvanized-steel frame upstream of energy recovery wheel in both supply and exhaust airstreams.
7. Electrical: Single electrical connection from attached unit ventilator.

2.9 FACTORY HYDRONIC PIPING PACKAGE

- A. Piping: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M Type C)] copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet. Crossover piping, [NPS 1-1/2 (DN 40)] [NPS 2 (DN 50)] <Insert pipe size> with shutoff valves.
- B. Control Valves: [Electric] [Pneumatic] actuators compatible with terminal controller and building controls.

Retain one or more of four subparagraphs below.

1. [Two][Three]-way, [two-position] [modulating] control valve for dual-temperature-water coil.
 2. [Two][Three]-way, [two-position] [modulating] control valve for chilled-water coil.
 3. [Two][Three]-way, [two-position] [modulating] control valve for hot-water heating coil.
 4. [Two][Three]-way, [two-position] [modulating] control valve for hot-water reheat coil.
- C. Hose Kits: Minimum 400-psig (2758-kPa) working pressure and operating temperatures from 33 to 211 deg F (0.5 to 99 deg C). Tag hose kits to equipment designations.
 1. Length: [24 inches (600 mm)] [36 inches (900 mm)] <Insert dimension>.
 2. Minimum Diameter: Equal to unit ventilator connection size.
 - D. Isolation Valves, Strainers, Unions, and Balance Valves:
 1. Two-Piece Ball Valves: Bronze body with stainless-steel ball and stem and galvanized-steel lever handle for each supply and return connection. If balancing

- device is combination shutoff type with memory stop, isolation valve may be omitted on the return.
2. Calibrated-Orifice Balancing Valves: Bronze body, ball type; **125-psig** (860-kPa) working pressure, **250 deg F** (121 deg C) maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and a memory stop to retain set position.
 3. Automatic Flow-Control Valve: Brass or ferrous-metal body; **300-psig** (2070-kPa) working pressure at **250 deg F** (121 deg C); with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of **2 to 80 psig** (13.8 to 552 kPa).
 4. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); **125-psig** (860-kPa) working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum **NPS 1/2** (DN 15) hose-end, full-port, ball-type blowdown valve in drain connection.
 5. Wrought-Copper Unions: ASME B16.22.

2.10 INTEGRAL COOLING CHASSIS

- A. Description: Assembly mounted within unit ventilator, factory assembled and tested; consisting of compressors, condenser coils, fans, motors, and refrigerant receivers; removable for maintenance, with plug and receptacle connections for control and power wiring. Construct, test, and rate condensing units according to AHRI 210/240 and ASHRAE 15.
- B. Casing: Galvanized steel with removable panels for access to controls and refrigerant piping.
- C. Exterior Louver: Extruded aluminum.
- D. Compressor: Hermetic, [**scroll**] [**reciprocating**] type; internally isolated for vibration with factory-installed safety devices as follows:
 1. Antirecycle timer.
 2. High-pressure cutout.
 3. Low-pressure cutout or loss-of-charge switch.
 4. Internal thermal-overload protection.
 5. Current- and voltage-sensitive safety devices.

Retain "Energy Efficiency" Paragraph below if applying for LEED certification or if required by Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1.

- E. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IES 90.1, "Energy Standard for Buildings except Low-Rise Residential Buildings."
- F. Refrigerant Piping Materials:
 1. Drawn-Temper Copper Tube: [**ASTM B 88, Type L** (ASTM B 88M, Type B)].

2. Annealed-Temper Copper Tube: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type K (ASTM B 88M, Type A)].
3. Wrought-Copper Fittings: ASME B16.22.

Retain one of two "Refrigerant" paragraphs below to require a specific refrigerant type; delete both if any refrigerant type is acceptable. LEED-NC, LEED-CS, and LEED for Schools Credit EA 4 award a single point if all HVAC&R equipment complies with requirements for enhanced refrigerant management. Retain second or third option in first paragraph or retain second paragraph to comply with Credit EA 4.

- G. Refrigerant: [R-22] [R-407C] [R-410A].
- H. Refrigerant: R-407C or R-410A.
- I. Low ambient controls to permit operation down to 45 deg F (7 deg C).
- J. Crankcase heater.
- K. Charging and service fittings.
- L. Filter dryer.
- M. Air-to-Air Heat Pump: Pilot-operated, sliding-type reversing valve with replaceable magnetic coil, and controls for air-to-air heat pump operation with supplemental heat.
- N. HGBP, constant-pressure expansion valve and controls to maintain continuous refrigeration system operation at 10 percent of full load.
- O. Condenser: Copper-tube, aluminum-fin coil, with liquid subcooler.
- P. Direct-Driven Condenser Fan: Forward curved, double width, centrifugal; thermoplastic or painted-steel wheels and galvanized-steel fan scrolls.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

1. Motor: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.11 BASIC UNIT CONTROLS

Retain first paragraph below and delete "Basic Unit Controls" Paragraph below if controls are part of overall temperature-control system.

- A. Control devices and operational sequences are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Basic Unit Controls:
 1. Control voltage transformer.

Verify control features with manufacturer.

2. **[Wall-mounting] [Unit-mounted]** thermostat with the following features.
 - a. Heat-cool-off switch.
 - b. Fan on-auto switch.

Retain first subparagraph below if multispeed motors are specified.

- c. Fan-speed switch.
 - d. **[Manual] [Automatic]** changeover.
 - e. Adjustable deadband.
 - f. **[Concealed] [Exposed]** set point.
 - g. **[Concealed] [Exposed]** indication.
 - h. **[Degree F] [Degree C]** indication.
3. **[Wall-mounting] [Unit-mounted]** humidistat.
 - a. **[Concealed] [Exposed]** set point.
 - b. **[Concealed] [Exposed]** indication.
4. **[Wall-mounting] [Unit-mounted]** temperature sensor.
5. Unoccupied-period-override push button.
6. Data entry and access port.
 - a. Input data includes room temperature, and humidity set points and occupied and unoccupied periods.
 - b. Output data includes room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

Retain "(DDC)Terminal Controller" Paragraph below and coordinate with "Basic Unit Controls" Paragraph above or with control devices specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

C. **[DDC]** Terminal Controller:

1. Safety Controls Operation: Freezestat shall stop fan and close outdoor-air damper if air less than **38 deg F (3 deg C)** enters coils.
2. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
3. Unoccupied-Period-Override Operation: **[Two] <Insert number>** hours.
4. Dual-Temperature Coil Operation:
 - a. Occupied Periods: When chilled water is available, **[open] [modulate]** control valve if room temperature exceeds thermostat set point. When hot water is available, **[open] [modulate]** control valve if room temperature falls below thermostat set point.
 - b. Unoccupied Periods: When chilled water is available, close control valve. When hot water is available, **[open] [modulate]** control valve if room temperature falls below thermostat setback temperature.
5. Hydronic Cooling-Coil Operation:

- a. Occupied Periods: **[Open] [Modulate]** control valve to provide cooling if room temperature exceeds thermostat set point.
- b. Unoccupied Periods: Close control valve.

Refrigerant coil may be cooling or heating with air-to-air heat pump.

6. Refrigerant-Coil Operation:

- a. Occupied Periods: Start compressor to maintain room temperature.
- b. Unoccupied Periods: **[Stop compressor cooling] [Cycle compressor for heating to maintain setback temperature].**

7. **[Supplemental]**Heating-Coil Operation:

- a. Occupied Periods: **[Open control valve] [Modulate control valve] [Energize electric-resistance coil]** to provide heating if room temperature falls below thermostat set point.
- b. Unoccupied Periods: Start fan and **[open control valve] [modulate control valve] [energize electric-resistance coil]** if room temperature falls below setback temperature.
- c. Switch refrigerant-reversing valve to operate supplemental coil for heating when outdoor temperature is below **[25 deg F (4 deg C)] <Insert temperature>**.

8. Reheat-Coil Operation:

Retain "Humidity Control for Occupied Periods" and "Humidity Control for Unoccupied Periods" subparagraphs below if reheat coil provides reheating only.

- a. Humidity Control for Occupied Periods: Humidistat **[opens control valve] [modulates control valve] [energizes electric-resistance coil]** to provide heating. As room temperature rises above set point, cooling-coil valve **[opens] [modulates]** to maintain room temperature.
- b. Humidity Control for Unoccupied Periods: **[Close control valve] [De-energize].**

Retain first "Outdoor-Air Damper Operation" Subparagraph below for fixed outdoor-air intake; retain second subparagraph for economizer cycle. Energy recovery wheel is provided with fixed outdoor-air damper described in first subparagraph.

9. Outdoor-Air Damper Operation: Open to **[25] <Insert number>** percent fixed minimum intake during occupied periods, and close during unoccupied periods.
10. Outdoor-Air Damper Operation: Open to **[25] <Insert number>** percent fixed minimum intake, and maximum 100 percent of the fan capacity to comply with ASHRAE Cycle II during occupied periods, and close during unoccupied periods. Microprocessor controller shall permit air-side economizer operation when outdoor air is less than **[60 deg F (15 deg C)] <Insert temperature>**.
11. Carbon Dioxide Sensor Operation: During occupied periods, reset minimum outdoor-air ratio down to minimum **[10] <Insert number>** percent to maintain maximum **[800-ppm] <Insert value>** concentration.

12. Face-and-Bypass Damper Operation: Position damper to face of coils until room temperature equals thermostat set point; bypass after room-temperature set point is achieved.
13. Cooling Lockout: During economizer cycle operation, block out cooling.
14. HGBP: Open HGBP solenoid valve to maintain minimum suction pressure at compressor.
15. Energy Recovery Wheel Operation:
 - a. Factory-mounted and -wired, starting relay and manual motor starter for field wiring.
 - b. Occupied period is established by [**remote signal**] [**room occupancy sensor**].
 - c. Energy recovery wheel and inlet and discharge fans operate during occupied periods after room temperature set point has been achieved.
 - d. Energy recovery wheel operates during occupied periods, but stops when unit ventilator controls call for cooling, and outdoor-air temperatures permit free air cooling.
 - e. Energy recovery wheel and fans stop during unoccupied periods.
16. Controller shall have volatile-memory backup.

D. Building Automation System (BAS) Interface Requirements:

1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at the central workstation.
3. Provide [**BACnet**] [**or**] [**LonWorks**] interface for central BAS workstation for the following functions:
 - a. Adjust set points.
 - b. Unit ventilator start, stop, and operating status.
 - c. Data inquiry to include [**outdoor-air damper position**,]supply- and room-air temperature[**and humidity**].
 - d. Occupied and unoccupied schedules.

E. Electrical Connection: Factory wire motors and controls for a single electrical connection.

2.12 METAL SHELVES AND CABINETS

Retain features required for Project. Verify available features with manufacturer. Coordinate this article with Drawings.

- A. Include manufacturer's standard cabinets to match unit ventilators with required installation hardware as indicated:
 1. Open Shelving with Reinforced Shelves:
 - a. [**Return-air plenum**] [**Radiation enclosure**] and aluminum bar grille with finish to match unit ventilator grille.
 - b. Through-piping enclosure with solid top.

2. Closed Shelving with Reinforced Shelves:
 - a. **[Return-air plenum] [Radiation enclosure]** and aluminum bar grille with finish to match unit ventilator grille.
 - b. Through-piping enclosure with solid top.
 - c. Two sliding doors with key-operated locks.
 3. Utility compartment with access panel with key-operated lock.
 4. Wall and corner filler sections, and end panels finished to match shelving.
- B. Painted Finish: Manufacturer's **[standard] [custom]** baked enamel, in color selected by Architect, applied to shelving before shipping.
- C. Cabinet Top: Plastic-laminate top in color and pattern selected by Architect from manufacturer's **[standard] [custom]** colors.

2.13 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of unit ventilator, delete this article and schedule unit ventilators on Drawings.

- A. Fan:
1. Airflow: **<Insert cfm (L/s)>**.
 2. External Static Pressure: **<Insert inches wg (kPa)>**.
 3. Fan Speed: **<Insert rpm>**.
 4. Motor Horsepower: **<Insert horsepower>**.
 5. Drive: **[Direct] [Belt]**.
- B. Cooling Capacity:
1. Total: **<Insert Btu/h (kW)>**.
 2. Sensible: **<Insert Btu/h (kW)>**.
 3. Entering-Air Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 4. Entering-Air Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
- C. Chilled-Water Coil:
1. Water Flow: **<Insert gpm (L/s)>**.
 2. Water-Side Pressure Loss: **<Insert feet wg (kPa)>**.
 3. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 4. Air-Side Pressure Drop: **<Insert inches wg (kPa)>**.
- D. Refrigerant Coil:
1. Suction Temperature: **<Insert deg F (deg C)>**.
 2. Air-Side Pressure Drop: **<Insert inches wg (kPa)>**.
- E. Condensing Unit:

1. Ambient Temperature: <Insert deg F (deg C)>.
2. Compressor Power Input: <Insert kilowatts>.

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1. If applying for LEED certification, efficiency must be equal to or greater than minimum efficiency required by ASHRAE/IES 90.1, Table 6.8.1A, "Air Conditioners and Condensing Units," for cooling-only equipment and Table 6.8.1B, "Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirements," for heat pump applications.

3. Cooling Energy Efficiency [(EER)] [(SEER)]: <Insert value>.

Retain "Heating Coefficient of Performance" Subparagraph below for heat pump applications.

4. Heating Coefficient of Performance: <Insert value>.
5. Voltage/Phase/Hertz: <Insert values>.
6. Full-Load Amperes: <Insert value>.
7. Maximum Circuit Amperes: <Insert value>.
8. Maximum Overcurrent Protection: <Insert amperage>.

F. Heating Capacity:

1. Output: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Air-Temperature Rise: <Insert deg F (deg C)>.

G. Hot-Water Heating Coil:

1. Water Flow: <Insert gpm (L/s)>.
2. Water-Side Pressure Loss: <Insert feet wg (kPa)>.
3. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
4. Entering-Water Temperature: <Insert deg F (deg C)>.

H. Steam Heating Coil:

1. Inlet Steam Pressure: <Insert psig (kPa)>.
2. Condensing Capacity: <Insert lb/h (g/s)>.
3. Air-Side Pressure Drop: <Insert inches wg (kPa)>.

I. Electric-Resistance Heating Coil:

1. Capacity: <Insert kilowatts>.
2. Number of Steps: <Insert number>.
3. Air-Side Pressure Drop: <Insert inches wg (kPa)>.

J. Reheat Capacity:

1. Output: <Insert Btu/h (kW)>.
2. Entering-Air Temperature: <Insert deg F (deg C)>.
3. Air-Temperature Rise: <Insert deg F (deg C)>.

K. Filters:

Retain third option in "Type" Subparagraph below if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

1. Type: [**Washable foam**] [**Coated glass fiber**] [**Pleated cotton-polyester media**].
2. Maximum Face Velocity: <Insert fpm (m/s)>.
3. Thickness: [**1 inch (25 mm)**] [**2 inches (50 mm)**] <Insert dimension>.

L. Energy Recovery Exhaust:

1. Airflow: <Insert cfm (L/s)>.
2. Entering-Air Dry-Bulb Temperature: <Insert deg F (deg C)>.
3. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
4. Leaving-Air Dry-Bulb Temperature: <Insert deg F (deg C)>.
5. Leaving-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
6. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
7. Fan Motor Horsepower: <Insert horsepower>.

M. Energy Recovery Outdoor Air:

1. Airflow: <Insert cfm (L/s)>.
2. Entering-Air Dry-Bulb Temperature: <Insert deg F (deg C)>.
3. Entering-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
4. Leaving-Air Dry-Bulb Temperature: <Insert deg F (deg C)>.
5. Leaving-Air Wet-Bulb Temperature: <Insert deg F (deg C)>.
6. Air-Side Pressure Drop: <Insert inches wg (kPa)>.
7. Motor Horsepower: <Insert horsepower>.

N. Energy Recovery Wheel:

1. Heat-Transfer Efficiency: <Insert percent>.
2. Drive Motor Horsepower: <Insert horsepower>.

O. Electrical Characteristics for Single-Point Connection:

1. Voltage/Phase/Hertz: <Insert values>.
2. Full-Load Amperes: <Insert value>.
3. Maximum Circuit Amperes: <Insert value>.
4. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas, with Installer present, to receive unit ventilators for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

- B. Examine roughing-in for piping and electrical connections to verify actual locations before unit ventilator installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install unit ventilators to comply with NFPA 90A.
- D. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- E. Protection: Provide finished cabinet units with protective covers during balance of construction.

Retain first paragraph below for horizontal, suspended units.

- F. Suspend horizontal unit ventilators from structure with threaded steel rods and minimum [0.25-inch (6.35-mm) **static-deflection, elastomeric vibration isolation hanger**] [1.0-inch (25-mm) **static-deflection spring hangers**]. Vibration isolators are specified in Section 230548 "Vibration and Seismic Controls for HVAC Piping and Equipment."

Verify mounting height in first paragraph below with authorities having jurisdiction to comply with requirements of the Americans with Disabilities Act.

- G. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices [48 inches (1220 mm)] [60 inches (1525 mm)] <Insert dimension> above finished floor.

Retain paragraph below for condensing units not packaged with unit ventilators.

- H. Comply with requirements in Section 236200 "Packaged Compressor and Condenser Units" for condensing units matched to refrigerant cooling coil packaged in unit ventilators.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:

1. Install piping adjacent to machine to allow service and maintenance.
2. Connect piping to unit ventilator factory hydronic piping package. Install piping package if shipped loose.
3. Connect condensate drain to indirect waste.
4. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
5. Install piping adjacent to machine to allow service and maintenance.

Retain first paragraph below for unit ventilators with remote condensing units.

- B. Install refrigerant piping as required by Section 232300 "Refrigerant Piping," and add refrigerant as required to compensate for length of piping.

Retain first paragraph below for ducted, unit ventilators. Coordinate duct installation requirements with Drawings and with requirements specified in Section 233113 "Metal Ducts," Section 233116 "Nonmetal Ducts," and Section 233300 "Air Duct Accessories."

- C. Connect supply-air and return-air ducts to unit ventilators with flexible duct connectors specified in Section 233300 "Air Duct Accessories." Comply with safety requirements in UL 1995 for duct connections.
- D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- F. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Retain first subparagraph below if units have electric heat.

2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

Retain subparagraph below if energy recovery wheel is required.

4. Record temperatures entering and leaving energy recovery wheel when outdoor-air temperature is a minimum of **15 deg F (8.3 deg C)** higher, or **20 deg F (11 deg C)** lower, than room temperature.

- D. Remove and replace malfunctioning units and retest as specified above.
- E. Prepare test and inspection reports.

3.5 ADJUSTING

Retain this article if control devices are specified in this Section; delete if they are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

- A. Adjust initial temperature and humidity set points.
- B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two]** **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.6 CLEANING

- A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets.
- B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.
- C. Install new filters.

3.7 DEMONSTRATION

Delete this article if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain unit ventilators.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238223

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SECTION 238229 - RADIATORS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes flat-pipe steel radiators.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
1. Include plans, elevations, sections, and details.
 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Indicate location and size of each field connection.

Retain first subparagraph below for hydronic radiators.

4. Indicate location and arrangement of piping valves and specialties.

Retain subparagraph below for radiators with integral controls; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

5. Indicate location and arrangement of integral controls and other accessories.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Color Samples for Initial Selection" and "Color Samples for Verification" paragraphs for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: For each exposed product and for each color and texture specified.
- D. Color Samples for Initial Selection: For radiators with factory-applied color finishes.
- E. Color Samples for Verification: For each type of exposed finish.
- F. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide **<Insert number>** mockup, **<Insert number>** feet long by **<Insert number>** feet wide, of **<typical exterior wall module>** **<one typical bay, under window enclosure assembly complete with induction units>**.
2. Locate **<where directed by DEN Project Manager>** **<Insert location>**.
3. Mockup may **<not>** remain as part of the Work.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Structural members, including wall construction, to which radiators will be attached.
 - 2. Method of attaching radiators to building structure.
 - 3. Penetrations of fire-rated wall and floor assemblies.
- B. Field quality-control reports.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.5 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 FLAT-PIPE STEEL RADIATORS

Copy this article and re-edit for each style of flat-pipe steel radiator, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Hydro-Air Components Inc.](#)
 - 2. [Quincy Hydronic Technology Inc.](#)
 - 3. [Runtal North America, Inc.](#)
 - 4. <Insert manufacturer's name>.

5. or approved equal.

B. Heating Elements: Steel, welded and formed into flat, square, steel header with minimum thickness of 0.109 inch (2.76 mm). Include threaded piping and air-vent connections.

Retain one of three "Working Pressure" subparagraphs below.

1. Working Pressure: 56 psig (386 kPa); 0.048 inch (1.22 mm).
2. Working Pressure: 85 psig (585 kPa); 0.058 inch (1.47 mm).
3. Working Pressure: 128 psig (881 kPa); 0.078 inch (1.98 mm).

If more than one configuration is required, delete subparagraphs below and schedule on Drawings.

4. Tube Height: <Insert inches (mm)>.
5. Tube Depth: <Insert inches (mm)>.
6. Tube Length: <Insert inches (mm)>.
7. Number of Tubes High: <Insert number>.
8. Number of Tubes Deep: <Insert number>.
9. Room Air Temperature: [65 deg F (18 deg C)] <Insert temperature>.
10. Heat Output: <Insert Btu/h (W)>.
11. Average Water Temperature: [180 deg F (82 deg C)] <Insert temperature>.
12. Temperature Drop: [10 deg F (5.56 deg C)] [20 deg F (11.1 deg C)] [30 deg F (16.6 deg C)] <Insert temperature>.
13. Pressure Loss: <Insert feet wg (kPa)>.

C. Mounting: [Wall brackets] [Floor pedestals] with maximum spacing of 36 inches (914 mm).

D. Finish: Baked-enamel finish in manufacturer's [standard] [custom] color as selected by DEN Project Manager.

E. Accessories:

1. Steel piping covers finished to match radiator finish.
2. Flexible Expansion Compensation Hoses: Minimum 400-psig (2758-kPa) working pressure, and operating temperatures from 33 to 211 deg F (0.5 to 99.5 deg C).
 - a. Length: [24 inches ((600 mm))] [36 inches (900 mm)] <Insert dimension>.
 - b. Minimum Diameter: Equal to connection size.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive radiators for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for hydronic-piping connections to verify actual locations before installation of radiators.

- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install units level and plumb.
- B. Install expansion compensation hoses.
- C. Install piping covers.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect radiators and components to piping according to Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
 - 1. Install shutoff valves on inlet and outlet, and balancing valve on outlet.
- C. Install control valves as required by Section 230923.11 "Control Valves."
- D. Install piping adjacent to radiators to allow service and maintenance.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following field tests and inspections:

Retain "Leak Test" Subparagraph below for hot-water radiators.

- 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- B. Units will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.5 CLEANING

- A. After construction is completed, including painting, clean exposed surfaces of units.
- B. Touch-up marred or scratched surfaces of factory-finished components, using finish materials furnished by manufacturer.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238229

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SECTION 238233 - CONVECTORS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes [**hydronic**] [**steam**] [**electric**] convectors.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. Include data substantiating that materials comply with requirements.

B. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include details and dimensions of custom-fabricated enclosures.
4. Indicate location and size of each field connection.

Retain first subparagraph below for hydronic and steam convectors.

5. Indicate location and arrangement of piping valves and specialties.

Retain first subparagraph below for convectors with integral controls; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

6. Indicate location and arrangement of integral controls.
7. Include enclosure joints, corner pieces, access doors, and other accessories.

Retain subparagraph below for electric convectors.

8. Include diagrams for power, signal, and control wiring.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Color Samples for Initial Selection" and "Color Samples for Verification" paragraphs for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: For each exposed product and for each color and texture specified.
- D. Color Samples for Initial Selection: For units with factory-applied color finishes.
- E. Color Samples for Verification: For each type of exposed finish.
- F. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide **<Insert number>** mockup, **<Insert number>** feet long by **<Insert number>** feet wide, of **<typical exterior wall module>** **<one typical bay, under window enclosure assembly complete with induction units>**.
2. Locate **<where directed by DEN Project Manager>** **<Insert location>**.
3. Mockup may **<not>** remain as part of the Work.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Structural members, including wall construction, to which convectors will be attached.
 - 2. Method of attaching convectors to building structure.
 - 3. Penetrations of fire-rated wall and floor assemblies.
- B. Field quality-control reports.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.5 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 ELECTRIC CONVECTORS

Copy this article and re-edit for each style of convector, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Berko; Marley Engineered Products.
 - 2. Chromalox.
 - 3. Indeeco.
 - 4. Markel Products Company; TPI Corporation.

5. [Marley Engineered Products.](#)
 6. [Ouellet Canada Inc.](#)
 7. [Qmark; Marley Engineered Products.](#)
 8. **<Insert manufacturer's name>.**
 9. or approved equal.
- B. Description: Factory-packaged units constructed according to UL 499, UL 1030, and UL 2021.
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Heating Elements: Nickel-chromium-wire heating element enclosed in metallic sheath mechanically bonded to fins, with high-temperature cutout and sensor running the full length of element. Element supports shall eliminate thermal expansion noise.

If more than one configuration is required, delete subparagraphs below and schedule on Drawings.

1. Volts: **<Insert value>.**
 2. Phase: **<Insert value>.**
 3. Hertz: **<Insert value>.**
 4. Heat Output: **[300] [500] [750] [1000] [1250] [1500] [1750] [2000] [2250] [2500]**
<Insert number> W.
- D. Front and Top Panel: Minimum **[0.0528-inch- (1.35-mm-)] [0.0677-inch- (1.7-mm-)]** **<Insert dimension>** thick steel with exposed corners rounded; removable front panels with tamper-resistant fasteners braced and reinforced for stiffness.
- E. Wall-Mounted Back and End Panels: Minimum **0.0428-inch- (1.1-mm-)** thick steel.
- F. Floor-Mounted Pedestals: Conceal conduit for power and control wiring at maximum **36-inch (914-mm)** spacing. Pedestal-mounted back panel shall be solid panel matching front panel.
- G. Support Brackets: Locate at maximum **36-inch (914-mm)** spacing to support front panel and element.
- H. Insulation: **1/2-inch- (13-mm-)** thick, fibrous glass on inside of the back of the enclosure.
- I. Finish: Baked-enamel finish in manufacturer's **[standard] [custom]** color as selected by DEN Project Manager.
- J. Damper: Knob-operated internal damper.
- K. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size **6 by 7 inches (150 by 175 mm)**, integral with enclosure.
- L. Enclosure Style: **[Sloped] [Flat]** top.

Retain features required for Project in subparagraphs below.

1. Front Inlet Grille: Punched louver; painted to match enclosure.
2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** colors.
 - c. Painted to match enclosure.
3. **[Top]** **[Front]** Outlet Grille: Punched louver; painted to match enclosure.
4. **[Top]** **[Front]** Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** colors.
 - c. Painted to match enclosure.
5. Enclosure Height: **<Insert inches (mm)>**.
6. Enclosure Depth: **<Insert inches (mm)>**.
7. Enclosure Length: **<Insert inches (mm)>**.

Retain "Unit Controls" Paragraph below for integral control device; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- M. Unit Controls: Integral **[line-voltage thermostat with minimum range of 60 to 90 deg F (15 to 32 deg C)] [low-voltage relay and control transformer for remote thermostat]**.
- N. Accessories: Integral disconnect switch, recessing flanges finished to match enclosure or overlapping front cover for fully recessed units, and rubber gaskets to seal cabinet at wall.

2.2 **[HOT-WATER]** **[STEAM]** CONVECTORS

Copy this article and re-edit for each style of convector, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Engineered Air.
 2. Rosemex.
 3. Slant/Fin Corporation.
 4. Sterling Hydronics; a Mestek company.
 5. Trane Inc.
 6. **<Insert manufacturer's name>**.
 7. or approved equal.

- B. Heating Elements: Seamless copper tubing mechanically expanded into evenly spaced aluminum fins and rolled into cast-**[iron]** **[or]** **[brass]** headers with inlet/outlet and air vent; steel side plates and supports. Factory-pressure-test element at minimum **100 psig** (690 kPa).

If more than one configuration is required, delete subparagraphs below and schedule on Drawings.

1. Element Height: **<Insert inches (mm)>**.
2. Element Depth: **<Insert inches (mm)>**.
3. Element Length: **<Insert inches (mm)>**.
4. Entering-Air Temperature: **[65 deg F (18 deg C)] <Insert temperature>**.

Retain first four subparagraphs below for hot-water convector.

5. Heat Output: **<Insert Btu/h per ft. (W/m)>**.
6. Average Water Temperature: **[180 deg F (82 deg C)] <Insert temperature>**.
7. Temperature Drop: **[10 deg F (5.56 deg C)] [20 deg F (11.1 deg C)] [30 deg F (16.6 deg C)] <Insert temperature>**.
8. Pressure Loss: **<Insert feet wg (kPa)>**.

Retain two subparagraphs below for steam convector.

9. Heat Output: **<Insert sq. ft. EDR (W)>**.
10. Entering Steam Pressure: **[1 psig (6.9 kPa)] <Insert value>**.

- C. Front and Top Panel: Minimum **[0.0528-inch- (1.35-mm-)] [0.0677-inch- (1.7-mm-)] <Insert dimension>** thick steel with exposed corners rounded; removable front panels with tamper-resistant fasteners braced and reinforced for stiffness.
- D. Wall-Mounted Back and End Panels: Minimum **0.0428-inch- (1.1-mm-)** thick steel.
- E. Floor-Mounted Pedestals: Conceal conduit for power and control wiring at maximum **36-inch (914-mm)** spacing. Pedestal-mounted back panel shall be solid panel matching front panel.
- F. Support Brackets: Locate at maximum **36-inch (914-mm)** spacing to support front panel and element.
- G. Insulation: **1/2-inch- (13-mm-)** thick, fibrous glass on inside of the back of the enclosure.
- H. Finish: Baked-enamel finish in manufacturer's **[standard]** **[custom]** color as selected by DEN Project Manager.
- I. Damper: Knob-operated internal damper.

Units with operable front panels may not require access doors.

- J. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size **6 by 7 inches (150 by 175 mm)**, integral with enclosure.
- K. Enclosure Style: **[Sloped]** **[Flat]** top.

Retain features required for Project in subparagraphs below.

1. Front Inlet Grille: Punched louver; painted to match enclosure.
2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** colors.
 - c. Painted to match enclosure.
3. **[Top]** **[Front]** Outlet Grille: Punched louver; painted to match enclosure.
4. **[Top]** **[Front]** Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** colors.
 - c. Painted to match enclosure.

Enclosure dimensions in three subparagraphs below include end pockets for controls and piping.

5. Enclosure Height: <Insert inches (mm)>.
6. Enclosure Depth: <Insert inches (mm)>.
7. Enclosure Length: <Insert inches (mm)>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive convectors for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for **[hydronic-piping]** **[steam-piping]** **[electrical]** connections to verify actual locations before installation of convector.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install convectors level and plumb.
- D. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- E. Protection: Provide finished cabinet units with protective covers during balance of construction.

Retain three paragraphs below for hot-water or steam convectors.

- F. Install valves within reach of access door provided in enclosure.
- G. Install air-seal gasket between wall and recessed flanges or front cover of fully recessed unit.
- H. Install piping within pedestals for freestanding units.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

Retain first five paragraphs below for hot-water or steam piping.

- A. Piping installation requirements are specified in [**Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties.**] [**Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties.**] Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect hot-water convectors and components to piping according to Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties."
 - 1. Install shutoff valves on inlet and outlet, and balancing valve on outlet.
- C. Connect steam convectors and components to piping according to Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties."
 - 1. Install shutoff valve on inlet; install strainer, steam trap, and shutoff valve on outlet.
- D. Install control valves as required by Section 230923.11 "Control Valves."
- E. Install piping adjacent to convectors to allow service and maintenance.

Retain two paragraphs below for electric convectors.

- F. Ground electric convectors according to Section 260526 "Grounding and Bonding for Electrical Systems."
- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- H. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

A. Perform the following field tests and inspections:

Retain "Leak Test" Subparagraph below for hot-water or steam convectors.

1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.

Retain "Operational Test" Subparagraph below for electric convectors.

2. Operational Test: After electrical circuitry has been energized, start convectors to confirm proper operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

B. Convectors will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

3.5 CLEANING

A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets.

B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238233

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SECTION 238236 - FINNED-TUBE RADIATION HEATERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes [hydronic] [steam] [electric], [baseboard] [and] [finned-tube] radiation heaters.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. Include data substantiating that materials comply with requirements.

B. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include details and dimensions of custom-fabricated enclosures.
4. Indicate location and size of each field connection.

Retain first subparagraph below for hydronic and steam convection units.

5. Indicate location and arrangement of piping valves and specialties.

Retain first subparagraph below for finned-tube radiation heaters with integral controls; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

6. Indicate location and arrangement of integral controls.
7. Include enclosure joints, corner pieces, access doors, and other accessories.

Retain subparagraph below for electric convection units.

8. Include diagrams for power, signal, and control wiring.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Color Samples for Initial Selection" and "Color Samples for Verification" paragraphs for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: For each exposed product and for each color and texture specified.
- D. Color Samples for Initial Selection: For finned-tube radiation heaters with factory-applied color finishes.
- E. Color Samples for Verification: For each type of exposed finish.
- F. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide **<Insert number>** mockup, **<Insert number>** feet long by **<Insert number>** feet wide, of **<typical exterior wall module>** **<one typical bay, under window enclosure assembly complete with induction units>**.
2. Locate **<where directed by DEN Project Manager>** **<Insert location>**.

3. Mockup may <not> remain as part of the Work.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Structural members, including wall construction, to which finned-tube radiation heaters will be attached.
 2. Method of attaching finned-tube radiation heaters to building structure.
 3. Penetrations of fire-rated wall and floor assemblies.
- B. Field quality-control reports.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.5 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 ELECTRIC BASEBOARD RADIATION HEATERS

Copy this article and re-edit for each style of baseboard radiation heater, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Berko; Marley Engineered Products.

2. [Chromalox](#).
3. [Indeeco](#).
4. [Markel Products Company; TPI Corporation](#).
5. [Marley Engineered Products](#).
6. [Ouellet Canada Inc.](#)
7. [Qmark; Marley Engineered Products](#).
8. **<Insert manufacturer's name>**.
9. or approved equal.

B. Description: Factory-packaged units constructed according to UL 499, UL 1030, and UL 2021.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Heating Elements: Nickel-chromium-wire heating element enclosed in metallic sheath mechanically bonded to fins, with high-temperature cutout and sensor running the full length of the element. Element supports shall eliminate thermal expansion noise.

Indicate length and total capacity on Drawings.

1. Volts: **<Insert value>**.
2. Phase: **<Insert value>**.
3. Hertz: **<Insert value>**.
4. Heat Output: **<Insert W/ft. (W/m)>**.

Retain "Enclosures" or "Rust-Resistant Enclosures" Paragraph below, or retain both and indicate location of each enclosure type on Drawings. Verify optional features with manufacturer.

D. Enclosures: Minimum [0.0329-inch- (0.85-mm-)] [0.0428-inch- (1.1-mm-)] **<Insert dimension>** thick steel, removable front cover.

1. Full-height back.
2. Full-length damper.
3. End panel.
4. **[Plastic end] [End]** caps.
5. Inside and outside corners.
6. Joiner pieces to snap together.
7. Enclosure Height: **<Insert inches (mm)>**.
8. Enclosure Depth: **<Insert inches (mm)>**.
9. Finish: Baked-enamel finish in manufacturer's **[standard] [custom]** color as selected by DEN Project Manager.
10. Element Brackets: Primed and painted steel to support front panel and element.

E. Rust-Resistant Enclosures: Minimum [0.040-inch- (1.0-mm-)] [0.052-inch- (1.3-mm-)] **<Insert dimension>** thick ASTM A 653/A 653M, **G60 (Z180)** galvanized-steel, removable front cover.

1. Full-height back.
2. Full-length damper.

3. End panel.
4. **[Plastic end] [End]** caps.
5. Inside and outside corners.
6. Joiner pieces to snap together.
7. Enclosure Height: **<Insert inches (mm)>**.
8. Enclosure Depth: **<Insert inches (mm)>**.
9. Finish: Baked-enamel finish in manufacturer's **[standard] [custom]** color as selected by DEN Project Manager.
10. Element Brackets: Primed and painted steel to support front panel and element.

Retain "Unit Controls" Paragraph below for integral control device; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- F. Unit Controls: **[Integral line-voltage thermostat] [Integral electronic thermostat] [Remote line-voltage thermostat]**.
- G. Accessories:
1. Filler sections without a heating element matching the adjacent enclosure.
 2. Straight-blade-type receptacles complying with DSCC W-C-596G/GEN, NEMA WD 1, NEMA WD 6, and UL 498; in color selected by DEN Project Manager.

2.2 **[HOT-WATER] [STEAM]** BASEBOARD RADIATION HEATERS

Copy this article and re-edit for each style of baseboard radiation heater, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [A.I.M. Radiant Heating.](#)
 2. [Embassy Industries, Inc.](#)
 3. [Haydon Corporation, Inc.](#)
 4. [Hydro-Air Components Inc.](#)
 5. [Rosemex.](#)
 6. [Slant/Fin Corporation.](#)
 7. [Sterling Hydronics; a Mestek company.](#)
 8. **<Insert manufacturer's name>**.
 9. or approved equal.
- B. Performance Ratings: Rate baseboard radiation heaters according to Hydronics Institute's "I=B=R Testing and Rating Standard for Baseboard Radiation."

Retain one of two "Heating Elements" paragraphs below.

- C. Heating Elements: Copper tubing mechanically expanded into flanged collars of evenly spaced aluminum fins resting on polypropylene element glides. One end of tube shall be belled.

If more than one configuration is required, delete nine subparagraphs below and schedule on Drawings.

1. Tube Diameter: [NPS 1/2 (DN 15)] [NPS 3/4 (DN 20)] [NPS 1 (DN 25)] [NPS 1-1/4 (DN 32)] <Insert pipe size>.
2. Fin Size: [2-1/2 by 2-1/2 inches (63 by 63 mm)] [3 by 3 inches (76 by 76 mm)] <Insert dimensions>.
3. Fin Spacing: [40 per foot (131 per m)] [50 per foot (164 per m)] [58 per foot (190 per m)] <Insert value>.
4. Number of Tiers: <Insert number>.
5. Heat Output: <Insert Btu/h per ft. (W/m)>.
6. Entering-Air Temperature: [65 deg F (18 deg C)] <Insert temperature>.

Retain first two subparagraphs below for hot-water radiation heaters.

7. Average Water Temperature: [180 deg F (82 deg C)] <Insert temperature>.
8. Minimum Water Velocity: [1/2 fps (0.15 m/s)] <Insert value>.

Retain "Entering Steam Pressure" Subparagraph below for steam radiation heaters.

9. Entering Steam Pressure: [1 psig (6.9 kPa)] <Insert value>.

- D. Heating Elements: Steel tubing mechanically expanded into flanged collars of evenly spaced steel fins resting on polypropylene element glides. Tube ends shall be threaded.

If more than one configuration is required, delete nine subparagraphs below and schedule on Drawings.

1. Tube Diameter: [NPS 1-1/4 (DN 32)] <Insert pipe size>.
2. Fin Size: [3 by 3 inches (76 by 76 mm)] <Insert dimensions>.
3. Fin Spacing: [52 per foot (171 per m)] <Insert value>.
4. Number of Tiers: <Insert number>.
5. Heat Output: <Insert Btu/h per ft. (W/m)>.
6. Entering-Air Temperature: [65 deg F (18 deg C)] <Insert temperature>.

Retain first two subparagraphs below for hot-water radiation heaters.

7. Average Water Temperature: [180 deg F (82 deg C)] <Insert temperature>.
8. Minimum Water Velocity: [1/2 fps (0.15 m/s)] <Insert value>.

Retain "Entering Steam Pressure" Subparagraph below for steam radiation heaters.

9. Entering Steam Pressure: [1 psig (6.9 kPa)] <Insert value>.

Retain "Enclosures" or "Rust-Resistant Enclosures" Paragraph below, or retain both and indicate location of each enclosure type on Drawings. Verify optional features with manufacturer.

- E. Enclosures: Minimum [0.0329-inch- (0.85-mm-)] [0.0428-inch- (1.1-mm-)] <Insert dimension> thick steel, removable front cover.

1. Full-height back.
2. Full-length damper.
3. End panel.
4. End caps.
5. Inside and outside corners.
6. Valve access door.

7. Joiner pieces to snap together.
 8. Enclosure Height: <Insert inches (mm)>.
 9. Enclosure Depth: <Insert inches (mm)>.
 10. Finish: Baked-enamel finish in manufacturer's [standard] [custom] color as selected by DEN Project Manager.
 11. Element Brackets: Primed and painted steel to support front panel and element.
- F. Rust-Resistant Enclosures: Minimum [0.040-inch- (1.0-mm-)] [0.052-inch- (1.3-mm-)] <Insert dimension> thick ASTM A 653/A 653M, G60 (Z180) galvanized-steel, removable front cover.
1. Full-height back.
 2. Full-length damper.
 3. End panel.
 4. End caps.
 5. Inside and outside corners.
 6. Valve access door.
 7. Joiner pieces to snap together.
 8. Enclosure Height: <Insert inches (mm)>.
 9. Enclosure Depth: <Insert inches (mm)>.
 10. Finish: Baked-enamel finish in manufacturer's [standard] [custom] color as selected by DEN Project Manager.
 11. Element Brackets: Primed and painted steel to support front panel and element.

2.3 ELECTRIC FINNED-TUBE RADIATION HEATERS

Copy this article and re-edit for each style of finned-tube radiation heater, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Berko; Marley Engineered Products.](#)
 2. [Chromalox.](#)
 3. [Indeeco.](#)
 4. [Markel Products Company; TPI Corporation.](#)
 5. [Marley Engineered Products.](#)
 6. [Ouellet Canada Inc.](#)
 7. [Qmark; Marley Engineered Products.](#)
 8. [Trane Inc.](#)
 9. <Insert manufacturer's name>.
 10. or approved equal.
- B. Description: Factory-packaged units constructed according to UL 499, UL 1030, and UL 2021.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Heating Elements: Nickel-chromium-wire heating element enclosed in metallic sheath mechanically bonded to fins, with high-temperature cutout and sensor running the full length of the element. Element supports shall eliminate thermal expansion noise.

Indicate length and total capacity on Drawings.

1. Volts: <Insert value>.
2. Phase: <Insert value>.
3. Hertz: <Insert value>.
4. Heat Output: <Insert W/ft. (W/m)>.

Retain "Front Panel" or "Rust-Resistant Front Panel" Paragraph below, or retain both and indicate location of each panel type on Drawings.

- D. Front Panel: Minimum [0.0428-inch- (1.1-mm-)] [0.0528-inch- (1.35-mm-)] <Insert dimension> thick steel.
- E. Rust-Resistant Front Panel: Minimum [0.052-inch- (1.3-mm-)] [0.064-inch- (1.6-mm-)] <Insert dimension> thick, ASTM A 653/A 653M, G60 (Z180) galvanized steel.
- F. Wall-Mounted Back Panel: Minimum 0.0329-inch- (0.85-mm-) thick steel, full height, with full-length channel support for front panel without exposed fasteners.
- G. Floor-Mounted Pedestals: Conceal conduit for power and control wiring at maximum 36-inch (914-mm) spacing. Pedestal-mounted back panel shall be solid panel matching front panel.
- H. Support Brackets: Locate at maximum 36-inch (914-mm) spacing to support front panel and element.
- I. Finish: Baked[-enamel][-epoxy] finish in manufacturer's [standard] [custom] color as selected by DEN Project Manager.
- J. Damper: Knob-operated internal damper at enclosure outlet.
- K. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size 6 by 7 inches (150 by 175 mm), integral with enclosure.
- L. Enclosure Style: [Sloped] [Flat] top.

Retain features required for Project in subparagraphs below.

1. Front Inlet Grille: Punched louver; painted to match enclosure.
2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.

- b. Anodized finish, color as selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** colors.
 - c. Painted to match enclosure.
3. **[Top]** **[Front]** Outlet Grille: Punched louver; painted to match enclosure.
 4. **[Top]** **[Front]** Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's **[standard]** **[custom]** colors.
 - c. Painted to match enclosure.
 5. Enclosure Height: **<Insert inches (mm)>**.
 6. Enclosure Depth: **<Insert inches (mm)>**.

Retain "Unit Controls" Paragraph below for integral control device; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- M. Unit Controls: Integral **[line-voltage thermostat with minimum range of 60 to 90 deg F (15 to 32 deg C)] [low-voltage relay and control transformer for remote thermostat]**.
- N. Accessories: Integral disconnect switch, filler sections, corners, relay sections, and splice plates all matching the enclosure and grille finishes.

2.4 **[HOT-WATER]** **[STEAM]** FINNED-TUBE RADIATION HEATERS

Copy this article and re-edit for each style of finned-tube radiation heater, or schedule on Drawings.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Embassy Industries, Inc.](#)
 2. [Engineered Air.](#)
 3. [Hydro-Air Components Inc.](#)
 4. [Quincy Hydronic Technology Inc.](#)
 5. [Rosemex.](#)
 6. [Slant/Fin Corporation.](#)
 7. [Sterling Hydronics; a Mestek company.](#)
 8. [Trane Inc.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Performance Ratings: Rate finned-tube radiation heaters according to Hydronics Institute's "I=B=R Testing and Rating Standard for Finned-Tube (Commercial) Radiation."

Retain one of two "Heating Elements" paragraphs below.

- C. Heating Elements: Copper tubing mechanically expanded into flanged collars of evenly spaced aluminum fins resting on element supports. One end of tube shall be belled.

If more than one configuration is required, delete nine subparagraphs below and schedule on Drawings.

1. Tube Diameter: [NPS 3/4 (DN 20)] [NPS 1 (DN 25)] [NPS 1-1/4 (DN 32)] <Insert pipe size>.
2. Fin Size: [3 by 3 inches (76 by 76 mm)] [4 by 4 inches (102 by 102 mm)] <Insert dimensions>.
3. Fin Spacing: [40 per foot (131 per m)] [50 per foot (164 per m)] [58 per foot (190 per m)] <Insert value>.
4. Number of Tiers: <Insert number>.
5. Heat Output: <Insert Btu/h per ft. (W/m)>.
6. Entering-Air Temperature: [65 deg F (18 deg C)] <Insert temperature>.

Retain first two subparagraphs below for hot-water radiation heaters.

7. Average Water Temperature: [180 deg F (82 deg C)] <Insert temperature>.
8. Minimum Water Velocity: [1/2 fps (0.15 m/s)] <Insert value>.

Retain "Entering Steam Pressure" Subparagraph below for steam radiation heaters.

9. Entering Steam Pressure: [1 psig (6.9 kPa)] <Insert value>.

- D. Heating Elements: Steel tubing mechanically expanded into flanged collars of evenly spaced steel fins resting on element supports. Tube ends shall be threaded.

If more than one configuration is required, delete nine subparagraphs below and schedule on Drawings.

1. Tube Diameter: [NPS 1-1/4 (DN 32)] <Insert pipe size>.
2. Fin Size: [4 by 4 inches (102 by 102 mm)] <Insert dimensions>.
3. Fin Spacing: [52 per foot (171 per m)] <Insert value>.
4. Number of Tiers: <Insert number>.
5. Heat Output: <Insert Btu/h per ft. (W/m)>.
6. Entering-Air Temperature: [65 deg F (18 deg C)] <Insert temperature>.

Retain first two subparagraphs below for hot-water radiation heaters.

7. Average Water Temperature: [180 deg F (82 deg C)] <Insert temperature>.
8. Minimum Water Velocity: [1/2 fps (0.15 m/s)] <Insert value>.

Retain "Entering Steam Pressure" Subparagraph below for steam radiation heaters.

9. Entering Steam Pressure: [1 psig (6.9 kPa)] <Insert value>.

- E. Element Supports: Ball-bearing cradle type to permit longitudinal movement on enclosure brackets.

Retain "Front Panel" or "Rust-Resistant Front Panel" Paragraph below, or retain both and indicate location of each panel type on Drawings.

- F. Front Panel: Minimum [0.0428-inch- (1.1-mm-)] [0.0528-inch- (1.35-mm-)] <Insert thickness> thick steel.

- G. Rust-Resistant Front Panel: Minimum [0.052-inch- (1.3-mm-)] [0.064-inch- (1.6-mm-)] **<Insert thickness>** thick, ASTM A 653/A 653M, G60 (Z180) galvanized steel.
- H. Wall-Mounted Back Panel: Minimum 0.0329-inch- (0.85-mm-) thick steel, full height, with full-length channel support for front panel without exposed fasteners.
- I. Floor-Mounted Pedestals: Conceal insulated piping at maximum 36-inch (914-mm) spacing. Pedestal-mounted back panel shall be solid panel matching front panel. Provide stainless-steel escutcheon for floor openings at pedestals.
- J. Support Brackets: Locate at maximum 36-inch (914-mm) spacing to support front panel and element.
- K. Finish: Baked[-enamel][-epoxy] finish in manufacturer's [standard] [custom] color as selected by DEN Project Manager.
- L. Damper: Knob-operated internal damper at enclosure outlet.
- M. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size 6 by 7 inches (150 by 175 mm), integral with enclosure.
- N. Enclosure Style: [Sloped] [Flat] top.

Retain features required for Project in subparagraphs below.

- 1. Front Inlet Grille: Punched louver; painted to match enclosure.
 - 2. Front Inlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's [standard] [custom] colors.
 - c. Painted to match enclosure.
 - 3. [Top] [Front] Outlet Grille: Punched louver; painted to match enclosure.
 - 4. [Top] [Front] Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by DEN Project Manager from manufacturer's [standard] [custom] colors.
 - c. Painted to match enclosure.
 - 5. Enclosure Height: <Insert inches (mm)>.
 - 6. Enclosure Depth: <Insert inches (mm)>.
- O. Accessories: Filler sections, corners, relay sections, and splice plates all matching the enclosure and grille finishes.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive finned-tube radiation heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for [**hydronic-piping**] [**steam-piping**] [**electrical**] connections to verify actual locations before installation of finned-tube radiation heaters.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BASEBOARD RADIATION HEATER INSTALLATION

- A. Install units level and plumb.
- B. Install enclosure continuously around corners, using outside and inside corner fittings.
- C. Join sections with splice plates and filler pieces to provide continuous enclosure.
- D. Install access doors for access to valves.
- E. Install enclosure continuously from wall to wall.
- F. Terminate enclosures with manufacturer's end caps except where enclosures are indicated to extend to adjoining walls.

Retain three paragraphs below for hot-water or steam units.

- G. Install valves within reach of access door provided in enclosure.
- H. Install air-seal gasket between wall and recessed flanges or front cover of fully recessed unit.
- I. Install piping within pedestals for freestanding units.

3.3 FINNED-TUBE RADIATION HEATER INSTALLATION

- A. Install units level and plumb.
- B. Install enclosure continuously around corners, using outside and inside corner fittings.
- C. Join sections with splice plates and filler pieces to provide continuous enclosure.
- D. Install access doors for access to valves.
- E. Install enclosure continuously from wall to wall.

- F. Terminate enclosures with manufacturer's end caps except where enclosures are indicated to extend to adjoining walls.

Retain three paragraphs below for hot-water or steam units.

- G. Install valves within reach of access door provided in enclosure.
- H. Install air-seal gasket between wall and recessed flanges or front cover of fully recessed unit.
- I. Install piping within pedestals for freestanding units.

3.4 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

Retain first five paragraphs below for hot-water or steam piping.

- A. Piping installation requirements are specified in [**Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties.**] [**Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties.**] Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect hot-water finned-tube radiation heaters and components to piping according to Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties."
 - 1. Install shutoff valves on inlet and outlet, and balancing valve on outlet.
- C. Connect steam finned-tube radiation heaters and components to piping according to Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties."
 - 1. Install shutoff valve on inlet; install strainer, steam trap, and shutoff valve on outlet.
- D. Install control valves as required by Section 230923.11 "Control Valves."
- E. Install piping adjacent to finned-tube radiation heaters to allow service and maintenance.

Retain two paragraphs below for electric finned-tube radiation heaters.

- F. Ground electric finned-tube radiation heaters according to Section 260526 "Grounding and Bonding for Electrical Systems."
- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

A. Perform the following field tests and inspections:

Retain "Leak Test" Subparagraph below for hot-water or steam finned-tube radiation heaters.

1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.

Retain "Operational Test" Subparagraph below for electric finned-tube radiation heaters.

2. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

B. Units will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

3.6 CLEANING

A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum inside of cabinets.

B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238236

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SECTION 238239 - UNIT HEATERS

1.1 This Section has no Section Text as it has been replaced by the Sections listed below. If e-SPECS Bindings have been associated to this Section, they should be updated to refer to the replacement sections below.

- A. SECTION **238239.13** - CABINET **UNIT HEATERS**
- B. SECTION **238239.16** - PROPELLER **UNIT HEATERS**
- C. SECTION **238239.19** – WALL AND CEILING **UNIT HEATERS**

PART 1 - GENERAL (Not Applicable)

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 238239

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SECTION 238239.13 - CABINET UNIT HEATERS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system designs that do not include cabinet unit heaters may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes cabinet unit heaters with centrifugal fans and **[hot-water] [steam] [electric-resistance heating]** coils.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. CWP: Cold working pressure.
- B. DDC: Direct digital control.
- C. PTFE: Polytetrafluoroethylene plastic.
- D. TFE: Tetrafluoroethylene plastic.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings:
 - 1. Include plans, elevations, sections, and details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include location and size of each field connection.
 - 4. Include details of anchorages and attachments to structure and to supported equipment.
 - 5. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.

Retain first subparagraph below for hot-water and steam cabinet unit heaters.

- 6. Indicate location and arrangement of piping valves and specialties.

Retain first subparagraph below for cabinet unit heaters with integral controls; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- 7. Indicate location and arrangement of integral controls.
- 8. Wiring Diagrams: Power, signal, and control wiring.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- D. Samples: For each exposed product and for each color and texture specified.
- E. Samples for Initial Selection: Finish colors for units with factory-applied color finishes.
- F. Samples for Verification: Finish colors for each type of cabinet unit heater indicated with factory-applied color finishes.
- G. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide **<Insert number>** mockup, **<Insert number>** feet long by **<Insert number>** feet wide, of **<typical exterior wall module> <one typical bay, under window enclosure assembly complete with induction units>**.
2. Locate **<where directed by DEN Project Manager> <Insert location>**.
3. Mockup may **<not>** remain as part of the Work.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Suspended ceiling components.
 2. Structural members to which cabinet unit heaters will be attached.
 3. Method of attaching hangers to building structure.
 4. Size and location of initial access modules for acoustical tile.
 5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. **<Insert item>**.
 6. Perimeter moldings for exposed or partially exposed cabinets.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: Submit certification that cabinet unit heaters, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Include detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For cabinet unit heaters to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Retain this article for cabinet unit heaters with filters. Extra materials may not be allowed for publicly funded projects.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Cabinet Unit-Heater Filters: Furnish [**one (1)**] <Insert number> spare filter(s) for each filter installed.

1.8 QUALITY ASSURANCE

- A. Comply with NFPA 70. Listed and labeled by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Edit or delete paragraphs below to suit Project and LEED requirements.

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IES 90.1.

- C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.9 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this Article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements".

- A. Special Warranty: Manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

1. Warranty Period: Minimum [four (4)] [five (5)] [ten (10)] <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- B. Factory-packaged and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.
- C. Radiated noise shall not exceed:
 - 1. NC 35 – In Office.
 - 2. NC 40 – Terminal/Concourse.
 - 3. NC 45 – Maintenance Facilities.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.2 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Airtherm; a Mestek company.
 - 2. Berko; Marley Engineered Products.
 - 3. Carrier Corporation; a UTC company.
 - 4. Chromalox, Inc.
 - 5. Dunham-Bush, Inc.
 - 6. Engineered Air.
 - 7. Indeeco.
 - 8. International Environmental Corporation.
 - 9. Markel Products Company; TPI Corporation.
 - 10. Marley Engineered Products.
 - 11. McQuay International.
 - 12. Ouellet Canada Inc.
 - 13. QMark; Marley Engineered Products.
 - 14. Rosemex Products.
 - 15. Trane Inc.
 - 16. USA Coil & Air.
 - 17. **<Insert manufacturer's name>.**
 - 18. or approved equal.

2.3 DESCRIPTION

- A. Factory-assembled and -tested unit complying with AHRI 440.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain paragraph below for electric cabinet unit heaters.

- C. Comply with UL 2021.

2.4 PERFORMANCE REQUIREMENTS

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IESNA 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires compliance with requirements in ASHRAE/IESNA 90.1.

- B. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

- C. Seismic Performance: Cabinet unit heaters shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

2.5 COIL SECTION INSULATION

Flexible elastomeric insulation and mineral-fiber insulation with a foil face are available from some manufacturers to reduce the number of glass or mineral fibers circulating through the air-conditioned space.

Retain first "Insulation Materials" Paragraph below for duct-liner-type, glass-fiber insulation.

- A. Insulation Materials: ASTM C 1071; surfaces exposed to airstream shall have [aluminum-foil facing] [erosion-resistant coating] to prevent erosion of glass fibers.
1. Thickness: [1/2 inch (13 mm)] [1 inch (25 mm)] [1-1/2 inches (38 mm)].
 2. Thermal Conductivity (k-Value): 0.26 Btu x in./h x sq. ft. at 75 deg F (0.037 W/m x K at 24 deg C) mean temperature.

3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
4. Adhesive: Comply with ASTM C 916 and with NFPA 90A or NFPA 90B.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Insulation Materials" Paragraph below for flexible elastomeric insulation.

- B. Insulation Materials: Comply with NFPA 90A or NFPA 90B. Unicellular polyethylene thermal plastic, preformed sheet insulation complying with ASTM C 534, Type II, except for density.
1. Thickness: [3/8 inch (9 mm)] [1/2 inch (13 mm)] [3/4 inch (19 mm)] [1 inch (25 mm)].
 2. Thermal Conductivity (k-Value): 0.24 Btu x in./h x sq. ft. at 75 deg F (0.034 W/m x K at 24 deg C) mean temperature.
 3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM C 411.
 4. Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph to comply with LEED Prerequisite IEQ 1.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.6 CABINETS

Retain "Material" Paragraph below for surface, semirecessed, and fully recessed units. Cabinet is not required for concealed units. Coordinate custom color requirements in paragraph below with Sample submittal requirements. Coordinate field painting with painting Sections.

- A. Material: Steel with [factory prime coating, ready for field painting] [baked-enamel finish with manufacturer's standard paint, in color selected by DEN Project Manager] [baked-enamel finish with manufacturer's custom paint, in color selected by DEN Project Manager].

First option in "Vertical Unit, Exposed Front Panels" and "Horizontal Unit, Exposed Bottom Panels" subparagraphs below is the equivalent of 16-gage steel; second option is the equivalent of 14-gage steel.

1. Vertical Unit, Exposed Front Panels: Minimum [0.0528-inch- (1.35-mm-)] [0.0677-inch- (1.7-mm-)] thick [galvanized] sheet steel, removable panels with channel-formed edges secured with tamperproof cam fasteners.
2. Horizontal Unit, Exposed Bottom Panels: Minimum [0.0528-inch- (1.35-mm-)] [0.0677-inch- (1.7-mm-)] thick [galvanized] sheet steel, removable panels secured with tamperproof cam fasteners and safety chain.

Retain "Recessed Flanges" Subparagraph below for units that are semirecessed or fully recessed in walls or ceilings.

3. Recessed Flanges: Steel, finished to match cabinet.
4. Control Access Door: Key operated.

Retain "Base" Subparagraph below for surface, vertical, wall-mounted units.

5. Base: Minimum 0.0528-inch- (1.35-mm-) thick steel, finished to match cabinet, [4 inches (100 mm)] [6 inches (150 mm)] <Insert dimension> high with leveling bolts.
6. Extended Piping Compartment: [8-inch- (200-mm-)] <Insert dimension> wide piping end pocket.

Accessories described in "False Back" and "Outdoor-Air Wall Box" subparagraphs below are furnished for vertical, wall-mounted units only.

7. False Back: Minimum 0.0428-inch- (1.1-mm-) thick steel, finished to match cabinet.
8. Outdoor-Air Wall Box: Minimum 0.1265-inch- (3.2-mm-) thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen; aluminum louver with [anodized] [baked-enamel] finish in color selected by DEN Project Manager from manufacturer's [standard] [custom] colors.

Retain second or third option in "Outdoor-Air Damper" Subparagraph below if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, and Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1.

- a. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with [manual] [electronic] [pneumatic], two-position actuators.

2.7 FILTERS

Verify available filter types with manufacturer. Indicate filter thickness in "Capacities and Characteristics" Article or in the Cabinet Unit-Heater Schedule on Drawings.

- A. Minimum Arrestance: According to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

Retain one or more of three subparagraphs below. If retaining more than one filter type, indicate type for each unit in the Cabinet Unit-Heater Schedule on Drawings.

1. Washable Foam: 70 percent arrestance and MERV 3.
2. Glass Fiber Treated with Adhesive: 80 percent arrestance and MERV 5.
3. Pleated: 90 percent arrestance and MERV 7.

2.8 COILS

Retain one of three coil paragraphs below.

- A. Hot-Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain.

- B. Steam Coil: Copper[**distributing**] tube, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm) and rated for a minimum working pressure of **75 psig** (517 kPa).

Some manufacturers do not provide electric-resistance heating coils in downflow configuration.

- C. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and hum, mounted in ceramic inserts in galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

2.9 CONTROLS

- A. Fan and Motor Board: Removable.

1. Fan: Forward curved, **high static**, double width, centrifugal, directly connected to motor; thermoplastic or painted-steel wheels and aluminum, painted-steel, or galvanized-steel fan scrolls.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert subparagraphs below to suit Project.

2. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
3. Wiring Terminations: Connect motor to chassis wiring with plug connection.

Retain "Factory, Hot-Water Piping Package" Paragraph below to require factory-piping package.

- B. Factory, Hot-Water Piping Package: [**ASTM B 88, Type L** (ASTM B 88M, Type B)] [**ASTM B 88, Type M** (ASTM B 88M Type C)] copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.

Retain one or more of first four subparagraphs below.

1. [**Two**] [**Three**]-way, [**two-position**] [**modulating**] control valve. [**Three-way valve packages shall include bypass line with manually adjustable balance device.**]
2. Hose Kits: Minimum **400-psig** (2758-kPa) working pressure, and operating temperatures from **33 to 211 deg F** (0.5 to 99 deg C). Tag hose kits to equipment designations.
 - a. Length: [**24 inches** (600 mm)] [**36 inches** (900 mm)] **<Insert dimension>**.
 - b. Minimum Diameter: Equal to cabinet unit-heater connection size.
3. Two-Piece, Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and **600-psig** (4140-kPa) minimum CWP rating and blowout-proof stem.

4. Calibrated-Orifice Balancing Valves: Bronze body, ball type, **125-psig** (860-kPa) working pressure, **250 deg F** (121 deg C) maximum operating temperature; with calibrated orifice or venturi, connection for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
5. Automatic Flow-Control Valve: Brass or ferrous-metal body, **300-psig** (2068-kPa) working pressure at **250 deg F** (121 deg C), with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow within plus or minus 10 percent of differential pressure range of **2 to 80 psig** (13.8 to 552 kPa).
6. Y-Pattern, Hot-Water Strainers: Cast-iron body (ASTM A 126, Class B); **125-psig** (860-kPa) minimum working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum **NPS 1/2** (DN 15) threaded pipe and full-port ball valve in strainer drain connection.
7. Wrought-Copper Unions: ASME B16.22.

Retain first paragraph below and delete "Basic Unit Controls" Paragraph below if controls are part of overall temperature-control system.

- C. Control devices and operational sequences are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- D. Basic Unit Controls:
 1. Control voltage transformer.

Verify control features with manufacturer.

2. **[Wall]** **[Unit]**-mounted thermostat with the following features:
 - a. Heat-off switch.
 - b. Fan on-auto switch.

Retain first subparagraph below if multispeed motors are specified.

- c. Manual fan-speed switch.
- d. Adjustable deadband.
- e. **[Concealed]** **[Exposed]** set point.
- f. **[Concealed]** **[Exposed]** indication.
- g. **Deg F** (Deg C) indication.
3. **[Wall]** **[Unit]**-mounted temperature sensor.
4. Unoccupied period override push button.
5. Data entry and access port.
 - a. Input data includes room temperature and occupied and unoccupied periods.
 - b. Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

Retain "(DDC)Terminal Controller" Paragraph below and coordinate with "Basic Unit Controls" Paragraph above or with control devices specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

E. **[DDC]Terminal Controller:**

1. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
2. Unoccupied Period Override: **[Two]** <Insert number> hours.
3. Unit Supply-Air Fan Operations:
 - a. Occupied Periods: Fan runs continuously.
 - b. Unoccupied Periods: Fan cycles to maintain setback room temperature.
4. Heating-Coil Operations:
 - a. Occupied Periods: **[Open control valve] [Modulate control valve] [Energize electric-resistance coil]** to provide heating if room temperature falls below thermostat set point.
 - b. Unoccupied Periods: Start fan and **[open control valve] [modulate control valve] [energize electric-resistance coil]** if room temperature falls below setback temperature.

Retain "Outdoor-Air Damper Operation" Subparagraph below for automatic outdoor-air intake damper.

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, and Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1.

5. Outdoor-Air Damper Operation:
 - a. Occupied Periods: Open dampers. Delay damper opening if room temperature is more than three degrees below set point.
 - b. Unoccupied Periods: Close damper.
6. Controller shall have volatile-memory backup.

F. Interface with DDC System for HVAC Requirements:

1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at central workstation.
3. Interface shall be **[BAC-net] [or] [LonWorks]** compatible for central DDC system for HVAC workstation and include the following functions:
 - a. Adjust set points.
 - b. Cabinet unit-heater start, stop, and operating status.
 - c. Data inquiry, including **[outdoor-air damper position and]**supply-air and room-air temperature.
 - d. Occupied and unoccupied schedules.

G. Electrical Connection: Factory-wired motors and controls for a single field connection.

2.10 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of cabinet unit heater, delete this article and schedule cabinet unit heaters on Drawings.

A. Cabinet:

1. Vertical, Surface Mounted: Upflow.
 - a. Top: **[Flat] [Sloped] [Flat or sloped]**.
 - b. Air Inlet: **[Open bottom] [Front, punched louver] [Front, extruded-aluminum bar grille]**.
 - c. Air Outlet: **[Front] [Top] [Front or top], [quad louver] [punched louver] [extruded-aluminum bar grille]**.
2. Vertical, Surface Mounted: Downflow.
 - a. Top: **[Flat] [Sloped] [Flat or sloped]**.
 - b. Air Inlet: **[Front] [Top] [Front or top], [punched louver] [extruded-aluminum bar grille]**.
 - c. Air Outlet: **Front, [quad louver] [punched louver] [extruded-aluminum bar grille]**.
3. Vertical, Semirecessed: Upflow.
 - a. Air Inlet: **[Open bottom] [Front, punched louver] [Front, extruded-aluminum bar grille]**.
 - b. Air Outlet: **[Front] [Top] [Front or top], [quad louver] [punched louver] [extruded-aluminum bar grille]**.
4. Vertical, Semirecessed: Downflow.
 - a. Air Inlet: **[Front] [Top] [Front or top], [punched louver] [extruded-aluminum bar grille]**.
 - b. Air Outlet: **Front, [quad louver] [punched louver] [extruded-aluminum bar grille]**.
5. Vertical, Fully Recessed: **[Upflow] [Downflow]**.
 - a. Air Inlet: **[Front] [Duct connection], [punched louver] [extruded-aluminum bar grille]**.
 - b. Air Outlet: **[Front] [Duct connection], [quad louver] [punched louver] [extruded-aluminum bar grille]**.
6. Horizontal, Surface Mounted:
 - a. Air Inlet: **[Bottom] [Front] [Bottom or front], [punched louver] [extruded-aluminum bar grille]**.
 - b. Air Outlet: **[Front] [Top] [Front or top], [quad louver] [punched louver] [extruded-aluminum bar grille]**.

7. Horizontal, Semirecessed:
 - a. Air Inlet: **[Bottom] [Front] [Bottom or front], [punched louver] [extruded-aluminum bar grille].**
 - b. Air Outlet: **[Front] [Top] [Front or top], [quad louver] [punched louver] [extruded-aluminum bar grille].**
 8. Horizontal, Fully Recessed:
 - a. Air Inlet: **[Front] [Duct connection], [punched louver] [extruded-aluminum bar grille].**
 - b. Air Outlet: **[Front] [Duct connection], [quad louver] [punched louver] [extruded-aluminum bar grille].**
- B. Concealed Unit Heater:
1. Vertical: **[Upflow] [Downflow].**
 - a. Air Inlet: **[Open bottom] [Front, punched louver] [Front, extruded-aluminum bar grille].**
 - b. Air Outlet: **[Front] [Top] [Front or top], [quad louver] [punched louver] [extruded-aluminum bar grille].**
 2. Horizontal: Upflow.
 - a. Air Inlet: **[Open bottom] [Front, punched louver] [Front, extruded-aluminum bar grille].**
 - b. Air Outlet: **[Front] [Top] [Front or top], [quad louver] [punched louver] [extruded-aluminum bar grille].**
- C. Fan:
1. Airflow: **<Insert cfm (L/s)>.**
 2. External Static Pressure: **<Insert inches wg (Pa)>.**
 3. Fan Speed: **<Insert rpm>.**
 4. Motor Horsepower: **<Insert value>.**
- D. Heating Capacity:
1. Output: **<Insert Btu/h (kW)>.**
 2. Entering-Air Temperature: **<Insert deg F (deg C)>.**
 3. Air-Temperature Rise: **<Insert deg F (deg C)>.**
- E. Hot-Water Heating Coil:
1. Water Flow: **<Insert gpm (L/s)>.**
 2. Water-Side Pressure Loss: **<Insert feet wg (kPa)>.**
 3. Entering-Water Temperature: **<Insert deg F (deg C)>.**
- F. Steam Heating Coil:

1. Inlet Steam Pressure: <Insert psig (kPa)>.
 2. Condensing Capacity: <Insert lb/h (g/s)>.
- G. Electric-Resistance Heating Coil:
1. Capacity: <Insert kilowatts>.
 2. Number of Steps: <Insert number>.
- H. Filters:
1. Face Area: <Insert sq. ft. (sq. m)>.
 2. Thickness: [1/2 inch (13 mm)] [1 inch (25 mm)] <Insert dimension>.
- I. Electrical Characteristics for Single-Point Connection:
1. Volts: <Insert value>.
 2. Phase: <Insert value>.
 3. Hertz: <Insert value>.
 4. Full-Load Amperes: <Insert value>.
 5. Minimum Circuit Ampacity: <Insert value>.
 6. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive cabinet unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for [piping and]electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.

Retain first paragraph below for vertical, wall-mounted cabinet unit heaters with wall boxes and outdoor-air intake louvers.

- C. Install wall boxes in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Section 079200 "Joint Sealants."
- D. Install cabinet unit heaters to comply with NFPA 90A.

- E. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- F. Protection: Provide finished cabinet units with protective covers during balance of construction.
- G. Suspend cabinet unit heaters from structure with elastomeric hangers[**and seismic restraints**]. Vibration isolators[**and seismic restraints**] are specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]

Retain first paragraph below if controls are provided by unit-heater manufacturer. To comply with requirements of the Americans with Disabilities Act, verify mounting height with authorities having jurisdiction.

- H. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.
- I. Install new filters in each fan-coil unit within two weeks of Substantial Completion.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in Section 232113 "Hydronic Piping," Section 232116 Hydronic Piping Specialties," Section 232213 "Steam and Condensate Heating Piping," and Section 232216 Steam and Condensate Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to machine to allow service and maintenance.
- C. Connect piping to cabinet unit heater's factory, hot-water piping package. Install the piping package if shipped loose.

Retain first paragraph below for concealed cabinet unit heaters. Coordinate duct installation requirements with Drawings and with requirements specified in Section 233113 "Metal Ducts," Section 233116 "Nonmetal Ducts," and Section 233300 "Air Duct Accessories."

- D. Connect supply and return ducts to cabinet unit heaters with flexible duct connectors specified in Section 233300 "Air Duct Accessories."
- E. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
- F. Install piping adjacent to machine to allow service and maintenance.

Retain first paragraph below for cabinet unit heaters with either hot-water or steam coils.

- G. Comply with safety requirements in UL 1995.

Retain first paragraph below for cabinet unit heaters if factory piping package is not required.

- H. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of cabinet unit heater. Hydronic specialties are specified in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties."

Retain first paragraph below for steam cabinet unit heaters.

- I. Unless otherwise indicated, install union and gate or ball valve on steam-supply connection and union, strainer, steam trap, and gate or ball valve on condensate-return connection of cabinet unit heater. Steam specialties are specified in Section 232216 Steam and Condensate Piping Specialties."
- J. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- K. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- L. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Retain first subparagraph below for units that have electric-resistance heating coils.

2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- B. Units will be considered defective if they do not pass tests and inspections.
- C. Retest as specified above after repairs or replacements are made.
- D. Prepare test and inspection reports.

3.5 ADJUSTING

Retain this article if control devices are specified in this Section; delete if they are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

- A. Adjust initial temperature set points.
- B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two]** <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.6 CLEANING

- A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets.
- B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.
- C. Install new filters.

3.7 DEMONSTRATION

Delete this article if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain cabinet unit heaters.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238239.13

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SECTION 238239.16 - PROPELLER UNIT HEATERS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system designs that do not include propeller unit heaters may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes propeller unit heaters with [hot-water] [steam] [electric-resistance heating] coils.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. CWP: Cold working pressure.
- B. PTFE: Polytetrafluoroethylene plastic.
- C. TFE: Tetrafluoroethylene plastic.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings:
 - 1. Include plans, elevations, sections, and details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include location and size of each field connection.
 - 4. Include details of anchorages and attachments to structure and to supported equipment.
 - 5. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.

Retain first subparagraph below for hot-water and steam propeller unit heaters.

- 6. Indicate location and arrangement of piping valves and specialties.

Retain first subparagraph below for propeller unit heaters with integral controls; delete if control devices are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

- 7. Indicate location and arrangement of integral controls.
- 8. Wiring Diagrams: Power, signal, and control wiring.

- D. Mock-up:

Use this paragraph for assessing full sized erected assemblies for review of construction, coordination of the Work of several sections, testing, or observation of operation.

Verify mockup requirements with DEN Project Manager.

1. Provide <Insert number> mockup, <Insert number> feet long by <Insert number> feet wide, of <typical exterior wall module> <one typical bay, under window enclosure assembly complete with induction units>.
2. Locate <where directed by DEN Project Manager> <Insert location>.
3. Mockup may <not> remain as part of the Work

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Suspended ceiling components.
 2. Structural members to which propeller unit heaters will be attached.
 3. Method of attaching hangers to building structure.
 4. Size and location of initial access modules for acoustical tile.
 5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. <Insert item>.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: Submit certification that propeller unit heaters, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Include detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For propeller unit heaters to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Radiated noise shall not exceed:
 1. NC 35 – In Office.
 2. NC 40 – Terminal/Concourse.
 3. NC 45 – Maintenance Facilities.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.2 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Airtherm; a Mestek company.
 2. Engineered Air.
 3. McQuay International.
 4. Rosemex Products.

5. [Ruffneck Heaters; a division of Lexa Corporation.](#)
6. [Trane Inc.](#)
7. **<Insert manufacturer's name>.**
8. or approved equal.

2.3 DESCRIPTION

- A. Assembly including casing, coil, fan, and motor in **[vertical] [and] [horizontal]** discharge configuration with adjustable discharge louvers.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain first paragraph below for electric propeller unit heaters.

- C. Comply with UL 2021.

Retain paragraph below for explosion-proof electric propeller unit heaters.

- D. Comply with UL 823.

2.4 PERFORMANCE REQUIREMENTS

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IESNA 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires compliance with requirements in ASHRAE/IESNA 90.1.

- B. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

- C. Seismic Performance: Propeller unit heaters shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

2.5 HOUSINGS

- A. Finish: Manufacturer's **[standard]** **[custom]** baked enamel applied to factory-assembled and -tested propeller unit heaters before shipping.

"Airstream Surfaces" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain paragraph to comply with LEED Prerequisite IEQ 1.

- B. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- C. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

2.6 COILS

- A. General Coil Requirements: Test and rate **[hot-water]** **[steam]** propeller unit-heater coils according to ASHRAE 33.

Retain one of eight coil paragraphs below. First "Hot-Water Coil" Paragraph is standard coil construction for hot-water heating systems. Remaining "Hot-Water Coil" paragraphs are for situations where higher pressure ratings are required or corrosion resistance is required for some fluids inside the coils.

- B. Hot-Water Coil: Copper tube, minimum **0.025-inch** (0.635-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm) and rated for a minimum working pressure of **200 psig** (1380 kPa) and a maximum entering-water temperature of **325 deg F** (163 deg C), with manual air vent. Test for leaks to **350 psig** (2413 kPa) underwater.
- C. Hot-Water Coil: Cupronickel tube, minimum **0.031-inch** (0.78-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm) and rated for a minimum working pressure of **400 psig** (2760 kPa) and a maximum entering-water temperature of **450 deg F** (232 deg C), with manual air vent. Test for leaks to **600 psig** (4137 kPa) underwater.
- D. Hot-Water Coil: Red-brass tube, minimum **0.049-inch** (1.24-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than **0.1 inch** (2.5 mm) and rated for a minimum working pressure of **260 psig** (1793 kPa) and a maximum entering-water temperature of **390 deg F** (199 deg C), with manual air vent. Test for leaks to **390 psig** (2689 kPa) underwater.

- E. Hot-Water Coil: Steel tube, minimum 0.049-inch (1.24-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 400 psig (2760 kPa) and a maximum entering-water temperature of 450 deg F (232 deg C), with manual air vent. Test for leaks to 600 psig (4137 kPa) underwater.

"Hot-Water Coil" Paragraph below is industrial-quality construction available from a limited number of manufacturers.

- F. Hot-Water Coil: Vertical steel tube, minimum 0.065-inch (1.65-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 400 psig (2760 kPa) and a maximum entering-water temperature of 450 deg F (232 deg C), with steel headers at top and bottom. Test for leaks to 600 psig (4137 kPa) underwater.

First "Steam Coil" Paragraph below is standard coil construction for steam heating systems. Second and third "Steam Coil" paragraphs are for situations where higher pressure ratings are required or corrosion resistance is required for some fluids inside the coils.

- G. Steam Coil: Copper tube, minimum 0.025-inch (0.635-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 75 psig (520 kPa).
- H. Steam Coil: Red-brass tube, minimum 0.049-inch (1.24-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 75 psig (520 kPa).

"Steam Coil" Paragraph below is industrial-quality construction available from a limited number of manufacturers.

- I. Steam Coil: Vertical steel tube, minimum 0.065-inch (1.65-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of [100 psig (690 kPa)] [200 psig (1380 kPa)], with steel headers at top and bottom.
- J. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in steel or corrosion-resistant metallic sheath with fins no closer than 0.16 inch (4 mm). Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F (288 deg C) at any point during normal operation.

1. Circuit Protection: One-time fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters.
2. Wiring Terminations: Stainless-steel or corrosion-resistant material.

2.7 FAN AND MOTOR

- A. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs below to suit Project.

- B. Motor: Permanently lubricated, [**explosion proof**] [**multispeed**] [**variable speed**]. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.8 CONTROLS

Delete this article if controls are part of control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC." See Evaluations for discussion on control schemes and energy efficiency.

- A. Control Devices:
1. [**Unit**] [**Wall**]-mounted, [**variable**] fan-speed switch.
 2. [**Unit**] [**Wall**]-mounted thermostat.

2.9 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of heater, delete this article and schedule propeller unit heaters on Drawings.

- A. Heating Capacity:
1. Heat Output: <Insert Btu/h (kW)>.
 2. Length of Throw: <Insert feet (m)>.
 3. Mounting Height: <Insert feet (m)>.
- B. Water Coil:
1. Entering-Water Temperature: <Insert deg F (deg C)>.
 2. Temperature Difference: <Insert deg F (deg C)>.
 3. Water Flow: <Insert gpm (L/s)>.
 4. Water-Side Pressure Drop: <Insert feet (kPa)>.
- C. Steam Coil:
1. Inlet Pressure: <Insert psig (kPa)>.
 2. Condensing Capacity: <Insert lb/h (g/s)>.
- D. Electric Coil:
1. Heating Capacity: <Insert kilowatts>.
 2. Number of Steps: <Insert number>.
- E. Supply Air:
1. Airflow: <Insert cfm (L/s)>.

2. Leaving-Air Temperature: <Insert deg F (deg C)>.
3. Entering-Air Temperature: <Insert deg F (deg C)>.

F. Fan Motor:

1. High Speed: <Insert rpm>.
2. Motor Size: <Insert horsepower>.

G. Electrical Characteristics for Single-Point Connection:

1. Volts: <Insert value>.
2. Phase: <Insert value>.
3. Hertz: <Insert value>.
4. Full-Load Amperes: <Insert value>.
5. Minimum Circuit Amperes: <Insert value>.
6. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive propeller unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for [**pipng and**] electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install propeller unit heaters to comply with NFPA 90A.
- D. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- E. Protection: Provide finished cabinet units with protective covers during balance of construction.
- F. Install propeller unit heaters level and plumb.
- G. Suspend propeller unit heaters from structure with all-thread hanger rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stop**]. Hanger rods and attachments to structure are specified in Section 230529 "Hangers

and Supports for HVAC Piping and Equipment." Vibration hangers are specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."]

Retain paragraph below if controls are provided by propeller unit-heater manufacturer. To comply with requirements of the Americans with Disabilities Act, verify mounting height with authorities having jurisdiction.

- H. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in Section 232113 "Hydronic Piping," Section 232116 Hydronic Piping Specialties," Section 232213 "Steam and Condensate Heating Piping," and Section 232216 Steam and Condensate Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to machine to allow service and maintenance.
- C. Connect piping to propeller unit heater's factory, hot-water piping package. Install the piping package if shipped loose.

Retain first paragraph below for propeller unit heaters with either hot-water or steam coils.

- D. Comply with safety requirements in UL 1995.

Retain first paragraph below for hot-water propeller unit heaters if factory piping package is not required.

- E. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of propeller unit heater. Hydronic specialties are specified in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties."

Retain first paragraph below for steam propeller unit heaters.

- F. Unless otherwise indicated, install union and gate or ball valve on steam-supply connection and union, strainer, steam trap, and gate or ball valve on condensate-return connection of propeller unit heater. Steam specialties are specified in Section 232216 Steam and Condensate Piping Specialties."
- G. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

- H. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- I. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Coordinate inspection and testing requirements with DEN Project Manager.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Retain first subparagraph below for units that have electric-resistance heating coils.

- 2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
- 3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Units will be considered defective if they do not pass tests and inspections.
- D. Retest as specified above after repairs or replacements are made.
- E. Prepare test and inspection reports.

3.5 ADJUSTING

Retain this article if control devices are specified in this Section; delete if they are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

- A. Adjust initial temperature set points.
- B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two]** <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.6 CLEANING

- A. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean inside of cabinets.
- B. Touch-up marred or scratched surfaces of factory-finished cabinets, using finish materials furnished by manufacturer.
- C. Install new filters.

3.7 DEMONSTRATION

Delete this article if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain propeller unit heaters.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238239.16

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SECTION 238239.19 - WALL AND CEILING UNIT HEATERS

This Section includes requirements for the LEED Rating System. However, equipment specified in this Section may not qualify for LEED Rating System prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system designs that do not include wall and ceiling unit heaters may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes wall and ceiling heaters with propeller fans and electric-resistance heating coils.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:
 - 1. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
- C. Shop Drawings:
 - 1. Include plans, elevations, sections, and details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include details of anchorages and attachments to structure and to supported equipment.
 - 4. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.
 - 5. Wiring Diagrams: Power, signal, and control wiring.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable.

Coordinate sample requirements with DEN Project Manager.

- D. Samples: For each exposed product and for each color and texture specified.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For wall and ceiling unit heaters to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 QUALITY ASSURANCE

- A. Comply with NFPA 70. Listed and labeled by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.6 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

When warranties are required, verify with Owner's counsel that special warranties stated in this Article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements".

- A. Special Warranty: Manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.
1. Warranty Period: Minimum **[four (4)] [five (5)] [ten (10)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Radiated noise shall not exceed:
1. NC 35 – In Office.
 2. NC 40 – Terminal/Concourse.
 3. NC 45 – Maintenance Facilities.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.2 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Berko; Marley Engineered Products.](#)
 2. [Chromalox, Inc.](#)
 3. [Indeeco.](#)
 4. [Markel Products Company; TPI Corporation.](#)
 5. [Marley Engineered Products.](#)
 6. [Ouellet Canada Inc.](#)
 7. [QMark; Marley Engineered Products.](#)
 8. [Trane Inc.](#)
 9. **<Insert manufacturer's name>.**
 10. or approved equal.

2.3 DESCRIPTION

- A. Assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.4 CABINET

- A. Front Panel: **[Stamped-steel louver] [Extruded-aluminum bar grille]**, with removable panels fastened with tamperproof fasteners.
- B. Finish: Baked enamel over baked-on primer with manufacturer's **[standard] [custom]** color selected by DEN Project Manager, applied to factory-assembled and -tested wall and ceiling heaters before shipping.

"Airstream Surfaces" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain paragraph to comply with LEED Prerequisite IEQ 1.

- C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Surface-Mounted Cabinet Enclosure: Steel with finish to match cabinet.

2.5 COIL

- A. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high-temperature protection.**[Provide integral circuit breaker for overcurrent protection.]**

2.6 FAN AND MOTOR

- A. Fan: Aluminum propeller directly connected to motor.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs below to suit Project.

- B. Motor: Permanently lubricated[, **multispeed**]. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.7 CONTROLS

- A. Controls: Unit-mounted thermostat.[**Low-voltage relay with transformer kit.**]
- B. Electrical Connection: Factory wire motors and controls for a single field connection[**with disconnect switch**].

2.8 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of heater, delete this article and schedule wall and ceiling heaters on Drawings.

- A. Airflow: <Insert cfm (L/s)>.
- B. Fan Speed: <Insert rpm>.
- C. Heating Coil: <Insert kilowatts>.
- D. Electrical Characteristics for Single-Point Connection:
1. Volts: <Insert value>.
 2. Phase: <Insert value>.
 3. Hertz: <Insert value>.
 4. Full-Load Amperes: <Insert value>.
 5. Minimum Circuit Ampacity: <Insert value>.
 6. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive wall and ceiling unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

- B. Examine roughing-in for electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Coordinate to assure correct recess size for recessed units.
- C. Install wall and ceiling unit heaters to comply with NFPA 90A.
- D. Install wall and ceiling unit heaters level and plumb.
- E. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.
- F. Protection: Provide finished cabinet units with protective covers during balance of construction.

Retain first paragraph below if controls are provided by unit-heater manufacturer. To comply with requirements of the Americans with Disabilities Act, verify mounting height with authorities having jurisdiction.

- G. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.
- H. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- I. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- J. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238239.19

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SECTION 238245 - CHILLED BEAMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes passive and active chilled beams.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for chilled beams.
 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories for chilled beams.
 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For chilled beams.
1. Include plans, elevations, sections, and **[mounting] [attachment]** details.
 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include diagrams for power, signal, and control wiring.

Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs below for two-stage Samples.

Coordinate sample requirements with DEN Project Manager.

- C. Samples for Initial Selection: For units with factory-applied finishes.
- D. Samples for Verification: For each type of exposed finish required, prepared on Samples of size indicated below.
1. Chilled-Beam Finishes: **[12 inches (300 mm) long by unit width] <Insert size>**.
- E. Product Schedule: For chilled beams. **[Use same designations indicated on Drawings.]**

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

- F. Delegated-Design Submittal: For chilled beams.
1. Include design calculations for selecting vibration isolators **[and seismic restraints]** and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Suspended ceiling components.
 2. Structural members to which chilled beams will be attached.
 3. Size and location of initial access modules for acoustical tile.
 4. Location of chilled beams including other building components integrated into chilled-beam configuration including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. **<Insert item>**.

Coordinate first subparagraph below with last subparagraph above.

5. Items penetrating finished ceiling including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. **<Insert item>**.
6. Perimeter moldings.
7. Chilled-beam frames.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: Submit certification that chilled beams, accessories, and components will withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.
- D. Sample Warranty: For manufacturer's warranty.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.5 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 PASSIVE CHILLED BEAMS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Halton Company.](#)
 2. [Semco Incorporated; a Flakt-Wood company.](#)
 3. [Swegon Inc.](#)
 4. [Trox USA Inc.](#)
 5. <Insert manufacturer's name>.
 6. or approved equal.
- B. Standards:
1. Comply with ASHRAE 55.

- C. Description: Sheet metal with primary air plenum, secondary chilled-water coil assembly, and mounting-bracket supports suitable for **[surface mounting] [exposed hangers] [recessed mounting] [lay-in installation flush with T-bar ceiling grid]**.
- D. Components:

Coordinate first subparagraph below with "Coordination Drawings" Paragraph in "Informational Submittals" Article.

1. Other building components integrated into chilled-beam configuration including the following:
 - a. Lighting fixtures.
 - b. Air inlets and outlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. **<Insert item>**.
2. Panel: Minimum **[0.0375-inch- (0.95-mm-)] <Insert dimension>** thick, galvanized-steel sheet.
3. Factory Piping: **[ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M, Type C)]** copper tube with ASME B16.22 wrought-copper fittings and brazed joints.
4. Hydronic Cooling Coils: Copper tube, with mechanically bonded **[0.006-inch- (0.15-mm)]** thick, aluminum fins spaced no closer than **0.1 inch (2.5 mm)**, rated for a minimum working pressure of **200 psig (1378 kPa)** and a maximum entering-water temperature of **220 deg F (104 deg C)**. Include manual air vent and drain valve.

Retain "Electrical Connections" Subparagraph below only when electrical components are included in chilled-beam configuration for insertion into ceiling systems.

5. Electrical Connections: Nonheating, high-temperature, insulated-copper leads.

Retain "Exposed Metal Finish" Paragraph below for exposed hanger-supported chilled-beam units.

- E. Exposed Metal Finish: **[Sheet metal with baked enamel] [Silk-screened finish to match appearance of acoustical ceiling tiles as selected by DEN Project Manager] [Factory prime coated, ready for field painting]**.

Retain "Color" Subparagraph below if retaining baked-enamel finish in "Exposed Metal Finish" Paragraph above; revise to suit Project.

1. Color: Manufacturer's **[standard] [custom]** paint color as selected by DEN Project Manager.

Retain "Surface-Mounted Trim" Subparagraph below for surface-mounted chilled-beam units.

2. Surface-Mounted Trim: Sheet metal with baked-enamel finish in manufacturer's **[standard] [custom]** paint color as selected by DEN Project Manager.

If Project has more than one type or size of passive chilled beam, delete "Capacities and Characteristics" Paragraph below and schedule chilled beams on Drawings.

F. Capacities and Characteristics:

1. Nominal Panel Size: [12 by 48 inches (300 by 1200 mm)] [24 by 48 inches (600 by 1200 mm)] [12 by 96 inches (300 by 2400 mm)] [12 by 118 inches (300 by 3000 mm)] **<Insert dimensions>**.
2. Nominal Depth: [4 inches (100 mm)] [7 inches (180 mm)] **<Insert dimension>**.
3. Room Temperature: [75 deg F (24 deg C)] **<Insert temperature>**.

Cooling capacity is determined by length of unit and water temperature. Coordinate selection with nominal panel size.

4. Cooling Capacity: **<Insert Btu/h (W)>**.
5. Chilled-Water Inlet Temperature: **<Insert deg F (deg C)>**.
6. Average Chilled-Water Temperature: **<Insert deg F (deg C)>**.
7. Chilled-Water Flow: **<Insert gpm (L/s)>**.

2.3 ACTIVE CHILLED BEAMS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Dadanco USA.](#)
2. [Halton Company.](#)
3. [Semco Incorporated; a Flakt-Wood company.](#)
4. [Swegon Inc.](#)
5. [Trox USA Inc.](#)
6. [TWA Panel Systems Inc.](#)
7. **<Insert manufacturer's name>**.
8. or approved equal.

B. Standards:

1. Comply with ASHRAE 55.

In "Description" Paragraph below, retain "and heating-water coil" option for active chilled beams that include heating. Active chilled beams may include heating coils as well as the standard chilled-water coils.

C. Description: Sheet metal with primary air plenum, secondary chilled-water coil[**and heating-water coil**] assembly, and mounting-bracket supports suitable for [surface mounting] [exposed hangers] [recessed mounting] [lay-in installation flush with T-bar ceiling grid].

D. Components:

Coordinate first subparagraph below with "Coordination Drawings" Paragraph in "Informational Submittals" Article.

1. Other building components integrated into chilled-beam configuration including the following:
 - a. Lighting fixtures.
 - b. Air inlets and outlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. <Insert item>.
2. Panel: Minimum [0.0375-inch- (0.95-mm-)] <Insert dimension> thick, galvanized-steel sheet.
3. Factory Piping: [ASTM B 88, Type L (ASTM B 88M, Type B)] [ASTM B 88, Type M (ASTM B 88M, Type C)] copper tube with ASME B16.22 wrought-copper fittings and brazed joints.
4. Hydronic Coils: Copper tube, with mechanically bonded [0.006-inch- (0.15-mm-)] thick, aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
 - a. Cooling Coil: [NPS 1/2 (DN 15)] <Insert pipe size>.
 - b. Heating Coil: [NPS 1/2 (DN 15)] <Insert pipe size>.

Active chilled beams have nozzles that direct the airflow over the coils.

5. Number of Nozzles: [Four] <Insert number>.

Retain "Electrical Connections" Subparagraph below only when electrical components are included in chilled-beam configuration for insertion into ceiling systems.

6. Electrical Connections: Nonheating, high-temperature, insulated-copper leads.

Retain "Exposed Metal Finish" Paragraph below for exposed hanger-supported chilled-beam units.

- E. Exposed Metal Finish: [Sheet metal with baked enamel] [Silk-screened finish to match appearance of acoustical ceiling tiles as selected by DEN Project Manager] [Factory prime coated, ready for field painting].

Retain "Color" Subparagraph below if retaining baked-enamel finish in "Exposed Metal Finish" Paragraph above; revise to suit Project.

1. Color: Manufacturer's [standard] [custom] paint color as selected by DEN Project Manager.

Retain "Surface-Mounted Trim" Subparagraph below for surface-mounted chilled-beam units.

2. Surface-Mounted Trim: Sheet metal with baked-enamel finish in manufacturer's [standard] [custom] paint color as selected by DEN Project Manager.

If Project has more than one type or size of active chilled beam, delete "Capacities and Characteristics" Paragraph below and schedule chilled beams on Drawings.

F. Capacities and Characteristics:

1. Nominal Panel Size: [12 by 48 inches (300 by 1200 mm)] [24 by 48 inches (600 by 1200 mm)] [12 by 96 inches (300 by 2400 mm)] [12 by 118 inches (300 by 3000 mm)] <Insert dimensions>.
2. Nominal Depth: [4 inches (100 mm)] [7 inches (180 mm)] <Insert dimension>.
3. Room Temperature for Cooling: [75 deg F (24 deg C)] <Insert temperature>.

Cooling capacity is determined by length of unit and water temperature. Coordinate selection with nominal panel size.

4. Cooling Capacity: <Insert Btu/h (W)>.
5. Chilled-Water Inlet Temperature: <Insert deg F (deg C)>.
6. Average Chilled-Water Temperature: <Insert deg F (deg C)>.
7. Chilled-Water Flow: <Insert gpm (L/s)>.
8. Room Temperature for Heating: [72 deg F (21 deg C)] <Insert temperature>.

Heating capacity is determined by length of unit and water temperature. Coordinate selection with nominal panel size.

9. Heating Capacity: <Insert Btu/h (W)>.
10. Heating-Water Inlet Temperature: <Insert deg F (deg C)>.
11. Heating-Water Flow: <Insert gpm (L/s)>.
12. Average Heating-Water Temperature: <Insert deg F (deg C)>.

2.4 CONTROLS AND SAFETIES

- A. Wall Thermostat: Bimetal sensing elements calibrated from 55 to 90 deg F (13 to 32 deg C); with contacts suitable for [low] [control]-voltage circuit, and manually operated on-off switch with contactors, relays, and control transformers.

Retain "Humidistat" Paragraph below only if active chilled beams are used in conjunction with central air-conditioning system and humidity control is included in Project.

- B. Humidistat: [Wall mounted] [Unit mounted] with [concealed] [exposed] set point and contacts suitable for [low] [control]-voltage circuit, and manually operated on-off switch with contactors, relays, and control transformers.

2.5 ACCESSORIES

- A. Purging Nipple: Copper, with threaded end connection.

Retain "clear anodized finish" option in "Chilled-Beam Unit Frame" Paragraph below only when using aluminum frames and when chilled beams are left exposed and are not part of an integrated ceiling system.

- B. Chilled-Beam Unit Frame: [Aluminum] [Steel], [clear anodized finish] [silk-screened finish to match appearance of acoustical ceiling panels selected by DEN Project Manager] [factory prime coated, ready for field painting] [baked-enamel finish].

Retain "Color" Subparagraph below if retaining baked-enamel finish in "Chilled-Beam Unit Frame" Paragraph above; revise to suit Project.

1. Color: Manufacturer's **[standard]** **[custom]** paint color, selected by DEN Project Manager.
- C. Flexible Water-Connector Hose: **[20 inches (500 mm)]** **[30 inches (750 mm)]** **[39 inches (1000 mm)]** long.
- D. Access Door: Hinged with **[four]** **<Insert number>** spring-loaded cabinet roller latches.

2.6 GENERAL FINISH REQUIREMENTS

- A. Protect mechanical finishes on exposed surfaces from damage by applying a strippable, temporary protective covering before shipping.

Retain first paragraph below only for chilled beams that will be finished to match adjacent materials.

- B. Finish chilled beams after assembly.
- C. Appearance of Finished Work: Variations in same piece are not acceptable. Variations in appearance of adjoining components are acceptable if they are within the range of approved Samples and are assembled or installed to minimize contrast.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive chilled beams for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for **[hot- and]**chilled-water piping to verify actual locations of piping connections before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install **[surface-mounted]** **[exposed hanger-mounted]** **[recessed-mounted]** **[lay-in ceiling-mounted]** chilled-beam units level and plumb.

Revise first paragraph below to delete or insert types of construction that penetrate or are supported by ceilings.

- B. Coordinate layout and installation of chilled beams and suspension-system components with other construction that penetrates ceilings or is supported by them,

including light fixtures, HVAC equipment, fire-suppression system, communications system, security system, and partition assemblies.

Retain "Seismic Restraints" Paragraph below for installation of equipment with seismic restraints.

- C. Seismic Restraints: Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- D. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- E. Comply with requirements for general-duty valves specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," Section 230523.14 "Check Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- F. Install continuous-thread hanger rods of size required to support chilled-beam weight.

Retain first paragraph below only when electrical components are field installed in chilled-beam configuration for insertion into ceiling systems.

- G. Comply with NECA 1.

Retain one of two "Wiring Method" paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings or if chilled-beam configuration does not include electrical components.

- H. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters[**and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used**]. Conceal raceways and cables except in unfinished spaces.

Retain first subparagraph below if retaining unenclosed wiring method in "Wiring Method" Paragraph above.

- 1. Install plenum cable in environmental air spaces, including plenum ceilings.
 - 2. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
 - 3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- I. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- J. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

Retain "Sprinklers" Paragraph below if sprinklers are integrated into chilled-beam configuration. Coordinate locations with wet-pipe sprinkler-system Drawings and reflected ceiling plan.

- K. Sprinklers: Comply with requirements for sprinkler-head installation in Section 211313 "Wet-Pipe Sprinkler Systems."

Retain "Lighting Fixtures" Paragraph below if lighting fixtures are integrated into chilled-beam configuration. Coordinate locations with interior-lighting Drawings and reflected ceiling plan.

- L. Lighting Fixtures: Comply with requirements for lighting-fixture installation in Section 265100 "Interior Lighting."

Retain "Speakers" Paragraph below when voice address-system speakers are integrated into chilled-beam configuration. Coordinate locations with public-address and notification-system Drawings and reflected ceiling plan.

- M. Speakers: Comply with requirements for speaker installation in Section 275116 "Public Address and Mass Notification Systems."

Retain "Intrusion-Detection Components" Paragraph below when intrusion-detection-system components are integrated into chilled-beam configuration. Coordinate locations with intrusion-detection system Drawings and reflected ceiling plan.

- N. Intrusion-Detection Components: Comply with the requirements for detection sensor installation in Section 281600 "Intrusion Detection."

Retain "Security Components" Paragraph below when video surveillance cameras are integrated into chilled-beam configuration.

- O. Security Components: Comply with requirements for video-camera installation in Section 282300 "Video Surveillance."

3.3 CONNECTIONS

Coordinate piping and ductwork installations with Drawings and with requirements specified in piping and ductwork systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to chilled beams, allow space for service and maintenance.
- C. Comply with requirements for ductwork specified in [**Section 233113 "Metal Ducts."**] [**Section 233116 "Nonmetal Ducts."**] [**Section 233113 "Metal Ducts" and Section 233116 "Nonmetal Ducts."**] Drawings indicate general arrangement of ductwork.

Coordinate first paragraph below with Drawings.

- D. Make piping and ductwork connections through [**right side**] [**left side**] [**top**] [**end**] of chilled-beam unit.

- E. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- F. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 IDENTIFICATION

Retain first paragraph below when chilled-beam configuration includes electrical components.

- A. Identify electrical-system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Identify hydronic piping and valves. Comply with requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.5 FIELD QUALITY CONTROL

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Test and adjust thermostatic controls and equipment. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Chilled beam will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.6 ADJUSTING

Humidity can only be controlled if active chilled beams are used with a central air-conditioning system. Retain "and humidity " option in first paragraph below if a central air-conditioning system is included in Project.

- A. Adjust initial temperature [**and humidity**] set points.
- B. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238245

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SECTION 238313 - RADIANT-HEATING ELECTRIC CABLES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes electric heating cables for ceiling or floor radiant heating, snow and ice melting on pavement, and freezer-floor frost-heave prevention with the following electric heating cables:
 - 1. Mineral insulated, series resistance.
 - 2. Plastic insulated, series resistance.
 - 3. Self-regulating, parallel resistance.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 210533 "Heat Tracing for Fire-Suppression Piping."
- 2. Section 220533 "Heat Tracing for Plumbing Piping."

3. Section 230533 "Heat Tracing for HVAC Piping."
4. Section 238213 "Valance Heating and Cooling Units" for factory-fabricated electric heating panels for ceiling and wall applications.
5. Section 238323 "Radiant-Heating Electric Panels."

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PRE-INSTALLATION CONFERENCE

Select one below. First number is minimum required.

- A. Convene **<one (1)>** **<Insert number>** week prior to commencing work of this Section at **[specify location]** **[location and time as determined by DEN Project Manager]**.
- B. Require attendance of parties directly affecting the work of this Section.
- C. Review sequencing of installation, protection from damage of finished installation, location and characteristics of electrical supply provisions to be provided as Division 26 work, and methods used for covering installations with insulation.

1.4 PERFORMANCE REQUIREMENTS

- A. Pipe Trace Heating: Freeze protection with outside temperature at **<Insert number>** degrees F.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 2. Schedule heating capacity, length of cable, spacing, and electrical power requirement for each electric heating cable required.
 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For electric **<heating cable>** **<and>** **<mat>**, layout, locations of terminations, thermostats, and branch circuit connections..
 1. Include plans, sections, details, and attachments to other work.
 2. Include diagrams for power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

Revise subparagraphs below to suit Project.

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Items installed in finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. Perimeter moldings.
 - g. <Insert item>.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
- C. Sample Warranty: For special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electric heating cables to include in operation and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Edit below to suit Project.

1. Accurately record actual locations of [heating cable,] [mat,] [temperature sensors,] [thermostats,] and branch circuit connections.

1.8 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for electric heating cable.

1. Warranty Period: Minimum [ten (10)] [fifteen (15)] <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 GENERAL REQUIREMENTS FOR ELECTRIC HEATING CABLES

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. General: Furnish and install a complete UL-listed system of heating cables, components, and controls to prevent pipelines from freezing.
- C. Products: The self-regulating heating cable shall consist of two (2) 16 AWG tinned-copper bus wires embedded in parallel in a self-regulating polymer core that varies its power output to respond to temperature all along its length, allowing the heating cable to be cut to length in the field. The heating cable shall be covered by a radiation-crosslinked, modified polyolefin dielectric jacket. To provide a ground path and to enhance the heating cable's ruggedness, the heating cable shall have a braid of tinned-copper and an outer jacket of [modified polyolefin (-CR)] [or] [fluoropolymer (-CT)], as required per section 427-23 of the NEC-1999.
- D. In order to conserve energy and to prevent overheating, the heating cable shall have a self-regulating factor of at least 90 percent. The self-regulation factor is defined as the

percentage reduction, without thermostatic control, of the heating cable output going from 40 degrees F pipe temperature operation to 150 degrees F pipe temperature operation.

- E. Heating cable shall be selected and applied according to the table below. The required heating cable output rating is in watts per foot at 50 degrees F. The indicated heating cable selection based on installation under 1" fiberglass insulation on metal piping.

Pipe Size (inches):	Minimum Ambient Temperatures:	
	-10 degrees F	-20 degrees F
3 or smaller	5 watts	5 watts
4	5 watts	8 watts
6	8 watts	8 watts
8	2 strips - 5 watts	2 strips- 8 watts
12 to 14	2 strips - 8 watts	2 strips - 8 watts

- F. Power connection, end seal, splice, and tee kit components shall be applied in the field.
- G. Heating cable circuit shall be protected by a ground fault device for equipment protection, in accordance with section 427-22 of the NEC-1999.

2.2 MINERAL-INSULATED, SERIES-RESISTANCE HEATING CABLES

Retain this article for snow melting on pavement.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Chromalox](#).
 2. [Delta-Therm Corporation](#).
 3. [Easy Heat; a division of EGS Electrical Group LLC](#).
 4. [Nelson Heat Trace; a division of EGS Electrical Group LLC](#).
 5. [Pyrotenax; a brand of Tyco Thermal Controls LLC](#).
 6. [Raychem; a brand of Tyco Thermal Controls LLC](#).
 7. [Trasor Corp](#).
 8. [Watts Radiant, Inc.; a subsidiary of Watts Water Technologies, Inc](#).
 9. **<Insert manufacturer's name>**.
 10. or approved equal.
- B. Comply with UL 1673.
- C. Heating Element: Single- or dual-conductor resistor wire. Terminate with waterproof, factory-assembled, nonheating leads with connectors at both ends.
- D. Electrical Insulating Mineral: Magnesium oxide.

Outer jacket in "Cable Cover" Paragraph below is optional feature and is required for waterproof applications; verify availability with manufacturer.

- E. Cable Cover: Copper-nickel alloy[**and high-density polyethylene outer jacket**].
- F. Maximum Operating Temperature: [300 deg F (150 deg C)] **<Insert temperature>**.

If Project has more than one type or configuration of electric heating cable, delete "Capacities and Characteristics" Paragraph below and schedule on Drawings. See Evaluations for sample schedule.

- G. Capacities and Characteristics:
 - 1. Maximum Heat Output: [6 W/ft. (19.7 W/m)] [7.5 W/ft. (24.6 W/m)] **<Insert value>**.
 - 2. Spacing: **<Insert inches (mm)>**.
 - 3. Electrical Characteristics for Single-Circuit Connection:

Verify available voltages, phase, and heat-output ratings with manufacturer. Most manufacturers supply this product in single phase only.

- a. Volts: [120] [208] [240] [277] [480] **<Insert value>**.
- b. Phase: **<Insert value>**.
- c. Hertz: **<Insert value>**.
- d. Full-Load Amperes: **<Insert value>**.
- e. Minimum Circuit Ampacity: **<Insert value>**.
- f. Maximum Overcurrent Protection: **<Insert amperage>**.

2.3 PLASTIC-INSULATED, SERIES-RESISTANCE HEATING CABLES

Retain this article for ceiling and floor radiant heating, freezer-floor frost-heave prevention, and snow and ice melting on pavement. Some manufacturers limit use of this product to stone, ceramic tile, or concrete floors.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Delta-Therm Corporation.
 - 2. Easy Heat; a division of EGS Electrical Group LLC.
 - 3. Nuheat Industries Ltd.
 - 4. Orbit Manufacturing.
 - 5. Pyrotenax; a brand of Tyco Thermal Controls LLC.
 - 6. Raychem; a brand of Tyco Thermal Controls LLC.
 - 7. WarmlyYours Inc.
 - 8. Watts Radiant, Inc.; a subsidiary of Watts Water Technologies, Inc.
 - 9. **<Insert manufacturer's name>**.
 - 10. or approved equal.
- B. Comply with UL 1673.

- C. Heating Element: Single resistor wire. Terminate with waterproof, factory-assembled, nonheating leads with connectors at both ends.
- D. Electrical Insulating Jacket: Minimum 4.0-mil (0.10-mm) Kapton with silicone or Tefzel.

Outer jacket in "Cable Cover" Paragraph below is optional feature and is required for waterproof applications; verify availability with manufacturer.

- E. Cable Cover: [Aluminum] [Stainless-steel] [Nickel] braid[with silicone or Hylar outer jacket].
- F. Maximum Operating Temperature: [300 deg F (150 deg C)] <Insert temperature>.

Retain "Cable-Heated Mats" Paragraph below for heating cables in factory-fabricated mats. Indicate length and spacing of cables on Drawings.

- G. Cable-Heated Mats: Factory-fabricated cable and fiberglass or plastic mesh with uniform [1-1/2-inch (38-mm)] [3-inch (76-mm)] <Insert dimension> cable spacing, in [18-inch (457-mm)] [36-inch (914-mm)] <Insert dimension> widths.

If Project has more than one type or configuration of electric heating cable, delete "Capacities and Characteristics" Paragraph below and schedule on Drawings. See Evaluations for sample schedule.

- H. Capacities and Characteristics:

Retain "Maximum Heat Output (Cable)" Subparagraph below for loose-laid heating cables.

- 1. Maximum Heat Output (Cable): [6 W/ft. (19.7 W/m)] [7.5 W/ft. (24.6 W/m)] <Insert value>.

Retain "Maximum Heat Output (Mat)" Subparagraph below for heating cables in factory-fabricated mats. Heat output depends on spacing of the heating cables within the mat. Verify output capacities with manufacturers.

- 2. Maximum Heat Output (Mat): [12 W/sq. ft. (129 W/sq. m)] [16 W/sq. ft. (172 W/sq. m)] <Insert value>.

Retain "Spacing" Subparagraph below for cable-heated mats.

- 3. Spacing: <Insert inches (mm)>.
- 4. Electrical Characteristics for Single-Circuit Connection:

Verify available voltages, phase, and heat-output ratings with manufacturer. Most manufacturers supply this product in single phase only.

- a. Volts: [120] [208] [240] [277] [480] <Insert value>.
- b. Phase: <Insert value>.
- c. Hertz: <Insert value>.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.4 SELF-REGULATING, PARALLEL-RESISTANCE HEATING CABLES

Retain this article for ceiling and floor radiant heating, freezer-floor frost-heave prevention, and snow and ice melting on pavement.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [BriskHeat](#).
 2. [Chromalox](#).
 3. [Delta-Therm Corporation](#).
 4. [Easy Heat; a division of EGS Electrical Group LLC](#).
 5. [Nelson Heat Trace; a division of EGS Electrical Group LLC](#).
 6. [Pyrotenax; a brand of Tyco Thermal Controls LLC](#).
 7. [Raychem; a brand of Tyco Thermal Controls LLC](#).
 8. [Thermon Americas Inc.](#)
 9. [Trasor Corp.](#)
 10. **<Insert manufacturer's name>**.
 11. or approved equal.
- B. Comply with UL 1673.
- C. Heating Element: Pair of parallel **[No. 16] [No. 18]** AWG, **[tinned] [nickel-coated]**, stranded copper bus wires embedded in crosslinked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled, nonheating leads with connectors at one end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.
- D. Electrical Insulating Jacket: Flame-retardant polyolefin.

Outer jacket in "Cable Cover" Paragraph below is optional feature and is required for waterproof applications; verify availability with manufacturer.

- E. Cable Cover: **[Tinned-copper] [Stainless-steel]** braid **[with polyolefin outer jacket with ultraviolet inhibitor]**.
- F. Maximum Operating Temperature: **[300 deg F (150 deg C)] <Insert temperature>**.

Retain "Cable-Heated Mats" Paragraph below for heating cables in factory-fabricated mats. Indicate length and spacing of cables on Drawings.

- G. Cable-Heated Mats: Factory-fabricated cable and fiberglass or plastic mesh with uniform **[1-1/2-inch (38-mm)] [3-inch (76-mm)] <Insert dimension>** cable spacing, in **[18-inch (457-mm)] [36-inch (914-mm)] <Insert dimension>** widths.

If Project has more than one type or configuration of electric heating cable, delete "Capacities and Characteristics" Paragraph below and schedule on Drawings. See Evaluations for sample schedule.

H. Capacities and Characteristics:

Retain "Maximum Heat Output (Cable)" Subparagraph below for loose-laid heating cables.

1. Maximum Heat Output (Cable): [3 W/ft. (9.8 W/m)] [5 W/ft. (16.4 W/m)] [8 W/ft. (26 W/m)] [10 W/ft. (32.8 W/m)] [12 W/ft. (39.4 W/m)] <Insert value>.

Retain "Maximum Heat Output (Mat)" Subparagraph below for heating cables in factory-fabricated mats. Heat output depends on spacing of the heating cables within the mat. Verify output capacities with manufacturers.

2. Maximum Heat Output (Mat): [6 W/sq. ft. (65 W/sq. m)] [12 W/sq. ft. (129 W/sq. m)] [16 W/sq. ft. (172 W/sq. m)] [24 W/sq. ft. (260 W/sq. m)] <Insert value>.

Retain "Spacing" Subparagraph below for cable-heated mats.

3. Spacing: <Insert inches (mm)>.
4. Electrical Characteristics for Single-Circuit Connection:

Verify available voltages, phase, and heat-output ratings with manufacturer. Most manufacturers supply this product in single phase only.

- a. Volts: [120] [208] [240] [277] [480] <Insert value>.
- b. Phase: <Insert value>.
- c. Hertz: <Insert value>.
- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

2.5 CONTROLS

Retain first paragraph below and delete remainder of this article to specify temperature controls in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC." Delete first paragraph and retain remaining paragraphs to require controls integral to the radiant-heating electric cables to be provided by cable manufacturer.

- A. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for control devices and sequence of operations for radiant-heating electric cables.

Retain "Wall-Mounted Thermostats for Ceiling and Floor Heating Cables" Paragraph below for room-temperature control of electric cables in ceilings and floors.

- B. Wall-Mounted Thermostats for Ceiling and Floor Heating Cables:
 1. Minimum temperature range from [50 to 90 deg F (10 to 32 deg C)] <Insert temperature range>.
 2. Manually operated with on-off switch.

Retain "Precipitation and Temperature Sensor for Snow Melting on Pavement" Paragraph below to operate electric heating cable for snow melting on pavement.

- C. Precipitation and Temperature Sensor for Snow Melting on Pavement:

1. **[Microprocessor-based] [Automatic]** control with manual on, automatic, and standby/reset switch.
2. Precipitation and temperature sensors shall sense the surface conditions of pavement and shall be programmed to energize the cable as follows:

Retain and revise features in "Temperature Span," "Adjustable Delay-Off Span," "Energize Cables," and "De-Energize Cables" subparagraphs below to suit Project. Verify available features with manufacturer.

- a. Temperature Span: [34 to 44 deg F (1 to 7 deg C)] **<Insert temperature range>**.
 - b. Adjustable Delay-Off Span: [30 to 90] **<Insert time>** minutes.
 - c. Energize Cables: Following [two] **<Insert time>**-minute delay if ambient temperature is below set point and precipitation is detected.
 - d. De-Energize Cables: On detection of a dry surface plus time delay.
3. Corrosion-proof and waterproof enclosure suitable for outdoor mounting, for controls and precipitation and temperature sensors.
 4. Minimum 30-A contactor to energize cable or close other contactors.
 5. Provide relay with contacts to indicate operational status, on or off, for interface with central HVAC control-system workstation.

2.6 ACCESSORIES

- A. Cable Installation Accessories: Fiberglass tape, heat-conductive putty, cable ties, silicone end seals and splice kits, and installation clips all furnished by manufacturer, or as recommended in writing by manufacturer.
- B. Embedded Heating-Cable Identification:

Retain one of three subparagraphs below.

1. Flush-mounted cast-iron boxes with identification on lid according to NFPA 70.
2. Mechanically fastened [metal] [plastic] signage with identification according to NFPA 70 and complying with requirements in [Section 101416 "Plaques."] [Section 101419 "Dimensional Letter Signage."] [Section 101423 "Panel Signage."]
3. Mechanically fastened [metal] [plastic] [concrete] post-mounted signage with identification according to NFPA 70 and complying with requirements in [Section 101416 "Plaques."] [Section 101419 "Dimensional Letter Signage."] [Section 101423 "Panel Signage."]

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine surfaces and substrates to receive electric heating cables or cable-heated mats for compliance with requirements for installation tolerances and other conditions affecting performance.

1. Ensure surfaces in contact with electric heating cables or cable-heated mats are free of burrs and sharp protrusions.
 2. Ensure surfaces and substrates are level and plumb.
- B. Verify field measurements are as shown on **[shop drawings] [Drawings]**.
- C. Verify that required utilities are available, in proper location, and ready for use.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.
- E. Beginning of installation means installer accepts conditions.

3.2 APPLICATIONS

Applications in this article are typical uses for each type of electric heating cable. Consult manufacturers for other applications.

- A. Install the following types of electric heating cable for the applications described:
1. Ceiling Radiant Heating: **[Plastic-insulated, series-resistance] [Self-regulating, parallel-resistance]** heating cable.
 2. Floor Radiant Heating: **[Plastic-insulated, series-resistance] [Self-regulating, parallel-resistance]** heating cable.
 3. Snow and Ice Melting on Pavement: **[Mineral-insulated, series-resistance] [Plastic-insulated, series-resistance] [Self-regulating, parallel-resistance]** heating cable.
 4. Freezer-Floor Frost-Heave Prevention: **[Plastic-insulated, series-resistance] [Self-regulating, parallel-resistance]** heating cable.

3.3 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Bending Radius: Six times cable diameter, minimum.
- C. Avoid pinching and making sharp bends in cable. Prevent damage by sharp rocks, metal, or other objects during installation.
- D. Do not install heating cable across piping expansion joints.
- E. Do not cross heating cable over itself.
- F. A tinned copper braid shall be used to provide an effective ground path on painted, stainless, or plastic pipes or tanks.
- G. Cable ends, splices and junction boxes shall be properly sealed to prevent moisture entry.

Indicate location of controls on Drawings.

- H. Install electric heating cable or cable-heated mats across expansion, construction, and control joints according to manufacturer's written instructions; use cable-protection conduit and slack cable to allow movement without damage to cable.
- I. Do not energize cables embedded in concrete or plaster until those assemblies are cured.

Coordinate "Electric Heating-Cable Installation for Ceiling Radiant Heating" Paragraph below with Drawings. Indicate details of how cable-heating array is installed in ceiling.

- J. Electric Heating-Cable Installation for Ceiling Radiant Heating: Install heating cable or cable-heated mat with heat-conductive fill materials such as plaster to ensure direct contact with finished radiant surfaces.

Coordinate "Electric Heating-Cable Installation for Floor Radiant Heating" Paragraph below with Drawings. Indicate details of how cable-heating array is installed in floor.

- K. Electric Heating-Cable Installation for Floor Radiant Heating: Install heating cable or cable-heated mat with heat-conductive fill materials such as concrete to ensure direct contact with finished radiant surfaces.

- L. Electric Heating-Cable or Cable-Heated-Mat Installation for Snow and Ice Melting in Pavement:

- 1. Install heating cable or cable-heated mat with heat-conductive fill materials such as asphalt or concrete to ensure direct contact with finished radiant surfaces.

Retain first subparagraph below for asphalt paving.

- 2. Install cables or cable-heated mats after applying bituminous binder course to lower base; ensure that second bituminous binder course is applied to cables or mats before pouring finish topping.

Retain first subparagraph below to require a flush-mounted box to identify embedded heating array. Coordinate with paving Sections.

- 3. Install embedded electric heating-cable or cable-heated-mat identification box where indicated in pavement before pavement work is completed.

Retain first subparagraph below for cast-in-place concrete paving and to require embedded heating array to be identified by stamping.

- 4. Stamp concrete with embedded electric heating-cable or cable-heated-mat identification according to NFPA 70 and complying with requirements in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]

Consider pavement-mounted sensor for snow melting on pavement.

- 5. Mount precipitation sensor in pavement.

- M. Electric Heating-Cable Installation for Freezer-Floor Frost-Heave Prevention: Install electric heating cable or cable-heated mat below insulation in subsoil.

Retain first subparagraph below to require a flush-mounted box to identify embedded heating array. Coordinate with finished floor work.

1. Install embedded electric heating-cable or cable-heated-mat identification box where indicated.

embedded electric heating-cable or cable-heated-mat identification

2. Install embedded electric heating-cable or cable-heated-mat identification according to NFPA 70 on adjacent structure and complying with requirements in **[Section 101416 "Plaques.]" [Section 101419 "Dimensional Letter Signage.]" [Section 101423 "Panel Signage.]**
3. Install embedded electric heating-cable or cable-heated-mat identification according to NFPA 70 on **[metal] [wood] [concrete]** post and complying with requirements in **[Section 101416 "Plaques.]" [Section 101419 "Dimensional Letter Signage.]" [Section 101423 "Panel Signage.]**

Retain subparagraph below to require embedded heating array to be identified by stamping.

4. Stamp concrete with embedded electric heating-cable or cable-heated-mat identification according to NFPA 70 and complying with requirements in **[Section 033000 "Cast-in-Place Concrete.]" [Section 033053 "Miscellaneous Cast-in-Place Concrete.]**

- N. Set field-adjustable switches and circuit-breaker trip ranges.

3.4 INSTALLATION - ELECTRICAL HEAT TRACING FOR PIPELINES

- A. Apply the heating cable linearly on the pipe after piping has been successfully pressure-tested. Secure the heating cable to piping with cable ties or fiberglass tape.
- B. Apply "Electrically Heat Traced" legend to the outside of the thermal insulation; refer to Section 260553 "Identification for Electrical Systems".
- C. Tests: After installation and before and after installing the thermal insulation, subject heating cable to testing using a 2500 VDC Megger. Minimum insulation resistance shall be 20 to 1000 megohms regardless of length.

3.5 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.6 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Perform tests after cable installation but before application of coverings such as insulation, wall or ceiling construction, or concrete.
 2. Test cables for electrical continuity and insulation integrity before energizing.
 3. Test cables to verify rating and power input. Energize and measure voltage and current simultaneously.
 4. Measure insulation resistance to manufacturer's recommended values. Use test instruments in accordance with manufacturer's instructions.
 5. Perform continuity and insulation resistance test on completed cable installation.
 6. Measure voltage and current at each unit.
- D. Repeat tests for continuity, insulation resistance, and input power after applying finished surface on heating cables.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. Radiant-heating electric cables will be considered defective if they do not pass tests and inspections.
- F. Make required corrections and re-test system.
- G. Prepare test and inspection reports.

3.7 PROTECTION

- A. Protect installed heating cables, including nonheating leads, from damage during construction.
- B. Remove and replace damaged radiant-heating electric cables and cable-heated mats.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238313

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SECTION 238316 - RADIANT-HEATING HYDRONIC PIPING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes radiant-heating piping, including pipes, fittings, and piping specialties.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. CWP: Cold working pressure.
- B. PEX: Crosslinked polyethylene.
- C. PEX/AL/PEX: Crosslinked polyethylene/aluminum/crosslinked polyethylene.
- D. PTFE: Polytetrafluoroethylene plastic.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data for piping, fittings, valves, manifolds, specialties, and controls; include pressure and temperature ratings, oxygen-barrier performance, fire-performance characteristics, and water-flow and pressure-drop characteristics.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Show piping layout and details drawn to scale, including valves, manifolds, controls, and support assemblies, and their attachments to building structure.
 - 1. Shop Drawing Scale: [1/4 inch = 1 foot (1:50)] **<Insert scale>**.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Suspended ceiling components.
 - 2. Structural members to which radiant-heating piping will be attached.
 - 3. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.

- e. Access panels.
- f. **<Insert item>**.

4. Perimeter moldings.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For radiant-heating piping valves and equipment to include in operation and maintenance manuals. Include installation instructions, spare parts lists, exploded assembly views.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

- 1. Record actual locations of [**valves, valve pits and manifolds.**] **<Insert other.>**

1.7 QUALITY ASSURANCE

- A. Conform to ASME B31.9 code for installation of piping system.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 1.
- B. Accept materials on site in shipping containers with labeling in place. Inspect for damage.
- C. Provide temporary end caps and closures on piping and fittings. Maintain in place until installation.
- D. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

1.9 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements".
- B. Tubing shall carry a twenty-five (25) year non-prorated warranty against failure due to defect in material and workmanship. Manifolds and other ancillary components shall be warranted for eighteen (18) months from date of shipment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

Piping, fittings, and materials described herein are generally restricted to 150 psig working steam pressure (WSP). For other pressure and temperature ratings, additional specifications and restrictions may be required

2.1 PEX PIPE AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [FloorHeat Company \(The\).](#)
 2. [Heat Innovations Inc.](#)
 3. [HeatLink Group Inc.](#)
 4. [Infloor Radiant Floor Heating.](#)
 5. [IPEX Inc.](#)
 6. [Mr Pex Systems Inc.](#)
 7. [REHAU Incorporated.](#)
 8. [Slant/Fin Corporation.](#)
 9. [Uponor.](#)
 10. [Viega LLC.](#)
 11. [Warmboard Inc.](#)
 12. [Watts Radiant, inc.; a Watts Water Technologies company.](#)
 13. [Zurn Industries, LLC; Zurn Pex, Inc.](#)
 14. **<Insert manufacturer's name>.**
 15. or approved equal.
- B. Pipe Material: PEX plastic according to ASTM F 876.

See discussion in the Evaluations about oxygen barrier in "Oxygen Barrier" Paragraph below. The referenced standard is the only standard used by plastic-tubing manufacturers that describes how to test and measure oxygen diffusion in plastic tube. It is a German national standard and is available in English; see the Evaluations for information about where it can be obtained.

- C. Oxygen Barrier: Limit oxygen diffusion through the tube to maximum 0.10 mg per cu. m/day at **104 deg F** (40 deg C) according to DIN 4726.
- D. Fittings: ASTM F 1807, metal insert and copper crimp rings.
- E. Pressure/Temperature Rating: Minimum **100 psig** (690 kPa) and **180 deg F** (82 deg C).

2.2 PEX/AL/PEX PIPE AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Heat Innovations Inc.](#)
 - 2. [IPEX Inc.](#)
 - 3. [Uponor.](#)
 - 4. [Viega LLC.](#)
 - 5. **<Insert manufacturer's name>**.
 - 6. or approved equal.
- B. Pipe Material: PEX plastic bonded to the inside and outside of a welded aluminum tube according to ASTM F 1281.

See discussion in the Evaluations about oxygen barrier in "Oxygen Barrier" Paragraph below. The referenced standard is the only standard used by plastic-tubing manufacturers that describes how to test and measure oxygen diffusion in plastic tube. It is a German national standard and is available in English; see the Evaluations for information about where it can be obtained.

- C. Oxygen Barrier: Limit oxygen diffusion through the pipe to maximum 0.10 mg per cu. m/day at **104 deg F** (40 deg C) according to DIN 4726.
- D. Fittings: ASTM F 1974, metal insert fittings with split ring and compression nut (compression joint) or metal insert fittings with copper crimp rings (crimp joint).
- E. Flame-Spread and Smoke-Developed Indices: 25 and 50 or less, respectively, tested according to ASTM E 84.
- F. Pressure/Temperature Rating: Minimum **100 psig** (690 kPa) and **210 deg F** (99 deg C).

2.3 EPDM PIPE AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Watts Radiant, inc.; a Watts Water Technologies company.](#)

2. **<Insert manufacturer's name>**.
 3. or approved equal.
- B. Pipe Material: Crosslinked EPDM inner and outer tubes.
- C. Wall Thickness: Minimum **0.125 inch** (3.2 mm).

See discussion in the Evaluations about oxygen barrier in "Oxygen Barrier" Paragraph below. The referenced standard is the only standard used by plastic-tubing manufacturers that describes how to test and measure oxygen diffusion in plastic tube. It is a German national standard and is available in English; see the Evaluations for information about where it can be obtained.

- D. Oxygen Barrier: Ductile aluminum foil layer applied to the inner tube to limit oxygen diffusion through the pipe to maximum 0.10 mg per cu. m/day at **104 deg F** (40 deg C) according to DIN 4726.
- E. Reinforcing Braid: Braided-aluminum wire between the inner and outer tube.
- F. Fittings: ASTM F 1807, copper with stainless-steel crimps or clamps.
- G. Pressure/Temperature Rating: Minimum **100 psig** (690 kPa) and **210 deg F** (99 deg C).

2.4 DISTRIBUTION MANIFOLDS

- A. Manifold: Minimum **NPS 1** (DN 25), **[brass] [copper] [modular plastic] [or] [stainless steel]**.

Some plastic modular manifolds do not have main shutoff valves. Each piping loop on manifold has its own supply and return shutoff.

- B. Main Shutoff Valves:
1. Factory installed on supply and return connections.
 2. **[Two] [Three]**-piece body.
 3. Body: Brass or bronze.
 4. Ball: Chrome-plated bronze.
 5. Seals: PTFE.
 6. CWP Rating: **150 psig** (1035 kPa).
 7. Maximum Operating Temperature: **225 deg F** (107 deg C).
- C. Manual Air Vents:
1. Body: Bronze.
 2. Internal Parts: Nonferrous.
 3. Operator: Key furnished with valve, or screwdriver bit.
 4. Inlet Connection: **NPS 1/2** (DN 15).
 5. Discharge Connection: **NPS 1/8** (DN 6).
 6. CWP Rating: **150 psig** (1035 kPa).
 7. Maximum Operating Temperature: **225 deg F** (107 deg C).

D. Balancing Valves:

1. Body: Plastic or bronze, ball or plug, or globe cartridge type.
2. Ball or Plug: Brass or stainless steel.
3. Globe Cartridge and Washer: Brass with EPDM composition washer.
4. Seat: PTFE.

Retain "Visual Flow Indicator" or "Differential Pressure Gage Connections" Subparagraph below.

5. Visual Flow Indicator: Flowmeter with visible indication in a clear plastic cap at top of valve.
6. Differential Pressure Gage Connections: Integral seals for portable meter to measure loss across calibrated orifice.
7. Handle Style: Lever or knob, with memory stop to retain set position if used for shutoff.
8. CWP Rating: Minimum 125 psig (860 kPa).
9. Maximum Operating Temperature: 250 deg F (121 deg C).

E. Zone Control Valves:

1. Body: Plastic or bronze, ball or plug, or globe cartridge type.
2. Ball or Plug: Brass or stainless steel.
3. Globe Cartridge and Washer: Brass with EPDM composition washer.
4. Seat: PTFE.
5. Actuator: Replaceable electric motor.
6. CWP Rating: Minimum 125 psig (860 kPa).
7. Maximum Operating Temperature: 250 deg F (121 deg C).

F. Thermometers:

1. Mount on supply and return connections.
2. Case: Dry type, metal or plastic, [2-inch (50-mm)] <Insert dimension> diameter.
3. Element: Bourdon tube or other type of pressure element.
4. Movement: Mechanical, connecting element and pointer.
5. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.
6. Pointer: Black metal.
7. Window: Plastic.
8. Connector: Rigid, back type.
9. Thermal System: Liquid- or mercury-filled bulb in copper-plated steel, aluminum, or brass stem.
10. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

G. Mounting Brackets: Copper, or plastic- or copper-clad steel, where in contact with manifold.

2.5 PIPING SPECIALTIES

Cable ties are used to tie piping to reinforcing wire or bars in concrete floors.

A. Cable Ties:

1. Fungus-inert, self-extinguishing, one-piece, self-locking, Type 6/6 nylon cable ties.
2. Minimum Width: **1/8 inch** (3 mm).
3. Tensile Strength: **20 lb** (9 kg), minimum.
4. Temperature Range: **Minus 40 to plus 185 deg F** (Minus 40 to plus 85 deg C).

Floor mounting staples are used to attach piping to floor, wall, or ceiling substrate.

B. Floor Mounting Staples:

1. Steel, with corrosion-resistant coating and smooth finish without sharp edges.
2. Minimum Thickness: **3/32 inch** (2.4 mm).
3. Width: Minimum, wider than tubing.

Floor mounting clamps are used to attach piping to floor, wall, or ceiling substrate.

C. Floor Mounting Clamps:

1. Two bolts, steel, with corrosion-resistant coating and smooth finish without sharp edges.
2. Minimum Thickness: **3/32 inch** (2.4 mm).
3. Width: Minimum, wider than tubing.

Floor mounting tracks are used to control spacing and attach piping to floor, wall, or ceiling substrate.

D. Floor Mounting Tracks:

1. Aluminum or plastic channel track with smooth finish and no sharp edges.
2. Minimum Thickness: **1/16 inch** (1.6 mm).
3. Slot Width: Snap fit to hold tubing.
4. Slot Spacing: [**2-inch** (50-mm)] [**3-inch** (75-mm)] **<Insert dimension>** intervals.

Grooved panels are used to control pipe spacing and to attach and maintain pipe contact with subfloor. Subfloor in "Channeled Subfloor" Paragraph below is a proprietary product of Warmboard.

E. Channeled Subfloor:

1. Plywood, APA-rated subfloor panel, composed of premium, tongue-and-groove, seven-layer, Douglas fir structural subfloor panels.
2. Particleboard manufactured to comply with Federal Housing Authority standards of less than 0.3-ppm formaldehyde.
3. Clad panel with minimum **0.025-inch-** (0.635-mm-) thick aluminum recessed in the grooves sized to maintain contact with radiant piping.

Modular interlocking blocks are used to control pipe spacing and to maintain pipe contact with subfloor.

F. Modular Interlocking Blocks:

1. Polypropylene snap-together blocks with grooves to support piping.

2. Galvanized sheet metal or aluminum emission plates.
3. Natural mineralboard cover panel.

Heat-emission plates are required for joist-space piping installation below the occupied space.

G. Heat-Emission Plates:

1. Formed aluminum suitable for radiant-heating piping.
2. Minimum Thickness: **1/16 inch** (1.6 mm).
3. Slot Width: Snap fit to maintain pressure fit on tubing.

2.6 CONTROLS

Retain first paragraph below and delete remainder of this article if controls are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

- A. Temperature-control devices and sequence of operations are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Provide system to accomplish the Sequence of Operation described [**in Section 230993.11 "Sequence of Operation for HVAC DDC"**] [**or as indicated on the drawings**].

Edit paragraph below to suit requirements.

- C. Provide control system packaged in a NEMA1 enclosure. System shall have LED display of actual and set point temperatures, [**inputs for "snow" sensor,**] [**supply**] [**and**] [**return water temperatures,**] [**boiler return sensor**] [**adjustable idle and melt set points,**] [**adjustable minimum system run time,**] [**adjustable minimum boiler return temperature set point,**] [**adjustable maximum system supply temperature set point,**] [**adjustable cold weather cut off**] [**adjustable system temperature difference,**] [**outputs for [motorized valve,**] [**burner,**] [**pumps],,**] [**alarm output**] [**remote communication option**].
- D. Control system shall be UL and CSA approved.

Retain and revise remainder of this article to specify controls in this Section.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- E. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. [Danfoss Inc.](#)
 2. [HeatLink Group Inc.](#)
 3. [Honeywell International Inc.](#)
 4. [Infloor Radiant Floor Heating.](#)

5. [IPEX Inc.](#)
6. [REHAU Incorporated.](#)
7. [Slant/Fin Corporation.](#)
8. [tekmar Control Systems, Ltd.](#)
9. [Uponor.](#)
10. [Viega LLC.](#)
11. [Watts Radiant, inc.: a Watts Water Technologies company.](#)
12. [Zurn Industries, LLC; Zurn Pex, Inc.](#)
13. **<Insert manufacturer's name>.**
14. or approved equal.

Retain "Wall-Mounted Thermostat" Paragraph below for room temperature control of radiant panels in ceilings and floors.

F. Wall-Mounted Thermostat:

1. Minimum temperature range from [50 to 90 deg F (10 to 32 deg C)] **<Insert temperature range>.**
2. Manually operated with on-off switch.
3. Day and night setback and clock program with minimum four periods per day.
4. Operate pumps or open zone control valves if room temperature falls below the thermostat setting, and stop pumps or close zone control valves when room temperature rises above the thermostat setting.

Retain "Heated-Panel Thermostat" Paragraph below to limit temperature a heated panel will achieve to satisfy room thermostat.

G. Heated-Panel Thermostat:

1. Remote bulb unit with adjustable temperature range from [50 to 90 deg F (10 to 32 deg C)] **<Insert temperature range>.**
2. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected pump or zone control valve.
3. Remote bulb on capillary tube, resistance temperature device, or thermistor for directly sensing radiant-panel temperature.
4. Stop pump or close zone control valves if heated-panel thermostat setting is exceeded.
5. Corrosion-resistant, waterproof control enclosure.

Retain "Heated-Panel Thermostat with Outdoor Temperature Reset" Paragraph below to limit temperature a heated panel will achieve to satisfy room thermostat and limit supply-water temperatures within outdoor temperature ranges.

H. Heated-Panel Thermostat with Outdoor Temperature Reset:

1. Remote bulb unit with adjustable temperature range from [50 to 90 deg F (10 to 32 deg C)] **<Insert temperature range>.**
2. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected pump or zone control valve.
3. Remote bulb on capillary tube, resistance temperature device, or thermistor for directly sensing radiant-panel and outdoor-air temperature.

4. Operate zone control valves to reset supply-water temperature inversely with outdoor-air temperature as follows:
 - a. Low outdoor-air temperature, [zero deg F (minus 18 deg C)] **<Insert temperature>** with high supply-water temperature [110 deg F (43 deg C)] **<Insert temperature>**.
 - b. High outdoor-air temperature, [60 deg F (16 deg C)] **<Insert temperature>** with low supply-water temperature [70 deg F (21 deg C)] **<Insert temperature>**.
5. Corrosion-resistant, waterproof control enclosure.

Retain "Precipitation and Temperature Sensor" Paragraph below to operate radiant-heating panel for snow melting on pavement.

- I. Precipitation and Temperature Sensor:
 1. **[Microprocessor-based] [Automatic]** control with manual on, automatic, and standby/reset switch.
 2. Precipitation and temperature sensors shall sense the surface conditions of pavement and shall be programmed to operate pump and zone control valves as follows:

Retain and revise required features in first four subparagraphs below. Verify availability with manufacturer.

- a. Temperature Span: [34 to 44 deg F (1 to 7 deg C)] **<Insert temperature range>**.
 - b. Adjustable Delay Off Span: [30 to 90] **<Insert numbers>** minutes.
 - c. Start Pump or Open Zone Control Valves: Following [two] **<Insert number>**-minute delay if ambient temperature is below set point and precipitation is detected.
 - d. Stop Pump or Close Zone Control Valves: On detection of a dry surface plus time delay.
3. Corrosion-proof and waterproof enclosure suitable for outdoor mounting, for controls and precipitation and temperature sensors.
 4. Minimum 30-A contactor to start pump and open valves.
 5. Precipitation sensor shall be mounted in pavement.
 6. Provide relay with contacts to indicate operational status, on or off, for interface with central HVAC control-system workstation.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine surfaces and substrates to receive radiant-heating piping for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

1. Ensure that surfaces and pipes in contact with radiant-heating piping are free of burrs and sharp protrusions.
 2. Ensure that surfaces and substrates are level and plumb.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

Retain this article if pipe materials vary among several locations; delete to require piping materials to be the same in all applications. Consult manufacturers for specific piping recommendations. Piping sizes must be shown on Drawings.

- A. Install the following types of radiant-heating piping for the applications described:
1. Piping in Exterior Pavement: [EPDM] [PEX] [PEX/AL/PEX].
 2. Piping in Interior Reinforced-Concrete Floors: [EPDM] [PEX] [PEX/AL/PEX].
 3. Piping in Level Fill Concrete Floors (Not Reinforced): [EPDM] [PEX] [PEX/AL/PEX].
 4. Piping in Ceilings: [EPDM] [PEX] [PEX/AL/PEX].
 5. Piping in Subfloors: [EPDM] [PEX] [PEX/AL/PEX].
 6. Piping below Wood Floors: [EPDM] [PEX] [PEX/AL/PEX].

3.3 INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicate piping locations and arrangements if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop Drawings or coordination drawings.
- B. Hydronic radiant heat tubing loops shall be installed in accordance with the manufacturer's recommendations and as indicated on the drawings.
- C. All fittings shall follow the shop drawings for tubing layout, tube spacing, manifold configuration, manifold location, and controls.
- D. All fittings should be accessible for maintenance. Tubing loops shall be installed without splices, as a minimum, from the point at which the tubing enters the panel to the point at which it exits the panel.
- E. Provide pipe hangers and supports in accordance with ASTM B31.9 unless indicated otherwise.
- F. Install isolation ball valves on all pipe branches from the mains to the manifolds.
- G. Do not install underground piping when bedding is wet or frozen.
- H. Install radiant-heating piping continuous from the manifold through the heated panel and back to the manifold without piping joints in heated panels.

- I. Connect radiant piping to manifold in a reverse-return arrangement.
- J. Do not bend pipes in radii smaller than manufacturer's minimum bend radius dimensions. The minimum bend radius for cold bending of the tube shall not be less than six (6) times the outside diameter. Bends with a radius less than stated shall require the use of a bend support as supplied by the tube manufacturer.
- K. Install manifolds in accessible locations, or install access panels to provide maintenance access as required in Section 083113 "Access Doors and Frames."
- L. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties" for pipes and connections to hydronic systems and for glycol-solution fill requirements.
- M. Fire- and Smoke-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials according to Section 078413 "Penetration Firestopping."
- N. Piping in Exterior Pavement:

Consult manufacturer for minimum dimensions required in subparagraphs below.

- 1. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
- 2. Space cable ties a maximum of [18 inches (457 mm)] <Insert dimension> o.c. and at center of turns or bends.
- 3. Maintain [3-inch (75-mm)] <Insert dimension> minimum cover.
- 4. Install a sleeve of 3/8-inch- (9.5-mm-) thick, foam-type insulation or PE pipe around tubing and extending for a minimum of [10 inches (250 mm)] <Insert dimension> on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
- 5. Maintain minimum 40-psig (275-kPa) pressure in piping during concrete placement and continue for 24 hours after placement.

- O. Piping in Interior Reinforced-Concrete Floors:

Consult manufacturer for minimum dimensions required in subparagraphs below.

- 1. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
- 2. Space cable ties a maximum of [18 inches (457 mm)] <Insert dimension> o.c. and at center of turns or bends.
- 3. Maintain [2-inch (50-mm)] <Insert dimension> minimum cover.
- 4. Install a sleeve of 3/8-inch- (9.5-mm-) thick, foam-type insulation or PE pipe around tubing and extending for a minimum of [10 inches (250 mm)] <Insert dimension> on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
- 5. Maintain minimum 40-psig (275-kPa) pressure in piping during concrete placement and continue for 24 hours after placement.

P. Piping in Level Fill Concrete Floors (Not Reinforced):

Consult manufacturer for minimum dimensions required in subparagraphs below.

1. Secure piping in concrete floors by attaching pipes to subfloor using tracks, clamps, or staples.
2. Space tracks, clamps, or staples a maximum of [18 inches (457 mm)] <Insert dimension> o.c. and at center of turns or bends.
3. Maintain [3/4-inch (19-mm)] <Insert dimension> minimum cover.
4. Install a sleeve of 3/8-inch- (9.5-mm-) thick, foam-type insulation or PE pipe around tubing and extending for a minimum of [10 inches (250 mm)] <Insert dimension> on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
5. Maintain minimum 40-psig (275-kPa) pressure in piping during the concrete pour and continue for 24 hours during curing.

Q. Piping in Ceiling:

Consult manufacturer for minimum dimensions required in subparagraphs below.

1. Secure piping by attaching pipes to ceiling substrate using clamps or staples.
2. Space clamps or staples a maximum of [18 inches (457 mm)] <Insert dimension> o.c. and at center of turns or bends.
3. Maintain [1-1/2-inch (38-mm)] <Insert dimension> minimum plaster cover.
4. Maintain minimum 40-psig (275-kPa) pressure in piping during the plaster application and continue for 24 hours during curing.

R. Piping in Subfloor:

1. Secure piping by laying in subfloor channels or modular interlocking blocks.
2. Use straight channel panels or blocks in the center and curved channel panels or blocks at the ends.
3. Finish floor with mineralboard panel cover or finished floor surface.

S. Piping below Wood Floor:

Consult manufacturer for minimum dimensions required in subparagraphs below.

1. Secure piping by attaching pipes to subfloor using heat-emission plates, clamps, or staples.
2. Space heat-emission plates, clamps, or staples a maximum of [4 inches (100 mm)] <Insert dimension> o.c. and at center of turns or bends.
3. Install heat-emission plates on underside of wood subfloor with maximum space between plates, as noted above, to maintain pipe contact with floor.

T. Revise locations and elevations from those indicated as required to suit field conditions and ensure integrity of piping and as approved by DEN Project Manager.

U. After system balancing has been completed, mark balancing valves to permanently indicate final position.

- V. Perform the following adjustments before operating the system:
1. Open valves to fully open position.
 2. Check operation of automatic valves.
 3. Set temperature controls so all zones call for full flow.
 4. Purge air from piping.
- W. After concrete or plaster heating panel has cured as recommended by concrete or plaster supplier, operate radiant-heating system as follows:
1. Start system heating at a maximum of **10 deg F (6 deg C)** above the ambient radiant-panel temperature and increase **10 deg F (6 deg C)** each following day until design temperature is achieved.
 2. For freeze protection, operate at a minimum of **60 deg F (16 deg C)** supply-water temperature.

3.4 CLEANING, FLUSHING, AND INSPECTING

- A. Clean and flush system, with clear water, of all dirt, metal chips, sand, and foreign matter. After flushing, remove, clean, and replace all strainer baskets or screens. Inspect each run of each system for completion of joints, supports, accessory items, and obvious leaks.
- B. Examine and inspect piping in accordance with ANSI B31.1, Chapter VI.

3.5 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Prepare radiant-heating piping for testing as follows:
1. Open all isolation valves and close bypass valves.
 2. Open and verify operation of zone control valves.
 3. Flush with clean water and clean strainers.
- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]. Notify DEN Project Manager at least 24 hours before performing leak test:
1. Leak Test: After installation, charge system and test for leaks. Subject piping to hydrostatic test pressure that is not less than 1.5 times the design pressure but not more than [100 psig (690 kPa)] **<Insert value>**. Test fails if leakage is observed, or pressure drop exceeds 5% of test pressure.
 2. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.
 3. Repair leaks and retest until no leaks exist.

4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Radiant-heating piping will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. Drain test water from piping systems after testing and repair work that has been completed.
- F. After completion, fill, clean, and treat systems. Refer to Section 232500 "HVAC Water Treatment".
- G. Protect hydronic piping system from damage during construction.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238316

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SECTION 238323 - RADIANT-HEATING ELECTRIC PANELS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes prefabricated radiant-heating electric panels.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 238213 "Valance Heating and Cooling Units" for factory-fabricated electric heating panels for ceiling and wall applications.
2. Section 238313 "Radiant-Heating Electric Cables."

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 PRE-INSTALLATION CONFERENCE

Select one below. First number is minimum required.

- A. Convene **<one (1)>** **<Insert number>** week prior to commencing work of this Section at **[specify location] [location and time as determined by DEN Project Manager]**.
- B. Require attendance of parties directly affecting the work of this Section.
- C. Review sequencing of installation, protection from damage of finished installation, location and characteristics of electrical supply provisions to be provided as Division 26 work, and methods used for covering installations with insulation.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For electric heating panels.
1. Include plans, sections, details, and attachments to other work.
 2. Include diagrams for power, signal, and control wiring.

Retain "Samples for Initial Selection" and "Samples for Verification for Radiant-Panel Finishes" paragraphs below for two-stage Samples. Delete first paragraph if colors are preselected and specified or scheduled. Retain second paragraph with or without first paragraph.

Coordinate sample requirements with DEN Project Manager.

- C. Samples for Initial Selection: For units with factory-applied color finishes.
- D. Samples for Verification for Radiant-Panel Finishes: **[12 by 12 inches (300 by 300 mm)] <Insert size>**.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections

specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

Revise subparagraphs below to suit Project.

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Structural members to which heating panels and suspension systems will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Items installed in finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. Perimeter moldings.
 - g. <Insert item>.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
- C. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electric heating panels to include in operation and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
1. Accurately record actual locations of **[heating panels]** **[temperature sensors,]** **[thermostats,]** and branch circuit connections.

1.7 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace electric heating panels that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for radiant-heating electric panels.

1. Warranty Period: Minimum [three (3)] [five (5)] <Insert number> years from date of Substantial Completion.]

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 GENERAL REQUIREMENTS FOR RADIANT-HEATING ELECTRIC PANELS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. General: Furnish and install a complete UL-listed system of heating panels, components, and controls.

2.2 PREFABRICATED RADIANT-HEATING ELECTRIC PANELS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Berko; c/o Marley Engineered Products.
 2. QMark; c/o Marley Engineered Products.

3. [SSHC, Inc.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

B. Description: Sheet-metal-enclosed panel with heating element suitable for **[lay-in installation flush with T-bar ceiling grid] [surface mounting] [recessed mounting]**. Comply with UL 2021.

1. Panel: Minimum **0.0276-inch- (0.7-mm-)** thick, galvanized sheet steel back panel riveted to minimum **0.0396-inch- (1.0-mm-)** thick, galvanized sheet steel front panel with fused-on crystalline surface.

Retain one of two "Heating Element" subparagraphs below.

2. Heating Element: Powdered graphite sandwiched between sheets of electric insulation.
3. Heating Element: Insulated resistive wires.
4. Electrical Connections: Nonheating, high-temperature, insulated-copper leads, factory connected to heating element.

Retain one of three "Exposed-Side Panel Finish" subparagraphs or "Surface-Mounted Trim" Subparagraph below. If more than one type of finish is required, indicate each type in a schedule on Drawings.

5. Exposed-Side Panel Finish: Apply silk-screened finish to match appearance of DEN Project Manager-selected acoustical ceiling tiles.
6. Exposed-Side Panel Finish: Factory prime coated, ready for field painting.
7. Exposed-Side Panel Finish: Baked-enamel finish in manufacturer's **[standard] [custom]** paint color as selected by DEN Project Manager.

Retain "Surface-Mounted Trim" Subparagraph below for surface-mounted panels.

8. Surface-Mounted Trim: Sheet metal with baked-enamel finish in manufacturer's **[standard] [custom]** paint color as selected by DEN Project Manager.

C. Wall Thermostat: Bimetal, sensing elements calibrated from **55 to 90 deg F (13 to 32 deg C)**; with contacts suitable for **[low] [line]**-voltage circuit, and manually operated on-off switch with contactors, relays, and control transformers.

If Project has more than one type or configuration of prefabricated radiant-heating electric panel, delete "Capacities and Characteristics" Paragraph below and schedule on Drawings. See Evaluations for sample schedule.

D. Capacities and Characteristics:

1. Nominal Panel Size: **[24 by 24 inches (600 by 600 mm)] [24 by 36 inches (600 by 900 mm)] [24 by 48 inches (600 by 1200 mm)] [24 by 60 inches (600 by 1500 mm)] <Insert custom size>**.
2. Heating Capacity: **[250] [375] [500] [570] [625] [750] [950] <Insert value> W**.
3. Electrical Characteristics for Single-Point Connection:
 - a. Volts: **<Insert value>**.
 - b. Phase: **<Insert value>**.
 - c. Hertz: **<Insert value>**.

- d. Full-Load Amperes: <Insert value>.
- e. Minimum Circuit Ampacity: <Insert value>.
- f. Maximum Overcurrent Protection: <Insert amperage>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine surfaces and substrates to receive electric heating panels for compliance with requirements for installation tolerances and other conditions affecting performance.
 - 1. Ensure surfaces in contact with electric heating panels are free of burrs and sharp protrusions.
 - 2. Ensure surfaces and substrates are level and plumb.
- B. Verify field measurements are as shown on [shop drawings] [Drawings].
- C. Verify that required utilities are available, in proper location, and ready for use.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.
- E. Beginning of installation means installer accepts conditions.

3.2 INSTALLATION

Indicate location of controls on Drawings.

- A. Install in accordance with manufacturer's instructions.
- B. Install radiant-heating panels level and plumb.
- C. Support for Radiant-Heating Panels in or on Grid-Type Suspended Ceilings: Use grid as a support element.
 - 1. Install a minimum of four ceiling-support-system rods or wires for each panel. Locate not more than 6 inches (150 mm) from panel corners.
 - 2. Support Clips: Fasten to panel and to ceiling grid members at or near each panel corner with clips designed for the application.
 - 3. Panels of Sizes Less Than Ceiling Grid: Install as indicated on reflected ceiling plans or center in acoustical panel, and support panels independently with at least two 3/4-inch (19-mm) metal channels spanning and secured to ceiling tees.

Retain subparagraph below if Project is in a seismic area.

- 4. Install at least one independent support rod or wire from structure to a tab on panel. Wire or rod shall have breaking strength of the weight of the panel at a safety factor of 3.

To comply with requirements of the Americans with Disabilities Act, verify mounting height in paragraph below with authorities having jurisdiction.

- D. Verify locations of thermostats with Drawings and room details before installation. Install devices [48 inches (1220 mm)] [60 inches (1525 mm)] <Insert dimension> above finished floor.

3.3 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: [Owner will engage] [Engage] a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections[with the assistance of a factory-authorized service representative]:
 1. Operate electric-heating elements through each stage to verify proper operation and electrical connections.
 2. Measure insulation resistance to manufacturer's recommended values. Use test instruments in accordance with manufacturer's instructions.
 3. Measure voltage and current at each unit.
 4. Test and adjust controls and safeties.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- D. Radiant-heating electric panels will be considered defective if they do not pass tests and inspections.
- E. Make required corrections and re-test system.
- F. Prepare test and inspection reports.

3.5 PROTECTION

- A. Protect installed radiant-heating electric panels from damage during construction.
- B. Remove and replace damaged radiant-heating electric panels.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238323

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SECTION 238413 - HUMIDIFIERS

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes the following humidifiers:
 - 1. Atomizing.
 - 2. Steam injection.
 - 3. Self-contained.
 - 4. Heated pan.
 - 5. Heat exchanger.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITION

Retain definition that remains after this Section has been edited.

- A. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: Provide catalog sheets indicating general assembly, dimensions, weights, materials, and certified performance ratings. Include rated capacities, operating characteristics, furnished specialties, and accessories.
1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail fabrication and installation of humidifiers. Include piping details, plans, elevations, sections, details of components, manifolds, and attachments to other work.
1. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

Retain paragraph and subparagraphs below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Detail humidifiers and adjacent equipment. Show support locations, type of support, weight on each support, required clearances, and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
1. Structural members to which humidifiers will be attached.
 2. Size and location of initial access modules for acoustical tile.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For humidifiers to include in operation and maintenance manuals.
1. Operation data: Include assembly instructions, float adjustment, bleed rates, and electrical requirements.
 2. Maintenance Data: Include instructions for lubrication, filter replacement, cleaning, and spare parts lists.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Retain this Article for self-contained humidifiers with electrode cylinders.

Extra materials may not be allowed for publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

Edit below to suit Project.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Supply [one (1)] <Insert number> replacement electrode cylinder with each self-contained humidifier.
 2. Supply [one (1)] <Insert number> set of belts for each type of unit.
 3. Supply [one (1)] <Insert number> of filter media.
 4. Supply chemical treatment materials suitable for [6] <Insert number> months of operation.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use. Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.
- B. Comply with ARI 640, "Commercial and Industrial Humidifiers."

1.9 COORDINATION

- A. Coordinate location and installation of humidifiers with manifolds in ducts and air-handling units or occupied space. Revise locations and elevations to suit field conditions and to ensure proper humidifier operation.

1.10 WARRANTY

- A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 230400 "Basic HVAC Requirements".

Edit paragraph below. Five year warranty is minimum required.

1. Provide **[five (5)]** <Insert number> year manufacturer warranty for **[units]** **[pumps]**.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Performance: As indicated on the drawings.
- B. Radiated noise for termsil air units shall not exceed:
 1. NC 35 – In Office.
 2. NC 40 – Terminal/Concourse.
 3. NC 45 – Maintenance Facilities.

2.2 WATER-PRESSURE ATOMIZING HUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Carel USA, LLC](#).
 2. [Herrmidifier](#).
 3. [Mee Industries Inc.](#)
 4. <Insert manufacturer's name.>
 5. or approved equal.
- B. Nozzles: ASTM A 666, Type **[304]** **[316]** stainless steel.
- C. Manifold: ASTM A 269, Type **[304]** **[316]** stainless-steel piping.

Retain paragraph below if manifold discharges into air in a duct.

- D. Droplet Filter: Biocide-treated polyethylene with maximum **0.30-inch wg** (75-Pa) resistance.

Retain one of first two paragraphs below. Stainless-steel piping is typically used with demineralized water.

- E. Piping and Fittings: ASTM A 269, Type [304] [316] stainless-steel pipe and fittings.
- F. Piping and Fittings: ASTM B 88 (ASTM B 88M), Type L copper pipe and wrought-copper fittings with brazed joints.
- G. Water Pump: Enclosed belt-drive ceramic plunger pump with [stainless-steel] [bronze] heads, and [single] [variable]-speed, totally enclosed, fan-cooled motor.
- H. Final Water-Filter Efficiency: Minimum [98] <Insert number> percent retention of suspended particles [10] [20] <Insert size> microns and larger from makeup water.
- I. Final Water-Filter Pressure Drop: Maximum [2 psig (14 kPa)] <Insert value> at design flow when clean[, and <Insert value> when dirty].
- J. Pump Controls:
 - 1. [Cycle] [Vary speed of] motor to satisfy humidistat.
 - 2. High-pressure solenoid valve for each control zone shown on Drawings.
 - 3. Building automation system interface for each control zone for start/stop and status indication and control at central workstation.

Retain first paragraph and subparagraphs below if humidifier discharges directly into occupied space.

- K. Dispersion Fan:
 - 1. Aluminum blade propeller fan with finger guard and single-speed motor interlocked to operate with humidifier.
 - 2. Fan Mounting: Above and behind manifold on bracket integral to wall-mounting manifold.
- L. Accessories:
 - 1. Humidistat: [Wall] [Return-duct]-mounting, solid-state, electronic-sensor controller capable of full-modulation or cycling control.
 - 2. Duct-mounting, high-limit humidistat.
 - 3. Airflow switch for preventing humidifier operation without airflow.

If Project has more than one type or size of humidifier, delete paragraph and subparagraphs below and schedule humidifiers on Drawings.

- M. Capacities and Characteristics:
 - 1. Humidification Rate: <Insert lb/h (g/s).>
 - 2. Dry-Bulb Air Temperature at Discharge: <Insert deg F (deg C).>
 - 3. Wet-Bulb Air Temperature at Discharge: <Insert deg F (deg C).>
 - 4. Number of Nozzles: <Insert number.>
 - 5. Nozzle Spacing: <Insert inches (mm).>
 - 6. Maximum Absorption Distance: <Insert inches (mm).>
 - 7. Minimum Makeup Water Supply Pressure: <Insert psig (kPa).>

8. Water Pump:
 - a. Discharge Pressure: [1000 psig (6894 kPa)] [2000 psig (13 790 kPa)] **<Insert pressure>**.
 - b. Motor Horsepower: **<Insert horsepower.>**

Retain first subparagraph and associated subparagraphs below if humidifier discharges directly into occupied space.

9. Dispersion Fan:
 - a. Airflow: **<Insert cfm (L/s).>**
 - b. Motor Horsepower: **<Insert horsepower.>**
10. Electrical Characteristics: Single point of connection.
 - a. Volts: **<Insert value.>**
 - b. Phase: **<Insert value.>**
 - c. Hertz: **<Insert value.>**
 - d. Full-Load Amperes: **<Insert value.>**
 - e. Minimum Circuit Ampacity: **<Insert value.>**
 - f. Maximum Overcurrent Protection: **<Insert amperage.>**

2.3 COMPRESSED-AIR ATOMIZING HUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Carel USA, LLC.](#)
 2. [Herrmidifier.](#)
 3. [Mee Industries Inc.](#)
 4. **<Insert manufacturer's name.>**
 5. or approved equal.
- B. Nozzles: ASTM A 666, Type [304] [316] stainless steel.
- C. Manifold: ASTM A 269, Type [304] [316] stainless-steel piping.

Retain first paragraph below if manifold discharges into air in a duct.

- D. Droplet Filter: Biocide-treated polyethylene with maximum 0.30-inch wg (75-Pa) resistance.
- E. Piping and Fittings: ASTM A 269, Type [304] [316] stainless-steel pipe and fittings.

Retain paragraph above with demineralized makeup water, and delete option in first paragraph below.

- F. Compressed-Air[**and Water**] Piping and Fittings: **ASTM B 88** (ASTM B 88M), Type L copper pipe and wrought-copper fittings with soldered joints.
- G. Final Water-Filter Efficiency: Minimum **[98]** **<Insert number>** percent retention of suspended particles **[10]** **[20]** **<Insert size>** microns and larger from makeup water.
- H. Final Water-Filter Pressure Drop: Maximum **[2 psig (14 kPa)]** **<Insert value>** at design flow when clean[, **and <Insert value> when dirty**].
- I. Air and Water Solenoid Controls:
 - 1. Cycle valves to satisfy humidistat.
 - 2. Solenoid valves for each control zone shown on Drawings.
 - 3. Building automation system interface for each control zone for start/stop and status indication and control at central workstation.

Retain first paragraph and subparagraphs below if humidifier discharges directly into occupied space.

- J. Dispersion Fan:
 - 1. Aluminum blade propeller fan with finger guard and single-speed motor interlocked to operate with humidifier.
 - 2. Fan Mounting: Above and behind manifold on bracket integral to wall-mounting manifold.
- K. Accessories:
 - 1. Humidistat: **[Wall]** **[Return-duct]**-mounting, solid-state, electronic-sensor controller capable of full-modulation or cycling control.
 - 2. Duct-mounting, high-limit humidistat.
 - 3. Airflow switch for preventing humidifier operation without airflow.

If Project has more than one type or size of humidifier, delete paragraph and subparagraphs below and schedule humidifiers on Drawings.

- L. Capacities and Characteristics:
 - 1. Humidification Rate: **<Insert lb/h (g/s).>**
 - 2. Dry-Bulb Air Temperature at Discharge: **<Insert deg F (deg C).>**
 - 3. Wet-Bulb Air Temperature at Discharge: **<Insert deg F (deg C).>**
 - 4. Number of Nozzles: **<Insert number.>**
 - 5. Nozzle Spacing: **<Insert inches (mm).>**
 - 6. Maximum Absorption Distance: **<Insert inches (mm).>**
 - 7. Minimum Makeup Water Supply Pressure: **<Insert psig (kPa).>**
 - 8. Compressed Air:
 - a. Airflow: **<Insert cfm (L/s).>**
 - b. Pressure: **<Insert psig (kPa).>**

Retain first subparagraph and associated subparagraphs below if humidifier discharges directly into occupied space.

9. Dispersion Fan:
 - a. Airflow: <Insert cfm (L/s).>
 - b. Motor Horsepower: <Insert horsepower.>
10. Electrical Characteristics: Single point of connection.
 - a. Volts: <Insert value.>
 - b. Phase: <Insert value.>
 - c. Hertz: <Insert value.>
 - d. Full-Load Amperes: <Insert value.>
 - e. Minimum Circuit Ampacity: <Insert value.>
 - f. Maximum Overcurrent Protection: <Insert amperage.>

2.4 STEAM-INJECTION HUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Armstrong International, Inc.](#)
 2. [Carel USA, LLC.](#)
 3. [DRI-STEEM Humidifier Company.](#)
 4. [Herrmidifier.](#)
 5. [Hygromatik; Spirax Sarco.](#)
 6. [Nortec Industries Inc.](#)
 7. [Pure Humidifier Company.](#)
 8. <Insert manufacturer's name.>
 9. or approved equal.

Retain one of first two paragraphs and associated subparagraphs below. Retain first for duct-mounting or plenum-mounting humidifier, second if humidifier discharges directly into occupied space.

- B. Manifold: ASTM A 666, Type 304 stainless steel[, **steam jacketed;**] [**insulated with 1/2-inch (13-mm) fiberglass and stainless-steel jacket; and**] extending the full width of duct or plenum with mounting brackets at ends.
- C. Discharge Nozzle and Dispersion Fan:
 1. Steam-jacketed discharge nozzle, aluminum blade propeller fan with finger guard, and single-speed motor interlocked to operate with humidifier.
 2. Fan Mounting: Above and behind discharge outlet on bracket integral to discharge outlet.
- D. Steam Separator: [**Cast iron**] [**ASTM A 666, Type 304 stainless steel**] with [**separate**] humidifier control valve.
- E. Humidifier Control Valve:

Retain one of two subparagraphs below.

1. Actuator: **[Pneumatic] [Electric]** modulating with spring return.
 2. Actuator: As specified in Section 230923.11 "Control Valves."
- F. Steam Trap: Inverted-bucket type, sized for a minimum of 3 times the maximum rated condensate flow of humidifier at **1/2-psig (3.4-kPa)** inlet pressure.
- G. Accessories:

Delete first two subparagraphs below if humidistats and aquastat are specified in Section 230923.19 "Moisture Instruments."

1. **[Wall] [Return-duct]**-mounting humidistat.
2. Duct-mounting, high-limit humidistat.
3. Aquastat mounted on steam condensate return piping to prevent cold operation of humidifier.
4. In-line strainer.
5. Airflow switch for preventing humidifier operation without airflow.

If Project has more than one type or size of humidifier, delete paragraph and subparagraphs below and schedule humidifiers on Drawings.

- H. Capacities and Characteristics:
1. Humidification Rate: **<Insert lb/h (g/s).>**
 2. Steam Supply Pressure: **<Insert psig (kPa).>**
 3. Dry-Bulb Air Temperature at Discharge: **<Insert deg F (deg C).>**
 4. Wet-Bulb Air Temperature at Discharge: **<Insert deg F (deg C).>**
 5. Maximum Absorption Distance: **<Insert inches (mm).>**

Delete subparagraph below if humidifier discharges directly into occupied space.

6. Number of Manifolds: **<Insert number.>**

Retain first subparagraph and associated subparagraphs below if humidifier discharges directly into occupied space.

7. Dispersion Fan:
 - a. Airflow: **<Insert cfm (L/s).>**
 - b. Motor Horsepower: **<Insert horsepower.>**
8. Electrical Characteristics: Single point of connection.
 - a. Volts: **<Insert value.>**
 - b. Phase: **<Insert value.>**
 - c. Hertz: **<Insert value.>**
 - d. Full-Load Amperes: **<Insert value.>**
 - e. Minimum Circuit Ampacity: **<Insert value.>**
 - f. Maximum Overcurrent Protection: **<Insert amperage.>**

2.5 SELF-CONTAINED HUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Armstrong International, Inc.](#)
2. [Carel USA, LLC.](#)
3. [Carnes Company.](#)
4. [Herrmidifier.](#)
5. [Hygromatik; Spirax Sarco.](#)
6. [Nortec Industries Inc.](#)
7. **<Insert manufacturer's name.>**
8. or approved equal.

Retain one of first three paragraphs and associated subparagraphs below. Verify heater type and features with humidifier manufacturer. Some heater features are proprietary.

B. Electric-Resistance Heater Container: Cleanable, ASTM A 666, Type [304] [316] stainless steel. Comply with UL 499.

Ionic bed inserts are a proprietary product of Armstrong.

C. Electrode Cylinder: Replaceable plastic assembly[**with disposable ionic bed inserts**]. Comply with UL 499.

Gas-fired, self-contained humidifiers are available from a limited number of manufacturers.

D. Gas-Fired Steam Generator: Factory assembled and tested.

1. Standard: Fabricate and label steam generator to comply with CSA.
2. Maximum Steam Pressure: 10 inches wg (2488 Pa).
3. Burner Type: [Natural-gas] [Propane] fired with modulating, low NOx infrared burner, minimum [82] **<Insert number>** percent efficient.
4. Gas Train: Safety shutoff valves, gas cock, strainer, pressure-regulating valve.
5. Ignition: Hot-surface ignition with flame safety system.
6. Combustion Chamber: Sealed with outdoor-air and flue-vent connections.
7. Heat-Exchanger Tank: Cleanable, ASTM A 666, Type [304] [316] stainless steel with corrosion-resistant coating[**and disposable ionic bed inserts**].

Retain one of first two paragraphs below. Retain first if humidifier discharges directly into occupied space.

E. Manifold: Stainless-steel tube with integral fan to discharge vapor directly into occupied space.

F. Manifold: ASTM A 666, Type [304] [316] stainless-steel tube extending across entire width of duct or plenum and equipped with mounting brackets on ends.

- G. Cabinet: Sheet metal enclosure for housing heater cylinder, electrical wiring, components, controls, and control panel. Enclosure shall include baked-enamel finish, hinged or removable access door, and threaded outlet in bottom of cabinet for drain piping.

Ionic bed inserts are a proprietary product of Armstrong.

H. Control Panel:

1. Factory-wired disconnect switch.
2. Liquid-crystal display.
3. Programmable keyboard.
4. Set-point adjustment.
5. Warning signal indicating end of replaceable cylinder[or ionic bed insert] life.
6. Low-voltage, control circuit.
7. Diagnostic, maintenance, alarm, and status features.
8. High-water [sensor] [float] to prevent overfilling.

I. Controls:

1. Microprocessor-based control system for modulating or cycling control, and start/stop and status monitoring for interface to central HVAC instrumentation and controls.
2. Solenoid-fill and automatic drain valves to maintain water level and temper hot drain water.
3. Field-adjustable timer to control drain cycle for flush duration and interval.
4. Controls shall drain tanks if no demand for humidification for more than 72 hours.
5. [Conductivity] [Float]-type level controls.

J. Accessories:

Delete first two subparagraphs below if humidistats are specified in Section 230923.19 "Moisture Instruments."

1. Humidistat: [Wall] [Return-duct]-mounting, solid-state, electronic-sensor controller capable of full modulation or cycling control.
2. Duct-mounting, high-limit humidistat.
3. Airflow switch for preventing humidifier operation without airflow.

If Project has more than one type or size of humidifier, delete paragraph and subparagraphs below and schedule humidifiers on Drawings.

K. Capacities and Characteristics:

1. Humidification Rate: <Insert lb/h (g/s).>
2. Dry-Bulb Air Temperature at Discharge: <Insert deg F (deg C).>
3. Wet-Bulb Air Temperature at Discharge: <Insert deg F (deg C).>
4. Number of Manifolds: <Insert number.>
5. Maximum Absorption Distance: <Insert inches (mm).>
6. Minimum Makeup Water Supply Pressure: <Insert psig (kPa).>

Retain subparagraph and associated subparagraphs below for electric-resistance or electrode-type heater.

7. Electric-Resistance Heater Container or Electrode Cylinder:
 - a. Power Input per Container or Cylinder: **<Insert kilowatts.>**
 - b. Number of Containers or Cylinders: **<Insert number.>**

Retain subparagraph and associated subparagraphs below for gas-fired generator.

8. Gas-Fired Generator:
 - a. Fuel Input: **<Insert Btu/h (kW).>**
 - b. Fuel Pressure: **<Insert inches wg (kPa).>**

Retain first subparagraph and associated subparagraphs below if humidifier discharges directly into occupied space.

9. Dispersion Fan:
 - a. Airflow: **<Insert cfm (L/s).>**
 - b. Motor Horsepower: **<Insert horsepower.>**
10. Electrical Characteristics: Single point of connection.
 - a. Volts: **<Insert value.>**
 - b. Phase: **<Insert value.>**
 - c. Hertz: **<Insert value.>**
 - d. Full-Load Amperes: **<Insert value.>**
 - e. Minimum Circuit Ampacity: **<Insert value.>**
 - f. Maximum Overcurrent Protection: **<Insert amperage.>**

2.6 HEATED-PAN HUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Armstrong International, Inc.](#)
 2. [DRI-STEEM Humidifier Company.](#)
 3. [Nortec Industries Inc.](#)
 4. [Pure Humidifier Company.](#)
 5. **<Insert manufacturer's name.>**
 6. or approved equal.
- B. Heat Source: **[Hot water] [Steam] [Electric resistance].**

Retain paragraph below for electric-resistance heat source.

- C. Comply with UL 499.

Ionic bed inserts are a proprietary product of Armstrong.

- D. Pan and Heat-Exchange Piping: ASTM A 666, Type **[304] [316]** stainless steel with corrosion-resistant coating, overflow, and drain fittings. **[Include disposable ionic bed inserts.]**

Retain one of first three paragraphs below for manifold in duct or plenum or for wall or ceiling mounting in occupied space. If manifold is not required, delete all three paragraphs.

- E. Manifold: ASTM A 666, Type **[304] [316]** stainless-steel, duct-mounting, single- or manifold-grid connected to heated-pan housing with flexible hose and extending across width of duct or plenum. Manifold shall have mounting brackets at both ends.
- F. Manifold: Inverted, ASTM A 666, Type **[304] [316]** stainless-steel U-tube with humidifier mounted directly under the duct.
- G. Manifold: ASTM A 666, Type **[304] [316]** stainless-steel tube with flexible hose to connect to humidifier, integral fan to discharge vapor directly into occupied space, and wall- or ceiling-mounting brackets.
- H. Controls:
1. Solenoid-fill and automatic drain valves to maintain water level and temper hot drain water.
 2. Field-adjustable timer to control drain cycle for flush duration and interval.
 3. **[Conductivity] [Float]**-type level controls.

Retain paragraph below for steam heated-pan humidifier.

- I. Piping Specialties: Inlet strainer, control valve, and steam trap.

Retain first paragraph below for hot-water, heated-pan humidifier.

- J. Piping Specialties: Inlet strainer and control valve.

- K. Accessories:

Delete first two subparagraphs below if humidistats are specified in Section 230923.19 "Moisture Instruments."

1. Humidistat: **[Wall] [Return-duct]**-mounting, solid-state, electronic-sensor controller capable of full modulation or cycling control.
2. Duct-mounting, high-limit humidistat.
3. Airflow switch for preventing humidifier operation without airflow.

If Project has more than one type or size of humidifier, delete paragraph and subparagraphs below and schedule humidifiers on Drawings.

- L. Capacities and Characteristics:

1. Humidification Rate: <Insert lb/h (g/s).>
2. Dry-Bulb Air Temperature at Pan or Discharge: <Insert deg F (deg C).>
3. Wet-Bulb Air Temperature at Pan or Discharge: <Insert deg F (deg C).>
4. Pan Length: <Insert inches (mm).>
5. Pan Width: <Insert inches (mm).>
6. Number of Manifolds: <Insert number.>
7. Maximum Absorption Distance: <Insert inches (mm).>
8. Minimum Makeup Water Supply Pressure: <Insert psig (kPa).>
9. Hot Water:
 - a. Water Flow: <Insert gpm (L/s).>
 - b. Pressure Loss Including Control Valve: <Insert feet (kPa).>
 - c. Entering Temperature: <Insert deg F (deg C).>
 - d. Leaving Temperature: <Insert deg F (deg C).>
10. Steam:
 - a. Supply Pressure at Control Valve Inlet: <Insert psig (kPa).>
 - b. Condensing Rate: <Insert lb/h (g/s).>

Retain subparagraph and associated subparagraphs below for electric-resistance or electrode-type heater.

11. Electric-Resistance Heater Container or Electrode Cylinder:
 - a. Power Input: <Insert kilowatts.>
 - b. Number of Steps: <Insert number.>

Retain first subparagraph and associated subparagraphs below if humidifier discharges directly into occupied space.

12. Dispersion Fan:
 - a. Airflow: <Insert cfm (L/s).>
 - b. Motor Horsepower: <Insert horsepower.>
13. Electrical Characteristics: Single point of connection.
 - a. Volts: <Insert value.>
 - b. Phase: <Insert value.>
 - c. Hertz: <Insert value.>
 - d. Full-Load Amperes: <Insert value.>
 - e. Minimum Circuit Ampacity: <Insert value.>
 - f. Maximum Overcurrent Protection: <Insert amperage.>

2.7 HEAT-EXCHANGER HUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Armstrong International, Inc.](#)
2. [Nortec Industries Inc.](#)
3. [Pure Humidifier Company.](#)
4. **<Insert manufacturer's name.>**
5. or approved equal.

B. Fabricate and label steam generator to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

Ionic bed inserts are a proprietary product of Armstrong.

C. Heat Exchanger: ASTM A 666, Type [304] [316] stainless steel with corrosion-resistant coating, overflow, and drain fittings. [**Include disposable ionic bed inserts.**]

Retain one of first two paragraphs below.

D. Manifold: ASTM A 666, Type [304] [316] stainless-steel[, **steam-jacketed**], duct-mounting, single- or manifold-grid connected to steam generator with flexible hose and extending across width of duct or plenum. Manifold shall have mounting brackets for both ends. [**Insulate with 1/2-inch (13-mm) fiberglass and stainless-steel jacket extending full width of duct or plenum with mounting brackets at ends.**]

E. Manifold: ASTM A 666, Type [304] [316] stainless-steel tube with flexible hose to connect to humidifier and integral fan to discharge vapor directly into occupied space. Manifold shall have wall- or ceiling-mounting brackets.

F. Controls:

1. Solenoid-fill and automatic drain valves to maintain water level and temper hot drain water.
2. Field-adjustable timer to control drain cycle for flush duration and interval.
3. [**Conductivity**] [**Float**]-type level controls.

G. Accessories:

Delete first two subparagraphs below if humidistats are specified in Section 230923.19 "Moisture Instruments."

1. Humidistat: [**Wall**] [**Return-duct**]-mounting, solid-state, electronic-sensor controller capable of full modulation.
2. Duct-mounting, high-limit humidistat.
3. Airflow switch for preventing humidifier operation without airflow.

If Project has more than one type or size of humidifier, delete paragraph and subparagraphs below and schedule humidifiers on Drawings.

H. Capacities and Characteristics:

1. Humidification Rate: <Insert lb/h (g/s).>
2. Dry-Bulb Air Temperature at Discharge: <Insert deg F (deg C).>
3. Wet-Bulb Air Temperature at Discharge: <Insert deg F (deg C).>
4. Manifold Steam Supply Pressure: <Insert psig (kPa).>
5. Number of Manifolds: <Insert number.>
6. Maximum Absorption Distance: <Insert inches (mm).>
7. Minimum Makeup Water Supply Pressure: <Insert psig (kPa).>
8. Steam:
 - a. Supply Pressure at Control Valve Inlet: <Insert psig (kPa).>
 - b. Condensing Rate: <Insert lb/h (g/s).>

Retain first subparagraph and associated subparagraphs below if humidifier discharges directly into occupied space.

9. Dispersion Fan:
 - a. Airflow: <Insert cfm (L/s).>
 - b. Motor Horsepower: <Insert horsepower.>
10. Electrical Characteristics: Single point of connection.
 - a. Volts: <Insert value.>
 - b. Phase: <Insert value.>
 - c. Hertz: <Insert value.>
 - d. Full-Load Amperes: <Insert value.>
 - e. Minimum Circuit Ampacity: <Insert value.>
 - f. Maximum Overcurrent Protection: <Insert amperage.>

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, air-handling units, and conditions for compliance with requirements for installation tolerances and other conditions affecting performance.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before humidifier installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install in accordance with manufacturer's instructions.
- B. Insulate exterior of unit same as specified for ductwork. Refer to Section 230713 "Duct Insulation".

- C. Place unit on 2 inch thick rigid closed-cell insulation board same size as unit tank, where applicable. Flash and counterflash with 0.036 inch galvanized steel entering and leaving sides. Refer to Section 230713 "Duct Insulation".
- D. Connect unit to water supply. Provide ball or gate valve on water supply and drain line. Provide 3/4 inch hose bibb accessible from interior.
- E. Pipe drain and overflow to nearest floor drain.
- F. Bolt spray pump directly to tank fitting. Insulate external spray piping. Refer to Section 220719 "Plumbing Piping Insulation".
- G. Provide globe valve and solenoid valve in 1/2 inch bleed line from drain. Refer to Section 232500 "Chemical Water Treatment".
- H. Provide low water cut-off in drain pan to stop spray pump.

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1. ASHRAE 62.1, Section 5.13 - "Humidifiers and Water-Spray Systems," sets requirements for water quality feeding humidifiers and limits obstructions downstream from humidifiers.

- I. Install humidifiers with required clearance for service and maintenance. [**Maintain path, downstream from humidifiers, clear of obstructions as required by ASHRAE 62.1.**]
- J. Seal humidifier manifold duct or plenum penetrations with flange.
- K. Install humidifier manifolds in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
- L. Install [**galvanized**] [**stainless**]-steel drain pan under each manifold mounted in duct.

Retain option in first subparagraph below to comply with LEED Prerequisite IEQ 1 or if required by Project requirements or authorities having jurisdiction.

1. Construct drain pans with connection for drain; insulated [**and complying with ASHRAE 62.1.**]
2. Connect to condensate trap and drainage piping.
3. Extend drain pan upstream and downstream from manifold a minimum distance recommended by manufacturer but not less than required by ASHRAE 62.1.

Retain paragraph below for self-contained, heated-pan, and heat-exchanger humidifiers.

- M. Install manifold supply piping pitched to drain condensate back to humidifier.

Retain paragraph below for steam-injection and heat-exchanger humidifiers.

- N. Install drip leg upstream from steam trap a minimum of [**12 inches (300 mm)**] <Insert height> tall for proper operation of trap.
- O. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

1. Install steam generators on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

Retain paragraph below for gas-fired, self-contained humidifiers.

- P. Install gas-fired steam generators according to NFPA 54.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
1. Install piping adjacent to humidifiers to allow service and maintenance.

Retain subparagraph below for all humidifier types except steam injection.

2. Install shutoff valve, strainer, backflow preventer, and union in humidifier makeup line.
- B. Install electrical devices and piping specialties furnished by manufacturer but not factory mounted.

Retain first four paragraphs below for gas-fired, self-contained humidifiers.

- C. Install piping from safety relief valves to nearest floor drain.
- D. Connect gas piping full size to steam-generator, gas-train inlet with union. Gas piping materials and specialties are specified in [**Section 231123 "Facility Natural-Gas Piping."**] [**Section 231126 "Facility Liquefied-Petroleum Gas Piping."**]
- E. Connect breeching full size to steam-generator outlet. Venting materials are specified in Section 235123 "Gas Vents."

- F. Connect combustion-air inlet to intake terminal using PVC piping with solvent-cemented joints. Run from boiler connection to outside and terminate adjacent to flue termination.
- G. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- H. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

Retain one of first two paragraphs below. Retain first paragraph to require a factory-authorized service representative to perform inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

Retain paragraph and subparagraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections and prepare test reports.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph and subparagraphs below to describe tests and inspections to be performed by either of the entities in two paragraphs above.

- C. Tests and Inspections:
 - 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Remove and replace malfunctioning units and retest as specified above.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain humidifiers. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238413

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SECTION 238416 - MECHANICAL DEHUMIDIFICATION UNITS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THE ENGINEER SHALL SUBMIT A WRITTEN REQUEST FOR ANY MAJOR DEVIATION FROM THE STANDARD SPECIFICATIONS TO THE DEN PROJECT MANAGER PRIOR TO EDITING THIS SECTION. MAJOR DEVIATIONS INCLUDE (BUT ARE NOT LIMITED TO) THE ADDITION OF NEW EQUIPMENT, MATERIALS OR INSTALLATION PRACTICES THAT ARE NOT CURRENTLY PART OF THIS SPECIFICATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.2 SUMMARY

Edit to suit Project

- A. Section includes packaged, factory-assembled and -tested, refrigerant-type, mechanical dehumidification units designed for [outdoor] [and] [indoor] installation.

1.3 PERFORMANCE REQUIREMENTS

Retain paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Dehumidification units shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each dehumidification unit indicated. Provide catalog data indicating general assembly, dimensions, weights, materials, and certified performance ratings. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

1. Include data substantiating that materials comply with requirements.

- B. LEED Submittals:

Coordinate "Product Data for Credit EA 4" Subparagraph below with requirements for refrigerants.

1. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite IEQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5, "Systems and Equipment."

- C. Shop Drawings: For each dehumidification unit indicated. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.

Paragraph below is defined in Section 013300 "Submittal Procedures" as a "Delegated-Design Submittal." Retain if Work of this Section is required to withstand specific design loads and design responsibilities have been delegated to Contractor or if structural data are required as another way to verify compliance with performance requirements. Professional engineer qualifications are specified in Section 014000 "Quality Requirements"

- D. Delegated-Design Submittal: For dehumidification units indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC."

- A. Seismic Qualification Certificates: For **<Insert equipment,>** accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Source quality-control reports.
- C. Field quality-control reports.
- D. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For dehumidification units to include in emergency, operation, and maintenance manuals.
 1. Operation Data: Include assembly instructions, float adjustment, bleed rates, and electrical requirements.
 2. Maintenance Data: Instructions for lubrication filter replacement, cleaning and spare parts lists.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Filters: **[One (1)] <Insert number>** set(s) of each type of filter specified.
 2. Fan Belts: **[One (1)] <Insert number>** set(s) for each belt-drive fan.

Edit paragraph below. Two is minimum required. Delete if no sprayed coil dehumidifiers in Project.

3. Provide **[two (2)] <Insert number> [spray nozzles] <Insert component>**.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application. Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.
- B. ASHRAE Compliance:

First subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, the availability of units having components and features that comply with these requirements.

1. Applicable requirements in ASHRAE 62.1, Section 5, "Systems and Equipment" and Section 7, "Construction and Startup."
2. Applicable requirements in ASHRAE 15, "Safety Standard for Refrigeration Systems."

"ASHRAE/IESNA 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. LEED Prerequisite EA 2 requires compliance with requirements in ASHRAE/IESNA 90.1.

- C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6, "Heating, Ventilating, and Air-Conditioning."

1.9 COORDINATION

- A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.
- B. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of dehumidification units that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components with manufacturers listed in Part 2.

1. Warranty Period for Compressors: Manufacturer's standard, but not less than **[two (2)] [five (5)] <Insert number>** years from date of Substantial Completion.
2. Warranty Period for Refrigerant Coils: Manufacturer's standard, but not less than **[five (5)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers in this article. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Comitale National Inc.](#)
 2. [Dectron Internationale.](#)
 3. [Dehumidifier Corporation of America.](#)
 4. [Desert Aire.](#)
 5. [DryAire Systems.](#)
 6. [Nautica Dehumidifiers, Inc.](#)
 7. [PoolPak Technologies Corporation.](#)
 8. [Thermoplus Air Inc.](#)
 9. **<Insert manufacturer's name>**.
 10. or approved equal.

2.2 CASINGS

In first paragraph below, retain single-wall construction, removable panels, and 1/2-inch- (13-mm-) thick thermal insulation for indoor units. Retain other options for outdoor units.

- A. Casing: **[Single] [Double]**-wall construction with corrosion-protective coating and exterior **[baked-enamel] [powder-coated]** finish, stainless-steel fasteners, knockouts for electrical and piping connections, condensate drain connection, and lifting lugs.
1. Access: **[Removable panels] [Hinged access doors]** with neoprene gaskets.
 2. Insulation: Minimum **[1/2-inch- (13-mm-) thick thermal insulation] [2-inch- (50-mm-) thick, glass-fiber-insulation fill with no metal structure through the insulation]**.

"Airstream Surfaces" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain subparagraph below to comply with LEED Prerequisite IEQ 1.

3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain last option in paragraph below to comply with LEED Prerequisite IEQ 1 or if required by project requirements or authorities having jurisdiction.

- B. Drain Pan and Connection: **[Plastic] [Stainless steel]**; insulated **[and complying with ASHRAE 62.1]**.

2.3 FANS

- A. Supply Fans: **[Forward curved] [Backward inclined]**, centrifugal; galvanized steel with **[baked-enamel] [powder-coated]** finish; belt driven with adjustable sheaves and self-aligning, grease-lubricated ball bearings with extended grease fittings easily accessible inside the casing of dehumidification unit.
- B. **[Exhaust] [Return]** Fans: **[Forward curved] [Backward inclined]**, centrifugal; galvanized steel with **[baked-enamel] [powder-coated]** finish; belt driven with adjustable sheaves and self-aligning, grease-lubricated ball bearings with extended grease fittings easily accessible inside the casing of dehumidification unit.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert subparagraphs below to suit Project.

- C. Fan Motor: Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

Retain subparagraph below if enclosure is not open-drip-proof type.

1. Enclosure Type: Totally enclosed, fan cooled.

2.4 FILTERS

Retain one or both paragraphs below. If retaining both, indicate filter type in a schedule.

- A. Glass Fiber: Minimum **[80] <Insert number>** percent arrestance according to ASHRAE 52.1, and **[MERV 5] <Insert value>** according to ASHRAE 52.2.

Retain "MERV 7" option in paragraph below if applying for LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, which requires a MERV rating of 6 or higher.

- B. Pleated: Minimum [90] <Insert number> percent arrestance according to ASHRAE 52.1, and [MERV 7] <Insert value> according to ASHRAE 52.2.

2.5 REFRIGERATION SYSTEM

LEED Prerequisite EA 2 requires minimum efficiency equal to requirements in ASHRAE/IESNA 90.1.

- A. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IESNA 90.1.
- B. Refrigerant Coils: Copper tubes with mechanically bonded aluminum fins; factory fabricated and tested to comply with ASHRAE 33 and ARI 410; with multiple refrigerant circuits, seamless-copper headers with brazed connections, and [galvanized] [stainless]-steel frame. Coil and fins shall have a polyester coating. Coils shall have a minimum 300-psig (2070-kPa) working-pressure rating and be factory tested to 450 psig (3105 kPa) and to 300 psig (2070 kPa) while underwater.
- C. Compressors: Hermetic, scroll compressors with integral vibration isolators and crankcase heaters that de-energize during compressor operation; with thermal-expansion valves, filter-dryers, sight glasses, compressor service valves, and liquid- and suction-line service valves.
 - 1. Number of Refrigerant Circuits: Two for compressor capacities more than 7-1/2 tons (26.4 kW).

Retain one of first two subparagraphs below to require a specific refrigerant type; delete both if any refrigerant type is acceptable. LEED-NC, LEED-CS, and LEED for Schools Credit EA 4 award a single point if all HVAC&R equipment meets requirements for enhanced refrigerant management. Retain second, third, or fourth option in first subparagraph or retain second subparagraph to comply with Credit EA 4.

- 2. Refrigerant: [R-22] [R-134a] [R-407C] [R-410A].
- 3. Refrigerant: R-134a, R-407C, or R-410A.
- 4. Capacity Control:

Retain applicable control features in first two subparagraphs below. First subparagraph is for multiple compressors and for pool dehumidifiers.

- a. Hot-gas bypass valve and piping on one compressor.
- b. Cycle compressor.

Retain applicable control features in first four subparagraphs below.

- 5. Low-Pressure Cutout: Manual reset after three automatic-reset failures.
- 6. High-Pressure Cutout: Manual reset.
- 7. Compressor Motor Overload Protection: Manual reset.
- 8. Antirecycling Timing Device: Prevent compressor restart for five minutes after shutdown.

Retain subparagraph below for ice rinks.

9. Defrost Cycle: Adjustable timer shuts off supply fan. Compressor cycles until suction line temperature confirms thawed evaporator coil. [**Timer limits defrost time to 10 minutes.**]

Heat exchanger in paragraph below is a feature used only for pool dehumidification units.

- D. Energy Recovery Heat Exchanger (Pool Heater): Cupronickel, coaxial, vented, double-wall construction for potable-water service.

2.6 REMOTE-MOUNTED, AIR-COOLED CONDENSER UNIT

- A. Casing: Steel, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
- B. Refrigerant Coil: ARI 206/110, copper tube with mechanically bonded aluminum fins; with liquid subcooler.
- C. Fan: Aluminum-propeller type, directly connected to permanently lubricated motor with integral thermal-overload protection.

Both paragraphs below include optional equipment that may not be available from all manufacturers.

- D. Adjustable, Low Ambient Head-Pressure Control: Designed to operate at temperatures as low as 0 deg F (minus 18 deg C) by cycling condenser fans and controlling speed of last fan of each circuit.
- E. Mounting Base: Polyethylene.

2.7 HEATING COILS

Retain one of three paragraphs below for heating coils, which are optional features.

- A. Hot-Water Coil: Continuous circuit coil fabricated according to ARI 410.
 1. Tubes: Copper.

Retain fin spacing in first subparagraph below if not in a schedule.

2. Fins: [**Aluminum**] [**Copper**] with fin spacing [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)].
3. Fin and Tube Joints: Mechanical bond.
4. Headers: Cast iron with drain and air vent tapings.
5. Frames: Galvanized-steel channel, 0.052 inch (1.3 mm).
6. Ratings: Design tested and rated according to ASHRAE 33 and ARI 410.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings; revise to suit Project.

- a. Working-Pressure Ratings: 200 psig (1380 kPa), 325 deg F (163 deg C).
7. Source Quality Control: Test to 300 psig (2070 kPa).
- B. Steam Coil: Distribution header coil fabricated according to ARI 410, with threaded steam supply and condensate connections.
 1. Tubes: Copper.

Retain fin spacing in first subparagraph below if not in a schedule.

2. Fins: [Aluminum] [Copper] with fin spacing [0.125 inch (3.18 mm)] [0.091 inch (2.31 mm)] [0.071 inch (1.80 mm)] [0.067 inch (1.70 mm)] [0.056 inch (1.42 mm)] [0.0075 inch (0.19 mm)].
3. Fin and Tube Joints: Mechanical bond.
4. Headers: Cast iron with drain and air vent tapings.
5. Frames: Galvanized-steel channel, 0.052 inch (1.3 mm).
6. Ratings: Design tested and rated according to ASHRAE 33 and ARI 410.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings; revise to suit Project.

- a. Working-Pressure Ratings: 100 psig (690 kPa), 400 deg F (205 deg C).
7. Source Quality Control: Test to 200 psig (1380 kPa).
- C. Electric-Resistance Heating Coil: Comply with UL 1995.

Retain one of first two subparagraphs below.

1. Heating Element: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium oxide powder in tubular-steel sheath; with spiral-wound, copper-plated steel fins continuously brazed to sheath.
2. Heating Element: Open-coil resistance wire of 80 percent nickel and 20 percent chromium; supported and insulated by floating ceramic bushings recessed into casing openings; fastened to supporting brackets and mounted in galvanized-steel frame.
3. Overtemperature Protection: Disk-type, automatic-reset, thermal-cutout safety device; serviceable through terminal box without removing heater from unit.
4. Thermal Cutouts: Load carrying, manual reset or replaceable, and factory wired in series with each heater stage.
5. Control: Disconnecting means, overcurrent protection, and airflow proving switch.

2.8 DAMPERS

If only a single unit is required for Project and the unit will have a damper option, retain one of first four paragraphs below. If Project includes multiple units with different damper arrangements, retain applicable paragraphs in this article and indicate in a schedule which unit gets each component.

- A. Outdoor-Air Dampers: Opposed-blade, **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** dampers with **[cadmium-plated]** steel operating rod rotating in sintered bronze or nylon bearings. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod. Size for 0 to 25 percent outdoor air, with **[manual]** **[motorized]** operator and filter.
- B. Face-and-Bypass Dampers: Opposed-blade, **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** dampers with **[cadmium-plated]** steel operating rods rotating in sintered bronze or nylon bearings with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

Dampers in first paragraph below are standard quality. Low-leakage dampers are available from some manufacturers and from manufacturers of temperature-control equipment.

- C. **[Outdoor- and Return-Air]** **[Outdoor-, Return-, and Exhaust-Air]** Dampers: Parallel-blade, **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** dampers mechanically fastened to **[cadmium-plated]** steel operating rod in reinforced cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.
- D. **[Outdoor- and Return-Air]** **[Outdoor-, Return-, and Exhaust-Air]** Dampers: Low-leakage, double-skin, airfoil-blade, **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** dampers with compressible jamb seals and extruded-vinyl blade edge seals in **[opposed]** **[parallel]**-blade arrangement with **[cadmium-plated]** steel operating rods rotating in **[stainless-steel sleeve]** **[sintered bronze or nylon]** bearings mounted in a single **[galvanized-steel]** **[aluminum]** **[extruded-aluminum]** frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed **5 cfm/sq. ft.** (0.22 L/s per sq. m) at **1-inch wg** (250 Pa) and **9 cfm/sq. ft.** (0.4 L/s per sq. m) at **4-inch wg** (1.0 MPa).
- E. Damper Operator: **[115]** **[24]**-V ac, close coupled, with gear train sealed in oil and with spring return.

2.9 CONTROLS

Retain first paragraph below to specify temperature controls in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC." Delete first paragraph and retain second paragraph to require controls integral to the dehumidification unit to be provided by manufacturer of dehumidification unit.

- A. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC" for control equipment and in Section 230993.11 "Sequence of Operations for HVAC DDC."
- B. Control Panel: Integral service compartment containing fan-motor thermal and overload cutouts, compressor thermal and overload cutouts, 115-V control transformer if required, magnetic contactors for fan and compressor motors, and a nonfused factory-mounted and -wired disconnect switch for single external electrical power connection.

Retain first paragraph below to require controls of dehumidification unit to interface with the DDC system for HVAC. Coordinate with Section 230923 "Direct Digital Control (DDC) System for HVAC."

- C. Interface with DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display status and alarms.

Retain one of three paragraphs below. Retain first paragraph for ice-rink units.

- D. Operating Control: Space humidistat cycles the compressor. Humidistat shall incorporate fan on-off-auto switch.

Retain first paragraph below for indoor pool units with typical manufacturer's control panel. Revise for installed and optional features.

- E. Operating Controls: Factory-installed microprocessor controller, capable of being remotely mounted.

- 1. Display the following on the face of controller:

- a. System on.
- b. System dehumidifying mode.
- c. System air-conditioning mode.
- d. System outdoor-air (economizer) mode.
- e. System heating pool water.
- f. Auxiliary space heat is operating.
- g. Unit requires service.
- h. Return-air (space) temperature.
- i. Return-air (space) humidity.

First two subparagraphs below are optional displays requiring additional hardware.

- j. Pool-water temperature.
- k. Outdoor-air temperature.

- 2. Indicate the following sensor failures on panel:

- a. Airflow: Dirty air filter, blocked airflow, and fan failure.
- b. Refrigerant high and low pressure.
- c. High water temperature.
- d. High and low evaporator temperature.
- e. Low water flow.
- f. Communication fault.
- g. System off.
- h. Antishort cycle delay.
- i. Power failure.

- 3. Provide access to the following set points on panel:

- a. Space temperature.
- b. Space relative humidity.
- c. Outdoor ventilation/air-conditioning changeover temperature.
- d. Airflow alarm.

4. Provide the following displays on panel:
 - a. Space temperature.
 - b. Space relative humidity.
 - c. Outdoor-air temperature.
 - d. Supply-air temperature.
 - e. Return-air temperature.
 - f. Airflow rating.
 - g. Air-off evaporator temperature.
 - h. Return-air relative humidity.
 - i. Service codes.

5. Provide the following controls on panel:
 - a. System on-off, fan continues to run.
 - b. Fan on-off.
 - c. Service code access.
 - d. System dehumidifying mode.
 - e. System air-conditioning mode.
 - f. System outdoor-air (economizer) mode.
 - g. Auxiliary space heat is operating.
 - h. Outdoor-air-temperature, conditioned-space-temperature, and control set-point-temperature digital display.
 - i. Outdoor enthalpy digital display.
 - j. Filter pressure drop digital display.
 - k. Status: Airflow, fans, system, unit operation, and operating mode.
 - l. Alarm digital display.

Retain paragraph below for manufacturer's typical microprocessor controller capable of being monitored, programmed, and linked on a local area network. Revise for installed and optional features.

- F. Operating Controls: Factory-installed microprocessor controller.
1. Factory-installed operator panel with backlit display, capable of being remotely mounted, allows menu-driven display for navigation and control of unit.
 2. Integral clock.
 3. Personal computer interface.
 4. Integral local area network for direct connection to **[BACnet]** **[LonWorks]** **[MODBUS]** <Insert other>.
 5. Factory programmed.
 6. Unit-Mounted Sensors:
 - a. Airflow switch.
 - b. Compressor-discharge temperature.
 - c. Evaporator-air temperature.
 - d. Pool-water-out temperature.
 - e. Pool-water-in temperature.
 - f. Relative humidity.
 - g. Return-air temperature.
 - h. Supply-air temperature.

7. Integral diagnostics.
8. Nonvolatile memory.
9. IP or SI display.
10. Provide the following status and alarm functions:
 - a. System: On-off.
 - b. Power failure.
 - c. Fan: Off, overload.
 - d. Compressor: On, turned off, overload, high pressure, low pressure, overheat, oil failure, and pumpdown.
 - e. Evaporator damper closed.
 - f. Pool: Low water flow, heating on.
 - g. Dehumidification: Call for, on.
 - h. Air Conditioning: Call for, on.
 - i. System outdoor-air (economizer) mode.
 - j. Auxiliary space heat on.
 - k. Alarms: Firestat, freezestat, and filters.
11. Provide the following controls via operator panel:
 - a. Compressor auto-off.
 - b. Fan auto-off.
 - c. Set-Point Adjustments: Relative humidity, temperatures, deadbands, and differentials.
 - d. Sensor calibration.

LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1 require continuous metering equipment for monitoring building energy-consumption performance over time. Retain four subparagraphs below if required to comply with requirements for this credit. Verify availability of control features with manufacturers.

12. Monitor constant and variable motor loads.
13. Monitor cooling load.
14. Monitor economizer cycles.
15. Monitor ventilation air volumes.

2.10 ACCESSORIES

Accessories listed in this article are optional features available from most manufacturers.

Heat exchanger in first paragraph below may be provided in place of optional, remote-mounted, air-cooled condenser unit.

- A. Water-Cooling Heat Exchanger: Coaxial, vented, double-wall construction; with three-way refrigerant control valve.

Coordinate connections for smoke detectors in first paragraph below with Section 283111 "Digital, Addressable Fire-Alarm System" or Section 283112 "Zoned (DC Loop) Fire-Alarm System."

- B. Smoke Detectors: Photoelectric detector located in return-air plenum, to de-energize unit.
1. Operating Voltage: 24-V dc, nominal.
 2. Self-Restoring: Detectors do not require resetting or readjusting after actuation to restore them to normal operation.
 3. Plug-in Arrangement: Detector and associated electronic components mounted in module with tamper-resistant connection to fixed base with twist-locking plug. Terminals in fixed base accept building wiring.
 4. Integral Visual-Indicating Light: Digital-display type indicating detector operation.
 5. Sensitivity: Can be tested and adjusted in-place after installation.

Retain first subparagraph below for addressable systems.

6. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to the fire-alarm control panel.
7. Sensor: Digital display or infrared light source with matching silicon-cell receiver.
8. Detector Sensitivity: Between 2.5 and 3.5 percent/foot (0.008 and 0.011 percent/mm) of smoke obscuration when tested according to UL 268A.

Retain subparagraph below if using combination smoke/thermal detectors.

9. Integral Thermal Detector: Fixed-temperature type with 135 deg F (57 deg C) setting.

See Evaluations in Section 262726 "Wiring Devices" for wiring device grades.

- C. Electrical Convenience Outlet: 115-V ac fused, duplex, straight-blade receptacles, separately fused and located inside casing of dehumidification unit or in roof-curb perimeter.

2.11 ROOF CURBS

Retain this article for outdoor units. Retain one of first two paragraphs below. Retain first for curbs with vibration isolation and seismic or wind restraints; retain second for curbs provided by manufacturer of dehumidification unit without vibration isolation and seismic or wind restraints.

- A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
- C. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
1. Materials: ASTM C 1071, Type I or II.
 2. Thickness: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (50 mm)] <Insert dimension>.
 3. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
 4. Liner Adhesive: Comply with ASTM C 916, Type I.

5. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 6. Liner materials applied in this location shall have airstream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric, depending on service-air velocity.
- D. Curb Height: [14 inches (355 mm)] [24 inches (610 mm)] [36 inches (910 mm)] <Insert dimension>.
- E. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match dehumidification unit; used to anchor unit to the curb and designed for loads at Project site. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for wind-load requirements.

2.12 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of dehumidification unit, delete this article and schedule dehumidification units on Drawings.

- A. Airflow through Unit:
1. Supply Air: <Insert cfm (L/s)>.
 2. Outside Air: <Insert cfm (L/s)>.
 3. Exhaust/Return Air: <Insert cfm (L/s)>.
- B. Supply Fan:
1. Speed: <Insert rpm>.
 2. External Static Pressure: <Insert inches wg (kPa)>.
 3. Motor Size: <Insert horsepower>.
- C. [Exhaust] [Return] Fan:
1. External Static Pressure: <Insert inches wg (kPa)>.
 2. Speed: <Insert rpm>.
 3. Motor Size: <Insert horsepower>.
- D. Refrigeration System:
1. Sensible Heat-Transfer Rate: <Insert Btu/h (kW)>.
 2. Total Heat-Transfer Rate: <Insert Btu/h (kW)>.
 3. Energy-Efficiency Ratio: <Insert number>.
 4. Dehumidification Capacity: <Insert lb of water/h (kg/h)>.
 5. Evaporator Coil Conditions:
 - a. Entering-Air, Dry-Bulb Temperature: <Insert deg F (deg C)>.
 - b. Entering-Air, Wet-Bulb Temperature: <Insert deg F (deg C)>.
 - c. Entering-Air, Dew-Point Temperature: <Insert deg F (deg C)>.

- d. Leaving-Air, Dry-Bulb Temperature: **<Insert deg F (deg C)>**.
 - e. Leaving-Air, Wet-Bulb Temperature: **<Insert deg F (deg C)>**.
 - f. Leaving-Air, Dew-Point Temperature: **<Insert deg F (deg C)>**.
6. Energy Recovery Heat Exchanger (Pool Heater):
- a. Water Flow Rate: **<Insert gpm (L/s)>**.
 - b. Water Pressure Loss: **<Insert feet of head (kPa)>**.
 - c. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - d. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
- E. Filters:
1. Thickness or Depth: **<Insert inches (mm)>**.
- F. Hydronic Heating Coil:
1. Heat-Transfer Rate: **<Insert Btu/h (kW)>**.
 2. Entering-Air Temperature: **<Insert deg F (deg C)>**.
 3. Leaving-Air Temperature: **<Insert deg F (deg C)>**.
 4. Water:
 - a. Water Flow: **<Insert gpm (L/s)>**.
 - b. Maximum Water Pressure Drop: **<Insert feet of head (kPa)>**.
 - c. Entering-Water Temperature: **<Insert deg F (deg C)>**.
 - d. Leaving-Water Temperature: **<Insert deg F (deg C)>**.
- G. Steam Heating Coil:
1. Steam Flow: **<Insert lb/h (g/s)>**.
 2. Inlet Steam Pressure: **<Insert psig (kPa)>**.
- H. Electric Heating Coil:
1. Heat-Transfer Rate: **<Insert kilowatts>**.
 2. Input: **<Insert kilowatts>**.
 3. Volts: **[120] [208] [230] <Insert value>**.
 4. Phase: **[Single] [Three]**.
 5. Hertz: 60.
 6. Full-Load Amperes: **<Insert value>**.
 7. Number of Steps: **<Insert number>**.
- I. Electrical Characteristics:
1. Volts: **[120] [208] [230] <Insert value>**.
 2. Phase: **[Single] [Three]**.
 3. Hertz: 60.
 4. Full-Load Amperes: **<Insert value>**.
 5. Minimum Circuit Ampacity: **<Insert value>**.
 6. Maximum Overcurrent Protection: **<Insert amperage>**.

2.13 SOURCE QUALITY CONTROL

- A. Verification of Performance: Factory test and rate dehumidification units according to ARI 910.
- B. Sound-Power-Level Ratings: Factory test and rate dehumidification units according to ARI 575.

2.14 SPRAYED COIL DEHUMIDIFIERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers in this article. See Section 016000 "Product Requirements."

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 - 1. **American Air Filter Co.**
 - 2. **Buffalo Forge Co.**
 - 3. **Trane Co.**
 - 4. or approved equal.
- B. **Manufactured units:**
 - 1. Units: Factory assembled consisting of casing, tank, spray headers, nozzles, **[spray pumps,]** water and drain connections, and cooling coils.
 - 2. Evaporation Performance: As indicated on the drawings.

Select one below.

- 3. Operating Static Pressure: **[3 inch wg negative] [3 inch wg positive] [6 inch wg positive]**.
- C. **Casing:**
 - 1. Assembly: Galvanized steel, minimum 0.0635 inch, reinforced and braced with galvanized steel angles with cadmium plated cap screws.
 - 2. Connection: 1-1/2 inch flanges on inlet and outlet with 1/4 x 1 inch adhesive backed neoprene gasket.

Select one below.

- 3. Doors: **[20 x 36 inch] [14 x 19 inch]** quick opening access door on one side with 1/4 inch thick plexiglass inspection window.

Edit paragraph below as needed.

- 4. Finish: Two (2) coats of **[zinc chromate, iron oxide, phenolic resin]** <Insert type> paint applied after assembly.
- 5. Removable Inlet Screen: Galvanized expanded metal on inlet side of dehumidifier.
- 6. Gasket and flange pipe penetrations, inspection panels, access doors, and other openings in casing.

D. Drain tank:

Edit paragraph below.

1. Tank: Welded stainless steel, 12 inches deep, **[0.1345 inch] [3/16 inch]**, **[finished inside and out with zinc chromate, iron oxide, phenolic resin paint] [prime coated]** and coated inside with **[1/8 inch asphalt mastic] [3/32 inch epoxy] [glass fiber reinforced plastic]** coating.

Edit paragraph below.

2. Connections: **[3/4 inch] [1 inch]** adjustable float valve assembly with brass rod and brass or polystyrene float; 2 inch drain and overflow with removable copper suction screen.
3. Fabricate: Lap and weld corners watertight. Weld fittings and piping supports to tank.

Select one below.

4. External Spray Piping: **[1-1/4 inch galvanized steel] [1-1/2 inch PVC]** piping.
5. Spray Nozzles: Bronze, self-cleaning.

E. Cooling coils:

1. Coil: **[ARI 410;]** copper tube, copper fin construction individually mounted on steel angle rails. Refer to Section 238216.11 "Hydronic Air Coils" and coil schedule for size and cooling capacity of unit.

Select one below.

2. Eliminators: **[Type 304 stainless steel,] [PVC]** mounted over drain pan.
3. Water Cooling Coil: As indicated on the drawings.

Engineer shall select either c or d

4. Refrigerant Cooling Coil: As indicated on the drawings.

F. Spray pumps:

Select one below.

1. Type: **[Vertical] [Horizontal]** shaft, single stage, close coupled, radially split casing, for 125 psi maximum working pressure.
2. Casing: Cast iron, with gage ports, drain plug, flanged suction and discharge.
3. Impeller: Bronze, fully enclosed, keyed to motor shaft extension.
4. Shaft: Stainless steel.
5. Seal: Carbon rotating against a stationary ceramic seat.
6. Performance: As indicated on the drawings.
7. Electrical Characteristics: As indicated on the drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for [**hot-water**] [**steam**] [**refrigerant**] piping systems to verify actual locations of piping connections before equipment installation.
- C. Examine walls, floors, and roofs for suitable conditions where dehumidification units will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

- 1. Install dehumidification units on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

- 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

3.3 INSTALLATION OF SPRAYED COIL DEHUMIDIFIERS

- A. Install in accordance with manufacturer's instructions.
- B. Install in ducts or casings in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible.
- C. Insulate exterior of unit same as specified for ductwork. Refer to Section 230713 Duct Insulation.
- D. Place unit on 2 inch thick closed-cell rigid insulation board same size as unit tank. Flash and counter-flash with 0.0396 inch galvanized steel on entering and leaving sides.

- E. Connect unit to water supply. Provide gate valve on water supply line. Provide 3/4 inch hose bibb accessible from interior.
- F. Provide shut-off valves for individual spray header isolation and balancing. [**Arrange to permit step control of sprays.**]
- G. Pipe drain and overflow to nearest floor drain.
- H. Bolt spray pump directly to tank fitting. Insulate piping located on exterior of unit. Refer to Section 230719 "HVAC Piping Insulation".
- I. Provide globe valve and solenoid valve in 1/2 inch bleed line from drain. Refer to Section 232500 "Chemical Water Treatment".

Engineer shall select either I or J.

- J. Provide 1/2 inch bleed line from spray pump discharge to nearest floor drain complete with globe valve set to pass 1/2 gph of spray water per 1000 cfm of air flow. Locate bleed line above flood level of drain tank.
- K. Provide low water cut-off in drain pan to stop spray pump.
- L. Connect unit coil to chilled water cooling system. Refer to Section 232113 "Hydronic Piping".
- M. Connect unit coil to refrigerant system. Refer to Section 232200 "Refrigerant Piping".

Engineer shall select either M or N.

- N. Connect unit to electrical supply. Refer to Section 260583 "Electrical Connections for Equipment".

3.4 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Where piping is installed adjacent to dehumidification units, allow space for service and maintenance of dehumidification units.

Flexible connectors in first paragraph below may be unnecessary. Coordinate requirements with Project conditions.

- B. Connect piping to dehumidification units mounted on vibration isolators with flexible connectors.
- C. Connect condensate drain pans using minimum **NPS 1-1/4 (DN 32)** copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan, and install cleanout at changes in direction.

Retain first paragraph below for units with remote-mounted air-cooled condensers.

- D. Refrigerant Piping: Comply with requirements in Section 232300 "Refrigerant Piping." Connect to supply and return coil tapplings with shutoff valve and union or flange at each connection.

Retain first paragraph below for units with hot-water coils.

- E. Hot-Water Piping: Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties." Connect to supply coil tapplings with shutoff valve, return coil tapplings with balancing valve, and union or flange at each connection.

Retain first paragraph below for units with steam coils.

- F. Steam and Condensate Piping: Comply with requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 Steam and Condensate Piping Specialties." Connect with shutoff valve and union or flange.

Coordinate duct installation requirements with Drawings and with requirements specified in duct systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- G. Duct installation requirements are specified in Section 233113 "Metal Ducts" and Section 233116 "Nonmetal Ducts." Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
 - 1. Install ducts to termination in roof-mounted frames. Where indicated, terminate return-air duct through roof structure and insulate the space between roof and bottom of dehumidification unit.

3.5 FIELD QUALITY CONTROL

Retain first paragraph below to require a factory-authorized service representative to perform inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with tests and inspections.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

C. Tests and Inspections:

1. Leak Test: After installation, fill water coils with water, and test coils and connections for leaks. Repair leaks and retest until no leaks exist.
2. Charge refrigerant coils with refrigerant and test for leaks. Repair leaks and retest until no leaks exist.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. Dehumidification unit will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.6 STARTUP SERVICE

A. **[Engage a factory-authorized service representative to perform] [Perform]** startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.

B. Perform the following final checks before startup:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Perform cleaning and adjusting specified in this Section.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify free fan wheel rotation and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Check lubrication of bearings, pulleys, belts, and other moving parts.
6. Set outside- and return-air mixing dampers to minimum outside-air setting.
7. Install clean filters.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

C. Starting procedures for dehumidification units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. Replace malfunctioning motors, bearings, and fan wheels.
2. Measure and record motor's electrical values for voltage and amperage.

3. Manually operate dampers from fully closed to fully open position and record fan performance.
 - D. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing of dehumidification unit.
 - E. Startup Report: Report findings during startup. Identify startup steps, corrective measures taken, and final results.
- 3.7 ADJUSTING
- A. Adjust damper linkages for proper damper operation.
 - B. Adjust initial temperature and humidity set points.
- 3.8 CLEANING
- A. Clean dehumidification units internally, on completion of installation, according to manufacturer's written instructions. Clean fan interiors to remove foreign material and construction dirt and dust. Vacuum clean fan wheels, cabinets, and coils' entering-air face.
 - B. After completing system installation, testing, and startup service of dehumidification units, clean filter housings and install new filters.
- 3.9 DEMONSTRATION
- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain dehumidification units.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 238416

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SECTION 260400 - BASIC ELECTRICAL REQUIREMENTS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Certain labor, materials, and equipment may be furnished under other Sections of these specifications, by utility Companies or by the Owner. When this is the case, the extent, source and description of these items will be as indicated on the drawings or as described in the specifications.
- B. Where a panel is installed, at least 25% of panel capacity, accounting for serving panel capacity, shall remain as spare capacity after project completion.
- C. Where existing panels are used for additional work, when six (6) or less spaces remain a new panel shall be installed.
- D. All electrical/electronic circuits, including audio, video, and fire alarm systems, shall be in an approved raceway system. No "wild circuits" will be accepted.
- E. The Designer of Record shall not design or specify and the Contractor shall not install rigid metal conduit, electrical metallic tubing, flexible steel conduit, liquid-tight flexible

steel conduit, non-metallic rigid conduit or innerduct in any horizontal or vertical concrete wall or slab structures or portions thereof, e.g., cast-in-place concrete floor slab on steel decking; cast-in-place concrete slabs integral with concrete structural support systems; prestressed concrete slabs; post-tensioned concrete slabs; precast concrete construction with or without field applied or plant fabricated concrete topping slabs, slabs on grade, foundation walls or in concrete cast-in-place walls, etc.

F. Related Sections:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Basic Electrical Requirements specifically applicable to all Division 26 Sections, in addition to Division 1 General Requirements, and Divisions 11, 14, 21, 22, 23, 27 and 28.
2. All electrical/electronic circuits and equipment from any other Division shall meet the requirements of Division 26.
3. Description: Work shall consist of furnishing all labor, equipment, supplies, and materials, unless otherwise specified, necessary for the installation of complete electrical systems as required by the specifications and as shown on the drawings, subject to the terms and conditions of the Contract. The Work shall also include the completion of those details of electrical work not mentioned or shown which are necessary for the successful operation of all electrical systems.
4. Temporary Power: See Division 1 for construction power constraints.

G. REFERENCE STANDARDS

Edit to delete, retain, or add any general standards that should be included

H. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.

I. Latest editions of the following:

1. ANSI/NFPA 70 - National Electrical Code (as adopted and amended by the Denver Building Department).
2. International Fire Code (as amended by the Denver Fire Department).
3. International Building Code (as adopted and amended by the Denver Building Department).
4. International Energy Conservation Code (as adopted and amended by the Denver Building Department).
5. ANSI/IEEE C2 - National Electrical Safety Code.
6. OSHA - Occupational Safety and Health Administration, as Amended
7. Underwriter's Laboratory (UL).
8. National Fire Protection Association (NFPA).
9. Other references as listed elsewhere in these specifications.
10. IEEE Standard 519- Recommended Practices and Requirement for Harmonic

Control in Electrical Power Systems.

1.3 DEFINITIONS

- A. "Furnish" or "Provide": To supply, install and connect complete and ready for safe and regular operation of particular work unless specifically otherwise noted.
- B. "Install": To erect, mount and connect complete with related accessories.
- C. "Supply": To purchase, procure, acquire and deliver complete with related accessories.
- D. "Work": Labor, materials, equipment, apparatus, controls, accessories, and other items required for proper and complete installation.
- E. "Wiring": Raceway, fittings, wire, boxes and related items.
- F. "Concealed": Embedded in masonry, concrete, or other construction, installed in furred spaces, within double partitions or hung ceilings, in trenches, in crawl spaces, or in enclosures.
- G. "Or Equal. Or Approved Equal": Refers to products that, in the opinion of the DEN Project Manager, are similar in all respect to products specified by proprietary brand name. (Refer to Section 01630 for procedures for submittal of proposed substitutions.)
- H. "Exposed": Not installed underground or "concealed" as defined above.
- I. "Indicated," "Shown" or "Noted": As indicated, shown or noted on drawings or specifications.
- J. "Similar" or "Equal": Same in materials, weight, size, design, construction, capacity, performance, and efficiency of specified product.
- K. "Reviewed," "Satisfactory," "Accepted," or "Directed": As reviewed, satisfactory, accepted, or directed by or to DEN Project Manager.
- L. "Related Work" includes all "Work" required for a complete working system.
- M. "Equipment": A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with, an electrical installation.
- N. "Busbar": A rigid metallic conductor, lug or bar used to make a common connection between more than one circuit. (Includes all termination assemblies.)
- O. "Shall": Mandatory requirements of this specification are characterized by the use of the word "shall".
- P. Refer to Article 100 of the currently adopted National Electrical Code for other definitions as applicable to this Project.

1.4 WORK SEQUENCE

- A. Construct Work in sequence under provisions of Division 1 where applicable.

1.5 DRAWINGS AND SPECIFICATIONS

- A. The Drawings indicate the general arrangement of circuits, outlets, panelboards and other work. Information shown on the Drawings is schematic; however, re-circuiting will not be permitted without specific acceptance. In cases of conflict between specifications and drawings, the specification shall have precedence. Data presented on the drawings is as accurate as planning can determine, but accuracy is not guaranteed and field verification of all dimensions, locations, levels, etc., to suit field conditions is required. Review all of the Contract Documents and adjust all work to conform to all conditions shown therein.
- B. Prior to submitting a bid, a site visit is required to ascertain all conditions affecting the proposed installation and to adjust all work accordingly. Costs for providing for these adjustments, including response to site constraints, shall be itemized and listed in the bid proposal.
- C. Discrepancies between different plans, between plans and specifications, between specifications, or regulations and codes governing this installation shall be brought to the attention of the DEN Project Manager in writing 72 hours before the date of bid opening. In the event such discrepancies exist, and the DEN Project Manager is not so notified, the adjudication of responsibility shall be solely at the discretion of the DEN Project Manager.

1.6 COORDINATION

- A. Prior to fabrication or installation of any electrical work, participate in detailed coordination planning meetings with all other building utilities system trades, under the direction of the General Contractor, so as to completely establish routings, elevations, space requirements, and coordination of access, layout, and suspension requirements in relationship to the building structure and the work of all other trades.
- B. Any electrical work penetrating concrete walls or floors shall require saw cutting and/or core drilling and shall require approval by the DEN Project Manager. The Contractor shall perform all necessary imaging (x-rays, etc.) as specified, and submit shop drawings of any saw cutting or core drilling to the DEN Project Manager prior to performing the Work. Refer to Section 017330 "Cutting and Patching" for additional requirements.
- C. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

1.7 COORDINATION DRAWINGS

- A. Where the Contractor modifies the design, through selection of equipment differing from that shown, coordination drawings shall be provided by the Contractor in accordance with Division 1 to a scale of 1/4"=1'0" or larger for equipment rooms, details, congested areas and sections; other plans at a scale of 1/8"=1'0". These drawings are to detail major elements, components, and systems of electrical equipment and materials in relationship with other systems, installations, and building components.
- B. Coordination drawings shall be in accordance with current DEN standards for format, and as outlined in Division 1.
- C. The Contractor shall indicate locations where space is limited for installation and access and where sequencing and coordination of installations are of importance to the efficient flow of the Work, including (but not necessarily limited to) the following:
 - 1. Indicate the proposed locations of raceway systems, equipment, and materials. Include the following:
 - a. Clearances for servicing equipment, including space for equipment disassembly required for periodic maintenance.
 - b. Exterior wall and foundation penetrations.
 - c. Fire-rated wall and floor penetrations.
 - d. Equipment connections and support details.
 - e. Sizes and location of required concrete pads and bases.
 - f. Support details.
 - 2. Indicate scheduling, sequencing, movement, and positioning of large equipment into the building during construction.
 - 3. Floor plans, elevations, and appropriate details are required to indicate penetrations in floors, walls, and ceilings and their relationship to other penetrations and installations.

1.8 SUBMITTALS

- A. Refer to Section 013300 "Submittal Procedures".
- B. Submit shop drawings, coordination drawings and product data in accordance with provisions of Division 1. Submit all required information under a given specification section together. Do not split out submittals under the same specification section.
- C. Prior to submission, shop drawings, material lists and catalog cut sheets or manufacturer's printed data shall be thoroughly checked for compliance with Contract requirements, compatibility with equipment being furnished by the Contractor or Owner, accuracy of dimensions, coordination with work of other trades, and conformance with sound and safe practice as to erection of installation. Each submittal shall bear Contractor's signed statement evidencing such checking.

- D. Clearly mark each shop drawing as follows for purposes of identification:
1. Shop Drawing.
 2. Equipment Identification Used on Contract Drawings.
 3. Date.
 4. Name of Project.
 5. Branch of Work.
 6. Project Manager's Name.
 7. Contractor's Name.
- E. Clearly mark printed material, catalog cut sheets, pamphlets or specification sheets, and shop drawings with the same designation shown on the Contract document schedules. Contractor agrees that submittals processed by the DEN Project Manager are not change orders; that the purpose of submittals is to demonstrate to the DEN Project Manager that the Contractor understands the design concept; and that the Contractor demonstrates this understanding by indicating which equipment and material the Contractor intends to furnish and install and by detailing the installation methods the Contractor intends to use.
- F. Contractor shall be responsible for dimensions (which the Contractor shall confirm and correlate at the job site), fabrication processes and techniques of construction, and coordination of the Contractor's Work with that of other trades. The Contractor shall check and verify all measurements and review shop drawings before submitting them. If any deviations from the specified requirements for any item of material or equipment exist, such deviation shall be expressly stated in writing and incorporated with the submittal.
- G. Maintain one copy of accepted shop drawings at the Project field office until completion of the Project, and make this copy available, upon request, to representatives of the DEN Project Manager and Owner.
- H. No equipment or materials shall be installed or stored at the jobsite until submittals for such equipment or materials have been given review action by the DEN Project Manager accepting their use.
- I. Shop drawings and manufacturer's published data shall be submitted for all equipment required for this Project.
- 1.9 RECORD DOCUMENTS
- A. Maintain a Contract set of electrical drawings and specifications at the site. Neatly mark all changes, discoveries and deviations from the original drawings. Use a reproducible color that contrasts with the prints. This shall be a separate set of drawings, not used for construction purposes, and shall be updated daily as the job progresses and shall be made available for inspection by the DEN Project Manager at all times. Upon completion of the Contract, this set of record drawings shall be delivered to the DEN Project Manager. Follow current DEN BIM standards, to be furnished to the successful bidder as well as the project-specific BIM execution plan. Record documents to be provided by the Contractor shall clearly and accurately show

the following:

1. Provide horizontal and vertical dimensions for all raceway systems, size and location, for both exterior and interior; locations of control devices; distribution and branch electrical circuitry; and fuse and circuit breaker size and arrangements.
2. Equipment locations (exposed and concealed), dimensioned from prominent building lines.
3. Approved substitutions, Contract Modifications, and actual equipment and materials installed.

1.10 REGULATORY REQUIREMENTS

- A. Obtain all permits, plan review, and inspections from authority having jurisdiction.
- B. The drawings and specifications take precedence when they are more stringent than codes, statutes, or ordinances in effect. Applicable codes, ordinances, standards and statutes take precedence when they are more stringent than the drawings and specifications.

1.11 ENVIRONMENTAL CONDITIONS

- A. The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:
 1. Location: Indoors/Outdoors.
 2. Altitude: 5,500 feet above sea level.
 3. Temperature range: -30°F to 120°F.

1.12 WARRANTY

- A. The entire electrical system installed under this Contract shall be left in proper working order. Replace, at no additional cost to the Owner, any work, materials, or equipment that evidences defects in design, construction, or workmanship within two (2) years, or any longer period specifically noted elsewhere in these specifications, from date of final acceptance.

PART 2 - PRODUCTS

2.1 MATERIALS AND EQUIPMENT

- A. Materials and Equipment: Acceptable to the authority having jurisdiction as suitable for the use intended, except where more stringent requirements are indicated by the Contract Documents.
- B. All equipment and materials installed shall be new, unless otherwise specified.

- C. Defective or damaged materials shall be replaced or repaired, prior to final acceptance, in a manner acceptable to the DEN Project Manager or Owner and at no additional cost to the Owner.
- D. All electrical "equipment" and assemblies shall be acceptable for installation only if labeled and listed by a nationally recognized testing laboratory, such as UL or an equivalent.
- E. All major equipment components shall have the manufacturer's name, address, model number, and serial number permanently attached in a conspicuous location.

2.2 STORAGE AND PROTECTION

- A. Store products in accordance with manufacturer's instructions, with seals and labels intact and legible. Store sensitive products in weather-tight enclosures; maintain within temperature and humidity ranges required by manufacturer's instructions.
- B. For exterior storage of fabricated products, place on sloped supports above ground. Cover products subject to deterioration with impervious sheet covering and provide ventilation to avoid condensation.
- C. Arrange storage to provide access for inspection. Periodically inspect to assure products are undamaged and are maintained under required conditions.

2.3 PRODUCT OPTIONS

- A. Products Specified by Reference Standards or by Description Only:
 - 1. Any product meeting those standards.
- B. Products Specified by Naming One or More Manufacturers with a Provision for Substitutions:
 - 1. Submit a request for substitution for any manufacturer not specifically named with supporting documentation for approval by DEN Project Manager.

2.4 PRODUCTS LIST

- A. Within fifteen (15) days after date of Notice to Proceed, submit complete list of major products required for submittal under these specifications, with name of manufacturer, trade name, and model number of each product.

2.5 SUBSTITUTIONS

- A. Refer to Division 1 General Requirements, Section 012510 "Substitutions".

PART 3 - EXECUTION

3.1 WORKMANSHIP

- A. Only quality workmanship will be accepted. Poor workmanship, improper layout of work and lack of coordination of Work, as determined by the DEN Project Manager, are not acceptable and shall be corrected at the contractors cost.
- B. Contractor shall include no more than one apprentice per Journeyman Electrician. Apprentices shall be under the direct supervision of a licensed electrician at all times.
- C. Any changes or deviations from the drawings and specifications must be accepted in writing by the DEN Project Manager. All errors in installation shall be corrected at the expense of the Contractor. All specialties shall be installed as detailed on the drawings. Where details or specific installation requirements are not provided, manufacturer's recommendations shall be followed.
- D. Upon completion of Work, all equipment and materials shall be installed complete, thoroughly tested, checked, correctly adjusted, and left ready for intended use or operation. All Work shall be thoroughly cleaned and all residues shall be removed from surfaces. Exterior surfaces of all material and equipment shall be left in a perfect, unblemished condition.
- E. Contractor shall provide a complete installation, including all required labor, material, cartage, testing, insurance, permits, and taxes.

3.2 CHASES, OPENINGS, CUTTING AND PATCHING

- A. Carefully lay out all work in advance so as to eliminate where possible, cutting, channeling, chasing, or drilling of floors, walls, partitions, ceilings and roofs. Any damage to the building, structure, piping, ducts, equipment or any defaced finish shall be repaired by skilled mechanics of the trades involved at no additional cost to the Owner and to the satisfaction of the DEN Project Manager. Any necessary cutting, channeling, drilling or welding as required for the proper support, concealment, installation or anchoring of raceways, outlets, or other electrical equipment shall be performed in a careful manner, and shall be pre-approved by the DEN Project Manager.
- B. All openings made in fire-rated walls, floors, or ceilings shall be sealed and made tight in a manner to conform to the fire rating for the barrier penetrated. Reference specification Section 078413 "Penetration Firestopping" for additional information.
- C. All penetrations required through completed concrete construction shall be core drilled at minimum size required. All penetrations in concrete require an x-ray or ground penetrating radar to determine if the location is clear of reinforcing steel and embedded systems. Precautions shall be taken when drilling to prevent damage to structural concrete.

3.3 ELECTRICAL INSTALLATIONS

- A. Coordinate electrical systems, equipment, and material installation with other building components. If the Contractor furnishes equipment of a different size, the Contractor shall furnish and install the proper fuses, circuit breaker, disconnect switch, wire and conduit required for the equipment furnished, at no additional cost to the Owner, and as deemed acceptable by the DEN Project Manager.

3.4 PROGRESS OF WORK

- A. Coordinate the progress of electrical work to conform to the progress of the Work of the other trades. Complete the entire installation as soon as the condition of the sites will permit. Any cost resulting from defective or ill-timed work performed under Division 26 shall be borne by the Contractor.

3.5 ELECTRICAL COMPLETION

- A. Training of Operating and Maintenance Personnel: Furnish the services of a qualified representative of the supplier of each item or system itemized below who shall instruct specific personnel, as designated by the Owner, in the operation and maintenance of that item or system.
 - 1. Instruction shall be given when the particular system is complete, shall be of the number of hours indicated, and at the time requested by the Owner. A representative of the Contractor shall be present for all demonstrations.

Add systems to list as appropriate for Project.

Systems:

Hours of Instruction:

- B. Operating and Maintenance Manuals and Parts Lists: Deliver three (3) complete operating & maintenance manuals and parts lists in three-ring binders to the Owner at the time of the above required training. The information shall be provided on the manufacturer's original data sheets. Fully explain the contents of the manuals as part of required training and instruct the Owner's personnel in the correct procedure in obtaining service, both during and after the guarantee period.
 - 1. The operating and maintenance manuals and parts lists shall give complete information as to whom the Owner shall contact for service and parts. Include address and phone number. Furnish evidence that an authorized service organization regularly carries a complete stock of repair parts for these items (or systems), and that the organization is available for service. Service shall be furnished within 24 hours after requested.
- C. Operating and Acceptance Tests: Provide all labor, instruments, and equipment for the

performance of tests as specified below and elsewhere in these specifications for all applicable equipment furnished and installed as part of this Contract. Submit three (3) copies of test reports to the DEN Project Manager for the DEN Project Manager's approval.

- D. Clean Up: Remove all materials, scrap, etc., relative to the electrical installation, and leave the premises and all equipment, lamps, fixtures, etc. in a clean, orderly condition. Clean all electrical equipment, such as switchboards, panel boards, luminaries etc. of construction dirt, dust, etc. and touch-up or repaint all scratches, blemishes, rust spots etc. to its original condition. Any costs to the Owner for cleanup of the site will be charged against the Contractor.
- E. Acceptance Demonstration: Upon completion of the Work, at a time to be designated by the DEN Project Manager, the Contractor shall demonstrate for the Owner the operation of the entire installation, including all systems provided or modified under this Contract.
- F. Final Acceptance by the Owner will not occur until all operating instructions are received and Owner's personnel have been thoroughly indoctrinated in the maintenance and operation of all equipment, as approved by DEN Project Manager.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260400

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SECTION 260510 - TESTING, ACCEPTANCES AND CERTIFICATION

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

THIS SECTION INCLUDES GENERAL REQUIREMENTS FOR THE NECESSARY FIELD-TESTING, STARTUP SERVICES AND CERTIFICATION FOR ALL ELECTRICAL AND MECHANICAL EQUIPMENT.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY OF REQUIREMENTS

Edit to suit Project.

- A. The Contractor shall provide the necessary field-testing and startup services for all electrical and mechanical equipment except as noted otherwise. The field-testing and startup services shall be in accordance with each equipment manufacturer's written recommendations for field-testing proving they meet Contract standards.
- B. The Contractor shall be responsible for furnishing all equipment, power source when needed, coordinating and performing electrical/electronic testing required by the Contract Documents. Testing requirements may be located on the Contract Drawings or other sections of the specifications.
- C. The Contractor shall provide all necessary assistance and cooperation with any Independent Testing Organization furnishing by the City. The Contractor shall correct, repair, or replace all equipment found to be defective by the Independent Testing Organization.

1.3 REFERENCE SPECIFICATIONS, CODES AND STANDARDS

Edit to delete, retain, or add any general standards that should be included for Project.

- A. Without limiting the generality of other requirements of these Specifications, all Work specified herein shall conform to or exceed the applicable requirements of the referenced Standards; provided, that wherever the provisions of said publications are in conflict with the requirements specified herein, the more stringent requirements shall apply unless in conflict with the equipment manufacturer's written recommendations:
1. Building Code and DEN Standards.
 2. ANSI/IEEE C2 - National Electrical Safety Code.
 3. OSHA - Occupational Safety and Health Administration, as Amended
 4. NETA - National Electric Testing Association
 5. NEMA ICS 1 - General Standards for Industrial Control and Systems.
 6. NEMA ICS 2 - Standards for Industrial Control Devices, Controllers, and Assemblies.
 7. NEMA ICS 6 - Enclosures for Industrial Controls and Systems.
 8. UL 1008 - Standard for Automatic Transfer Switches.
 9. NFPA 70 - National Electrical Code, including but not limited to use in emergency and standby systems in accordance with Articles 517, 700, 701 and 702.
 10. NFPA 72 - National Fire Alarm Code (as adopted and amended by the Denver Building Code and DEN Standards).
 11. NFPA 101 - National Electrical Safety Code (as adopted and amended by the Denver Building Code and DEN Standards).
 12. NFPA 110 - Standard for Emergency and Standby Power Systems (as adopted and amended by the Denver Building Code and DEN Standards).
 13. IEEE Standard 446 - IEEE Recommended Practice for Emergency and Standby Power Systems (Orange Book)
 14. NEMA Standard ICS-2-447 - AC Automatic Transfer Switches.
 15. IEC - Standard for Automatic Transfer Switches.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 SUBMITTALS

- A. Comply with Division 1 submittal requirements.
- B. Five (5) copies of complete certified test reports shall be submitted to the DEN Project Manager by the contractor. Electronic copy of test reports in pdf format to also be submitted to the DEN Project Manager. The test reports shall include the following as a minimum:
1. Power cable high potential test reports:
 - a. Insulation resistance tests.
 - b. Continuity tests.
 2. Transformer test reports to include where applicable:

- a. Transformer turns ratio.
 - b. Winding resistance.
 - c. Insulation power factor.
 - d. K Factor.
3. All electrical/electronic equipment and systems functional test report.
 4. All other reports required by individual specification sections.
 5. Generator load bank test report.
 6. Transfer Switch test report.
 7. Load balance report for each switch board, panel board and switch gear.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. The electrical and mechanical equipment shall be completely tested in the field in the presence of DEN Inspectors in accordance with good and accepted industry engineering practices to assure that:
 1. The equipment has not been damaged during manufacturing, shipping, or installation.
 2. The equipment has been installed according to the requirements Contract Documents.
 3. The equipment meets the requirements of the Contract Documents.
- B. If the Contractor finds during the testing that any piece of equipment failed to satisfactorily pass the required field test, the DEN Project Manager shall be promptly notified and the Contractor shall take the necessary actions for the prompt repair or replacement.
- C. A retest to demonstrate the equipment will meet the requirements of the Contract Documents shall be scheduled with the DEN Project Manager.

2.2 ENGINE GENERATOR SYSTEM (WHEN FURNISHED AND INSTALLED AS PART OF THIS CONTRACT).

- A. Test generator operation per tests as specified in Section 263213 "Engine Generators".

2.3 BYPASS ISOLATION TRANSFER SWITCH (WHEN FURNISHED AND INSTALLED AS PART OF THIS CONTRACT).

- A. Test transfer switch operation per tests as specified in Section 263600 "Transfer Switches"

2.4 HVAC

- A. Test the operation of all heaters and air conditioners.
- B. Test the Lead Lag Control circuits.

2.5 GROUND RESISTANCE TEST

- A. Before connecting a ground rod to the system test the resistance to earth. Where test show resistance to ground over 5 OHMS, an additional ground rod shall be added.
- B. Upon completion of installation of electrical grounding system, test ground resistance to earth in accordance with ANSI/IEEE81. Submit test results to the DEN Project Manager

2.6 CONDUCTOR INSULATION TEST

- A. Prior to energizing, all building service cables feeders to and/or from transformers, switchboards, panel boards are to be tested with a 1000-volt insulation megohm meter to determine insulation resistance levels. Test cables rated for three hundred volt with a 500-volt megohm meter or as recommended by the manufacturer. All field test data is to be recorded, corrected to a baseline temperature and furnished to the DEN Project Manager. A test is to include meggering between conductors and between each conductor and ground. Cables are to be meggered after installation with cables disconnected at both ends. Insulation test values shall meet or exceed the values given below:

Conductor Size: (AWG or KCMIL)	Resistance: (Megaohms - 1,000 ft.)
12-8	200
6-2/0	100
3/0-750	100

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

- A. TESTING
 - 1. The Contractor shall allow only certified personnel to perform the testing.
 - 2. The Contractor shall perform the testing using all necessary safety precautions and proper test equipment.
 - 3. The Contractor shall notify the DEN Project Manager three (3) days in advance of the proposed testing dates.
 - 4. Witness of testing by DEN Inspector, Electrical Maintenance and Electrical Inspector.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260510

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SECTION 260513 - MEDIUM-VOLTAGE CABLES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes cables and related cable splices, terminations, and accessories for medium-voltage (2001 to 35,000 V) electrical distribution systems.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. Jacket: A continuous nonmetallic outer covering for conductors or cables.
- B. NETA ATS: Acceptance Testing Specification.
- C. Sheath: A continuous metallic covering for conductors or cables.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of cable. Include splices and terminations for cables and cable accessories.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable.

- B. Samples: 16-inch (400-mm) lengths for each type of cable specified.

1.5 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For installer.

Retain "Material Certificates" Paragraph below to require submittal of material certificates from manufacturers.

- B. Material Certificates: For each type of cable and accessory, signed by manufacturers.

Retain reports below if required.

- C. Source quality-control reports.

Delete test reports below if not required. Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- D. Field quality-control reports.
- E. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

1.6 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

Revise "Installer" Paragraph below to include certification that may be specific to Project location.

- A. Installer: Engage a cable splicer, trained and certified by splice material manufacturer, to install, splice, and terminate medium-voltage cable.

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use first

paragraph below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain paragraph and subparagraph below if Contractor or manufacturer selects testing agency.

- B. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
- C. Source Limitations: Obtain cables and accessories through one source from a single manufacturer.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Edit paragraph below to suit Project. See Editing Instruction No. 2 in the Evaluations.

- E. Comply with IEEE C2 and NFPA 70.

1.8 PROJECT CONDITIONS

Delete this article if no interruption of existing electric service is required.

- A. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated.
- B. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown. Do not proceed with interruption of electric service without Owner's written permission.
- C. Any electrical work penetrating concrete walls or floors shall require saw cutting and/or core drilling and shall require approval by the DEN Project Manager. The contractor shall submit shop drawings of any saw cutting or core drilling to the DEN Project Manager prior to performing the work. Refer to Section 033000 "Cast-In-Place Concrete" for cutting and patching work.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

- D. CONSTRUCTION WASTE MANAGEMENT
 - 1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall

be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

Refer to Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

Retain lists below with either paragraph above.

1. Cables:
 - a. American Insulated Wire Corp.; a Leviton Company.
 - b. General Cable Technologies Corporation.
 - c. Kerite Co. (The); Hubbell Incorporated.
 - d. Okonite Company (The).
 - e. Pirelli Cables & Systems NA.
 - f. Rome Cable Corporation.
 - g. Southwire Company.
 - h. <Insert manufacturer>
 - i. or approved equal.

2. Cable Splicing and Terminating Products and Accessories:
 - a. Engineered Products Company.
 - b. G&W Electric Company.
 - c. MPHusky.
 - d. Raychem Corp.; Telephone Energy and Industrial Division; Tyco International Ltd.
 - e. RTE Components; Cooper Power Systems, Inc.
 - f. Scott Fetzer Co. (The); Adalet.
 - g. Thomas & Betts Corporation.
 - h. Thomas & Betts Corporation/Elastimold.
 - i. 3M; Electrical Products Division.
 - j. <Insert manufacturer>
 - k. or approved equal.

2.2 CABLES

Retain first option in paragraph below for crosslinked polyethylene insulation, second for ethylene-propylene insulation.

- A. Cable Type: [**MV90**] [MV105.]

Retain first option in first paragraph below for tape shielded cables, second for concentric neutral designs.

- B. Comply with UL 1072, AEIC CS 8, ICEA S-93-639, and ICEA S-97-682 , ICEA S-94-649.
- C. Conductor: Copper.
- D. Conductor Stranding: [**Compact round, concentric lay, Class B**] [Concentric lay, **Class B**].

Delete paragraph below if strand filling is not required for Project.

- E. Strand Filling: Conductor interstices are filled with impermeable compound.

See Editing Instruction No. 3 in the Evaluations for a discussion about insulation options in first two paragraphs and associated subparagraphs below.

- F. Conductor Insulation: Crosslinked polyethylene.

Retain paragraph above or below.

- G. Conductor Insulation: Ethylene-propylene rubber.

Retain two subparagraphs below with either paragraph above. These options are cable voltage ratings, not system voltages.

1. Voltage Rating: [5] [8] [15] [25] [35] kV.
2. Insulation Thickness: [100] [133] percent insulation level.

Delete two paragraphs below for unshielded cable. For shielded cable, select and edit first paragraph or select second. See Editing Instruction No. 4 in the Evaluations.

- H. Shielding: [**Copper tape**] [**Solid copper wires**], helically applied over semiconducting insulation shield.
- I. Shielding and Jacket: Corrugated copper drain wires embedded in extruded, chlorinated, polyethylene jacket.

Edit subparagraph below for multiconductor cable.

1. Circuit Identification: Color-coded tape (black, red, blue) under the metallic shielding.

2.3 SPLICE KITS

- A. Connectors and Splice Kits: Comply with IEEE 404; type as recommended by cable or splicing kit manufacturer for the application.
- B. Splicing Products: As recommended, in writing, by splicing kit manufacturer for specific sizes, ratings, and configurations of cable conductors. Include all components required for complete splice, with detailed instructions.

Delete subparagraphs below not required.

- 1. Combination tape and cold-shrink-rubber sleeve kit with re-jacketing by cast-epoxy-resin encasement or other waterproof, abrasion-resistant material.
- 2. Heat-shrink splicing kit of uniform, cross-section, polymeric construction with outer heat-shrink jacket.
- 3. Premolded, cold-shrink-rubber, in-line splicing kit.
- 4. Premolded EPDM splicing body kit with cable joint sealed by interference fit of mating parts and cable.

2.4 SOLID TERMINATIONS

Retain one of or both "Multiconductor Cable Sheath Seals" and "Shielded-Cable Terminations" paragraphs below.

- 1. Multiconductor Cable Sheath Seals: Type recommended by seal manufacturer for type of cable and installation conditions, including orientation.

Retain one of three subparagraphs below.

- 2. Cold-shrink sheath seal kit with preformed sleeve openings sized for cable and insulated conductors.
- 3. Heat-shrink sheath seal kit with phase- and ground-conductor re-jacketing tubes, cable-end sealing boot, and sealing plugs for unused ground-wire openings in boot.
- 4. Cast-epoxy-resin sheath seal kit with wraparound mold and packaged, two-part, epoxy-resin casting material.

- B. Shielded-Cable Terminations: Comply with the following classes of IEEE 48. Insulation class shall be equivalent to that of cable. Include shield ground strap for shielded cable terminations.

Retain one or more of six subparagraphs below.

- 1. Class 1 Terminations: Modular type, furnished as a kit, with stress-relief tube; multiple, molded-silicone-rubber, insulator modules; shield ground strap; and compression-type connector.
- 2. Class 1 Terminations: Heat-shrink type with heat-shrink inner stress control and outer nontracking tubes; multiple, molded, nontracking skirt modules; and compression-type connector.

3. Class 1 Terminations: Modular type, furnished as a kit, with stress-relief shield terminator; multiple-wet-process, porcelain, insulator modules; shield ground strap; and compression-type connector.
 4. Class 1 Terminations, Indoors: Kit with stress-relief tube, nontracking insulator tube, shield ground strap, compression-type connector, and end seal.
 5. Class 2 Terminations, Indoors: Kit with stress-relief tube, nontracking insulator tube, shield ground strap, and compression-type connector. Include silicone-rubber tape; cold-shrink-rubber sleeve; or heat-shrink, plastic-sleeve moisture seal for end of insulation whether or not supplied with kits.
 6. Class 3 Terminations: Kit with stress cone and compression-type connector.
- C. Nonshielded-Cable Terminations: Kit with compression-type connector. Include silicone-rubber tape, cold-shrink-rubber sleeve, or heat-shrink plastic-sleeve moisture seal for end of insulation whether or not supplied with kits.

2.5 SEPARABLE INSULATED CONNECTORS

Retain "Description" Paragraph below to ensure that elbow-type terminators at equipment such as substations, transformers, and switchgear mate with bushing terminals in equipment.

- A. Description: Modular system, complying with IEEE 386, with disconnecting, single-pole, cable terminators and with matching, stationary, plug-in, dead-front terminals designed for cable voltage and for sealing against moisture.

Delete paragraph below unless terminations take the place of splices at cable junctions, such as in manholes and cable vaults.

- B. Terminations at Distribution Points: Modular type, consisting of terminators installed on cables and modular, dead-front, terminal junctions for interconnecting cables.

Delete three paragraphs below if not required. Delete test-point feature for load-break unit if not required.

- C. Load-Break Cable Terminators: Elbow-type units with 200-A-load make/break and continuous-current rating; coordinated with insulation diameter, conductor size, and material of cable being terminated. Include test point on terminator body that is capacitance coupled.
- D. Dead-Break Cable Terminators: Elbow-type unit with 600-A continuous-current rating; designed for de-energized disconnecting and connecting; coordinated with insulation diameter, conductor size, and material of cable being terminated. Include test point on terminator body that is capacitance coupled.
- E. Dead-Front Terminal Junctions: Modular bracket-mounted groups of dead-front stationary terminals that mate and match with above cable terminators. Two-, three-, or four-terminal units as indicated, with fully rated, insulated, watertight conductor connection between terminals and complete with grounding lug, manufacturer's standard accessory stands, stainless-steel mounting brackets, and attaching hardware.

Delete drain wire below if not required.

1. Protective Cap: Insulating, electrostatic-shielding, water-sealing cap with drain wire.
2. Portable Feed-Through Accessory: Two-terminal, dead-front junction arranged for removable mounting on accessory stand of stationary terminal junction.
3. Grounding Kit: Jumpered elbows, portable feed-through accessory units, protective caps, test rods suitable for concurrently grounding three phases of feeders, and carrying case.
4. Standoff Insulator: Portable, single dead-front terminal for removable mounting on accessory stand of stationary terminal junction. Insulators suitable for fully insulated isolation of energized cable-elbow terminator.

Delete first paragraph below if fault indicators are not required.

- F. Test-Point Fault Indicators: Applicable current-trip ratings and arranged for installation in test points of load-break separable connectors, and complete with self-resetting indicators capable of being installed with shotgun hot stick and tested with test tool.
- G. Tool Set: Shotgun hot stick with energized terminal indicator, fault-indicator test tool, and carrying case.

2.6 ARC-PROOFING MATERIALS

Retain this article to require arc-proof cables.

- A. Tape for First Course on Metal Objects: **10-mil-** (250-micrometer-) thick, corrosion-protective, moisture-resistant, PVC pipe-wrapping tape.
- B. Arc-Proofing Tape: Fireproof tape, flexible, conformable, intumescent to **0.3 inch** (8 mm) thick, and compatible with cable jacket.
- C. Glass-Cloth Tape: Pressure-sensitive adhesive type, **1 inch** (25 mm) wide.

2.7 FAULT INDICATORS

Coordinate "Indicators" Paragraph below with Drawings by indicating current-trip ratings and quantities.

- A. Indicators: [**Automatically**] [**Manually**] reset fault indicator[**with inrush restraint feature**], arranged to clamp to cable sheath and provide a display after a fault has occurred in cable. Instrument shall not be affected by heat, moisture, and corrosive conditions and shall be recommended by manufacturer for installation conditions.

Retain "Resetting Tool" Paragraph below if retaining manually reset option in "Indicators" Paragraph above.

- B. Resetting Tool: Designed for use with fault indicators, with moisture-resistant storage and carrying case.

2.8 SOURCE QUALITY CONTROL

Revise first paragraph below for cable type specified. First option below refers to shielded cable, second option to concentric neutral cable designs.

- A. Test and inspect cables according to [ICEA S-97-682] [ICEA S-94-649] before shipping.

Retain paragraph below if sealed or strand-filled conductors are specified.

- B. Test strand-filled cables for water-penetration resistance according to ICEA T-31-610, using a test pressure of 5 psig (35 kPa).

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install cables according to IEEE 576.
- B. Determine required separation between wiring and other work.
- C. Determine routing to avoid interference with other work.
- D. Minimum wire size shall be based on the over current protection device and as governed by the NEC.
- E. Place an equal number of conductors for each phase in the same raceway.
- F. Pull Conductors: Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
 - 1. Where necessary, use manufacturer-approved pulling compound or lubricant that will not deteriorate conductor or insulation.
 - 2. Use pulling means, including fish tape, cable, rope, and basket-weave cable grips that will not damage cables and raceways. Do not use rope hitches for pulling attachment to cable. Use pull-in guides, cable feeders, and draw-in protectors as required to protect cables during installation.
 - 3. Pulling winches and other necessary pulling equipment shall be of adequate capacity to ensure a continuous pull on the cable. Strain gages shall be used to monitor the cable pulling tension.
 - 4. Do not pull cables with ends unsealed. Seal cable ends with rubber tape.
 - 5. Pull all conductors into a raceway at the same time.
 - 6. Install wire in raceway after interior of building has been physically protected from the weather and all mechanical work likely to injure conductors has been completed.
- G. Neatly train and lace wiring inside boxes, equipment, and panel boards. Make temporary connections to panel board devices with sufficient slack conductor to facilitate reconnections required for balancing loads between phases.

- H. Support cables according to Section 260529 "Hangers and Supports for Electrical Systems."
- I. All building wire and cable shall be installed in an approved raceway.
- J. All buried conduits containing medium-voltage cabling shall be installed in concrete encased duct banks.
- K. Install "Caution- Medium-Voltage" warning tape at least **12 inches** (305 mm) above concrete encased duct banks.
- L. Conductors shall not be pulled in concrete encased conduits before concrete is placed.
- M. In manholes, handholes, pull boxes, junction boxes, and cable vaults, train cables around walls by the longest route from entry to exit and support cables at intervals adequate to prevent sag.

Revise first paragraph below if separable insulated connectors are used.

- N. Install cable splices at pull points and elsewhere as indicated; use standard kits.
- O. Install terminations at ends of conductors and seal multiconductor cable ends with standard kits.

Coordinate paragraph and subparagraphs below with Drawings by indicating locations of separable insulated connectors.

- P. Install separable insulated-connector components as follows:
 - 1. Protective Cap: At each terminal junction, with one on each terminal to which no feeder is indicated to be connected.
 - 2. Portable Feed-Through Accessory: Three.
 - 3. Standoff Insulator: Three.

Delete first paragraph and subparagraphs below if cables are not arc proofed.

- Q. Arc Proofing: Unless otherwise indicated, arc proof medium-voltage cable at locations not protected by conduit, cable tray, direct burial, or termination materials. In addition to arc-proofing tape manufacturer's written instructions, apply arc proofing as follows:
 - 1. Clean cable sheath.
 - 2. Wrap metallic cable components with **10-mil** (250-micrometer) pipe-wrapping tape.
 - 3. Smooth surface contours with electrical insulation putty.
 - 4. Apply arc-proofing tape in one half-lapped layer with coated side toward cable.
 - 5. Band arc-proofing tape with **1-inch-** (25-mm-) wide bands of half-lapped, adhesive, glass-cloth tape **2 inches** (50 mm) o.c.
- R. Where harmonic currents exist on circuits that supply electric discharge lighting, data processing or similar equipment, a full size neutral conductor shall be provided for each single-phase circuit.

- S. Seal around cables passing through fire-rated elements according to Section 078413 "Penetration Firestopping."

Coordinate first paragraph below with Drawings by indicating locations of fault indicators or edit paragraph to describe locations.

- T. Install fault indicators on each phase where indicated.
- U. Ground shields of shielded cable at terminations, splices, and separable insulated connectors. Ground metal bodies of terminators, splices, cable and separable insulated-connector fittings, and hardware.
- V. Identify cables according to Section 260553 "Identification for Electrical Systems."

3.2 FIELD QUALITY CONTROL

- A. Perform the following field tests and inspections and prepare test reports:

Edit to suit Project. Delete subparagraphs if testing will be performed by Owner-engaged testing and inspecting agency.

See Editing Instruction No. 5 in the Evaluations for discussion about NETA testing.

1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
2. Field inspection and testing will be performed under provisions of Division 01.
3. Inspect wire and cable for physical damage and proper connection.
4. Torque conductor connections and terminations to manufacturer's recommended values. Submit torque values for all connections with a torque schedule and witness signature.
5. After installing medium-voltage cables and before electrical circuitry has been energized, test for compliance with requirements.
6. Perform continuity test on all feeder and branch circuit conductors. Verify proper phasing connections.
7. Verify cables are colored coded and labeled according to contract documents.

Retain one or more of three subparagraphs below, or delete all. Each of the three tests performs different functions, and the tests are not mutually exclusive. See Evaluations for comparative discussion of the three test methods.

8. Perform direct-current High Potential test of each new conductor according to NETA ATS, Ch. 7.3.3. Do not exceed cable manufacturer's recommended maximum test voltage.
9. Perform Partial Discharge test of each new conductor according to NETA ATS, Ch. 7.3.3 and to test equipment manufacturer's recommendations.
10. Perform Dissipation Factor test of each new conductor according to NETA ATS, Ch. 7.3.3 and to test equipment manufacturer's recommendations.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

11. Medium-voltage cables will be considered defective if they do not pass tests and

- inspections.
12. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260513

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SECTION 260519 - LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes the following:

Adjust list below to suit Project.

1. Building wires and cables rated 600 V and less.
2. Connectors, splices, and terminations rated 600 V and less.

- B. Related Sections include the following:

List below only products and equipment that the reader might expect to find in this Section but are specified elsewhere.

1. Division 26 Section "Medium-Voltage Cables" for single-conductor and multiconductor cables, cable splices, and terminations for electrical distribution systems with 2001 to 35,000 V.
2. Division 26 Section "Undercarpet Electrical Power Cables" for flat cables for undercarpet installations.
3. Division 27 Section "Communications Horizontal Cabling" for cabling used for voice and data circuits.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in

this Section affected by Alternates.

1.3 DEFINITIONS

Retain abbreviations that remain after this Section has been edited.

- A. EPDM: Ethylene-propylene-diene terpolymer rubber.
- B. NBR: Acrylonitrile-butadiene rubber.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN ELECTRICAL ENGINEER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.

1.5 INFORMATIONAL SUBMITTALS

Coordinate paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For testing agency.

Retain paragraph below if Contractor is responsible for field quality control testing.

- B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- B. Comply with NFPA 70.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CONDUCTORS AND CABLES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of first two paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. American Insulated Wire Corp.; a Leviton Company.
 2. General Cable Corporation.
 3. Southwire Company.
 4. Encore Wire Corp.
 5. Cerro Wire and Cable Company.
 6. CME Wire.
 7. Coleman Cable Inc.
 8. <Insert manufacturer>
 9. or approved equal.
- B. All conductors shall be copper.
- C. AC cable and Modular wiring are not permitted.
- D. MC Cable: Comply with NEMA WC 70. Provide internal equipment grounding conductor throughout.
- E. Copper Conductors: Comply with NEMA WC 70.
- F. Conductor Insulation: Comply with NEMA WC 70 for Types [THW] [THHN-THWN] [XHHW].
- G. Remote Control and Signal Cable
1. Control Cable for Class 1 Remote Control and Signal Circuits: Copper conductor, 600 volt insulation, rated at 60 deg C, individual conductors twisted together, shielded, and covered with a PVC jacket.
 2. Control Cable for Class 2 or Class 3 Remote Control and Signal Circuits: Copper

conductor, individual conductors twisted together, shielded, and covered with a PVC jacket; UL listed.

2.2 CONNECTORS AND SPLICES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. AFC Cable Systems, Inc.
 2. Hubbell Power Systems, Inc.
 3. O-Z/Gedney; EGS Electrical Group LLC.
 4. 3M; Electrical Products Division.
 5. Tyco Electronics Corp.
 6. Ideal.
 7. <Insert manufacturer>
 8. or approved equal.
- B. Description: Factory-fabricated connectors and splices of size, ampacity rating, material, type, and class for application and service indicated.

PART 3 - EXECUTION

3.1 CONDUCTOR MATERIAL APPLICATIONS

- A. Feeders: Copper. Solid for No. 12 AWG and smaller; stranded for No. 10 AWG and larger.
- B. Branch Circuits: Copper. Solid for No. 12 AWG and smaller; stranded for No. 10 AWG and larger, except for connection to vibrating equipment then stranded shall be used.
- C. Prohibited Cable Types: UF, NM, SE, AC.

3.2 CONDUCTOR INSULATION AND MULTICONDUCTOR CABLE APPLICATIONS AND WIRING METHODS

This Article provides examples of application requirements for conductors and cables. Edit to select wiring methods for various environments in Project. Add other methods if required. Revise conductor insulation and cable type designations to suit Project conditions, authorities having jurisdiction, and practice. Refer to NFPA 70 and to UL's "Electrical Construction Equipment Directory" for additional application information about conductor sizes, insulation temperature ratings in cables, and product-use classifications and restrictions.

See Editing Instruction No. 2 in the Evaluations for use of Type MI cable as service entrance conductor inside a building.

- A. Minimum wire size shall be based on the over current protection device and as governed by the NEC.
- B. Service Entrance: **[Type THHN-THWN, single conductors in raceway] [Type XHHW, single conductors in raceway].**
- C. Exposed Feeders: **[Type THHN-THWN, single conductors in raceway], [Type XHHW, single conductors in raceway].**
- D. Feeders Concealed in Ceilings, Walls, Partitions, and Crawlspace: **[Type THHN-THWN, single conductors in raceway], [Type XHHW, single conductors in raceway].**

Coordinate first paragraph below with Division 26 Section "Underground Ducts and Raceways for Electrical Systems."

- E. Feeders below Slabs-on-Grade, and Underground: **[Type THHN-THWN, single conductors in raceway], [Type XHHW, single conductors in raceway].**
- F. Feeders Installed below Raised Flooring: **[Type THHN-THWN, single conductors in raceway], [Type XHHW, single conductors in raceway].**
- G. Feeders in Cable Tray: **[Type THHN-THWN, single conductors in raceway], [Type XHHW, single conductors in raceway].**
- H. Exposed Branch Circuits, Including in Crawlspace: **[Type THHN-THWN, single conductors in raceway].**
- I. Branch Circuits Concealed in Ceilings, Walls, and Partitions: **[Type THHN-THWN, single conductors in raceway].**

Coordinate first paragraph below with Division 26 Section "Underground Ducts and Raceways for Electrical Systems."

- J. Branch Circuits Concealed in Concrete, below Slabs-on-Grade, and Underground: **[Type THHN-THWN, single conductors in raceway].**
- K. Branch Circuits Installed below Raised Flooring: **[Type THHN-THWN, single conductors in raceway].**
- L. Branch Circuits in Cable Tray: **[Type THHN-THWN, single conductors in raceway].**
- M. Class 1 Remote Control and Signal Circuits: Type THHN-THWN, in raceway or cable tray as applicable, or Copper conductor, 600 volt insulation, individual conductors twisted together, shielded, and covered with a PVC jacket.
- N. Class 2 Remote Control and Signal Circuits: Type THHN-THWN, in raceway or cable tray as applicable, or Copper conductor, individual conductors twisted together, shielded, and covered with a PVC jacket; UL listed.

- O. All power, control, data, communication and signal wire or cable shall be installed in an approved raceway.

The following paragraph and subparagraphs shall be deleted except for concession projects or where specifically allowed by the DEN project manger.

- P. MC Cable allowed for use in 20-Ampere branch circuits, with the following conditions:
 1. Cable shall be run concealed in all locations. Where circuiting must be exposed, provide single conductor building wire in approved raceway.
 2. Home run from first device to panel board shall be single conductor building wire in approved raceway.
 3. MC cable shall be supported using approved methods throughout. Do not run cables unsupported in any area, including above accessible ceilings, in unfinished areas, etc.

3.3 INSTALLATION OF CONDUCTORS AND CABLES

- A. All power, control, data, communication and signal wire or cable shall be installed in an approved raceway (raceway shall be defined as conduit or cable tray as applicable).
- B. Verify raceways are open, continuous and clear of debris before installing cables.
- C. Pull all conductors into a raceway at the same time. Use a listed wire pulling lubricant for pulling No. 4 AWG and larger wires.
- D. Completely and thoroughly swab raceway system before installing conductors for conduit in floors, concrete, or below grade.
- E. Use manufacturer-approved pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
- F. Install wire in raceway after interior of building has been physically protected from the weather and all mechanical work likely to injure conductors has been completed.
- G. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips, that will not damage cables or raceway.
- H. Pulling winches and other necessary pulling equipment shall be of adequate capacity to ensure a continuous pull on the cable. Strain gages shall be used to monitor the cable pulling tension.
- I. Install exposed cables parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible.
- J. Neatly train wiring inside boxes, equipment, and panel boards. Make temporary connections to panel board devices with sufficient slack conductor to facilitate reconnections required for balancing loads between phases.

- K. Support cables according to Division 26 Section "Hangers and Supports for Electrical Systems."
- L. Complete cable tray systems installation according to Section 260536 "Cable Trays for Electrical Systems" prior to installing conductors and cables.
- M. Conductors shall not be pulled in concrete encased conduits before concrete is placed.
- N. For connection to vibrating equipment, stranded wire shall be used.
- O. All wiring shall be installed in a new approved raceway system. Existing conduits shall not be used unless approved by the DEN Project Manager.
- P. Where harmonic currents exist on feeders that supply panelboards that serve electronic equipment of 40 percent or more of the panelboards total ampacity, two (2) full size neutral conductors or a neutral conductor rated at 200 percent shall be provided to the panelboard being served. A neutral bus bar rated at 200 percent shall also be provided in the panelboard.
- Q. Shared Neutrals: Prohibited. A full-size neutral conductor shall be provided for each single-phase circuit.

3.4 CONNECTIONS

- A. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.
- B. Splice only in accessible junction and outlet boxes.
- C. Make splices and taps that are compatible with conductor material and that possess equivalent or better mechanical strength and insulation ratings than unspliced conductors.
- D. Wiring at Outlets: Install conductor at each outlet, with at least [**6 inches (150 mm)**] [**12 inches (300 mm)**] of slack.

3.5 IDENTIFICATION

- A. Identify and color-code conductors and cables according to Section 260553 "Identification for Electrical Systems."
- B. Identify each spare conductor at each end with identity number and location of other end of conductor, and identify as spare conductor.

3.6 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Division 26 Section "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.7 FIRESTOPPING

- A. Apply firestopping to electrical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly according to Division 07 Section "Penetration Firestopping."

3.8 FIELD QUALITY CONTROL

Retain paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections and prepare test reports.

Retain first paragraph and subparagraphs below to describe tests and inspections to be performed by either of the entities in two paragraphs above.

Performing NETA tests on all conductors and cables can be expensive. Consider limiting testing to a certain group of conductors, such as service entrance and feeder conductors, or to those conductors feeding critical equipment and services. To require all conductors and cables to be tested, delete option in first subparagraph below and delete associated subparagraph.

1. Field inspection and testing will be performed under provisions of Division 01.
2. After installing conductors and cables and before electrical circuitry has been energized, test[**service entrance and feeder conductors, and conductors feeding the following critical equipment and services**] for compliance with requirements.
 - a. Prior to energizing, all building service cables, feeders to and/or from transformers, switchboards and panel boards are to be tested with a 500-volt insulation megohm meter to determine insulation resistance levels. All field test data is to be recorded, corrected to a baseline temperature and furnished to the DEN Project Manager. A test is to include meggering for one minute between conductors and between each conductor and ground. Cables are to be meggered after installation with cables disconnected at both ends. Insulation test values shall meet or exceed the values given below.

Conductor Size (AWG or KCMIL):	Resistance (Megohms-1,000ft):
12-8	200
6-2/0	100
3/0-750	100

Consider the cost and benefit of infrared scanning of cable and conductor splices before retaining subparagraph and associated subparagraphs below.

3. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each splice in cables and conductors No. 3 AWG and larger. Remove box and equipment covers so splices are accessible to portable scanner.
 - a. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each splice eleven (11) months after date of Substantial Completion.
 - b. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
 - c. Record of Infrared Scanning: Prepare a certified report that identifies splices checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.
 4. Inspect wire and cable for physical damage and proper connection.
- B. Test and Inspection Reports: Prepare a written report to record the following:
1. Test procedures used.
 2. Test results that comply with requirements.
 3. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
- C. Remove and replace malfunctioning units and retest as specified above.
- D. Cables will be considered defective if they do not pass tests and inspections.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260519

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SECTION 260523 - CONTROL-VOLTAGE ELECTRICAL POWER CABLES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. UTP cabling.
 - 2. 50/125 62.5/125-micrometer, multimode optical fiber cabling.
 - 3. RS-232 cabling.
 - 4. RS-485 cabling.
 - 5. Low-voltage control cabling.
 - 6. Control-circuit conductors.
 - 7. Identification products.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. Basket Cable Tray: A fabricated structure consisting of wire mesh bottom and side rails.
- B. Channel Cable Tray: A fabricated structure consisting of a one-piece, ventilated-bottom or solid-bottom channel section.
- C. EMI: Electromagnetic interference.
- D. IDC: Insulation displacement connector.
- E. Ladder Cable Tray: A fabricated structure consisting of two longitudinal side rails connected by individual transverse members (rungs).
- F. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control and signaling power-limited circuits.
- G. Open Cabling: Passing telecommunications cabling through open space (e.g., between the studs of a wall cavity).
- H. RCDD: Registered Communications Distribution Designer.
- I. Solid-Bottom or Nonventilated Cable Tray: A fabricated structure consisting of integral or separate longitudinal side rails, and a bottom without ventilation openings.
- J. Trough or Ventilated Cable Tray: A fabricated structure consisting of integral or separate longitudinal rails and a bottom having openings sufficient for the passage of air and using 75 percent or less of the plan area of the surface to support cables.
- K. UTP: Unshielded twisted pair.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN ELECTRICAL ENGINEER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For cable tray layout, showing cable tray route to scale, with relationship between the tray and adjacent structural, electrical, and mechanical elements. Include the following:
 - 1. Vertical and horizontal offsets and transitions.
 - 2. Clearances for access above and to side of cable trays.
 - 3. Vertical elevation of cable trays above the floor or bottom of ceiling structure.
 - 4. Load calculations to show dead and live loads as not exceeding manufacturer's rating for tray and its support elements.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified layout technician, installation supervisor, and field inspector.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

1.6 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For wire and cable to include in maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

Retain first paragraph below if Contractor or manufacturer selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Division 01 Section "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of an NRTL.

Retain subparagraph below for UTP and optical fiber cabling. See Editing Instruction No. 2 in the Evaluations for discussion of qualifications of the RCDD designation.

- 1. Testing Agency's Field Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.
- B. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1. Flame-Spread Index: [25] <Insert value> or less.
 - 2. Smoke-Developed Index: [50] [450] <Insert value> or less.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.8 DELIVERY, STORAGE, AND HANDLING

According to BICSI ITSIM, telecommunications cables should be tested upon receipt. Low-voltage wires

and cables do not normally require testing before installation.

- A. Test cables upon receipt at Project site.

Retain one or both of first two subparagraphs below.

1. Test optical fiber cable to determine the continuity of the strand end to end. Use **[optical fiber flashlight] [optical loss test set] [optical fiber flashlight or optical loss test set]** <Insert test>.
2. Test optical fiber cable on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector; include the loss value of each. Retain test data and include the record in maintenance data.
3. Test each pair of UTP cable for open and short circuits.

1.9 PROJECT CONDITIONS

- A. Environmental Limitations: Do not deliver or install UTP and optical fiber cables and connecting materials until wet work in spaces is complete and dry, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 PATHWAYS

Retain first paragraph below if the use of open cabling is permitted.

- A. Support of Open Cabling: NRTL labeled for support of **[Category 5e] [Category 6]** <Insert other cabling types> cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.
 1. Support brackets with cable tie slots for fastening cable ties to brackets.
 2. Lacing bars, spools, J-hooks, and D-rings.
 3. Straps and other devices.
- B. Cable Trays:

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first

subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cable Management Solutions, Inc.
 - b. Cablofil Inc.
 - c. Cooper B-Line, Inc.
 - d. Cope - Tyco/Allied Tube & Conduit.
 - e. GS Metals Corp.
 - f. <Insert manufacturer>
 - g. or approved equal.

Besides both corrosion-protection options in subparagraph below, alternative methods include trays fabricated from Types 304 and 316 stainless steel, steel with electrogalvanized zinc plating then coated with yellow dichromate, steel coated with PVC, and steel with powder coating,

2. Cable Tray Materials: Metal, suitable for indoors and protected against corrosion by [electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inch (0.012 mm) thick] [hot-dip galvanizing, complying with ASTM A 123/A 123M, Grade 0.55, not less than 0.002165 inch (0.055 mm) thick].

Retain one or more of five subparagraphs below. If multiple types or various dimensions of cable trays are required, delete subparagraphs and indicate location and dimensions on Drawings. Trays in first subparagraph are generally available in widths of between 2 and 24 inches (50 and 600 mm) and in depths of between 1 and 4 inches (25 and 100 mm).

- a. Basket Cable Trays: [6 inches (150 mm) wide and 2 inches (50 mm) deep] <Insert dimensions>. Wire mesh spacing shall not exceed 2 by 4 inches (50 by 100 mm).

Trays in first subparagraph below are generally available in widths of between 6 and 36 inches (150 and 915 mm).

- b. Trough or Ventilated Cable Trays: [Nominally 6 inches (150 mm)] <Insert dimension> wide.

Trays in first subparagraph below are generally available in widths of between 6 and 36 inches (150 and 915 mm) and in rung spacings of between 6 and 18 inches (150 and 455 mm).

- c. Ladder Cable Trays: [Nominally 18 inches (455 mm)] <Insert dimension> wide, and a rung spacing of [12 inches (305 mm)] <Insert dimension>.

Trays in first subparagraph below are generally available in widths of 3, 4, and 6 inches (75, 100, and 150 mm).

- d. Channel Cable Trays: One-piece construction, [nominally 4 inches (100 mm)] <Insert dimension> wide. Slot spacing shall not exceed 4-1/2 inches (115 mm) o.c.

Trays in subparagraph below are generally available in widths of between 6 and 36 inches (150 and 915 mm).

- e. Solid-Bottom or Nonventilated Cable Trays: One-piece construction, [nominally 12 inches (305 mm)] <Insert dimension> wide. Provide [with]

[**without**] solid covers.

- C. Conduit and Boxes: Comply with requirements in Division 26 Section "Raceway and Boxes for Electrical Systems." [**Flexible metal conduit shall not be used.**]

1. Outlet boxes shall be no smaller than **2 inches** (50 mm) wide, **3 inches** (75 mm) high, and **2-1/2 inches** (64 mm) deep.

2.2 BACKBOARDS

- A. Description: Plywood, [**fire-retardant treated,**] **3/4 by 48 by 96 inches** (19 by 1220 by 2440 mm). Comply with requirements for plywood backing panels in Division 06 Section "Rough Carpentry."

2.3 UTP CABLE

Copy this article and re-edit for each product if cable products with multiple four-pair binder groups are specified.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Belden CDT Inc.; Electronics Division.
2. Berk-Tek; a Nexans company.
3. CommScope, Inc.
4. Draka USA.
5. Genesis Cable Products; Honeywell International, Inc.
6. KRONE Incorporated.
7. Mohawk; a division of Belden CDT.
8. Nordex/CDT; a subsidiary of Cable Design Technologies.
9. Superior Essex Inc.
10. SYSTIMAX Solutions; a CommScope, Inc. brand.
11. 3M.
12. Tyco Electronics/AMP Netconnect; Tyco International Ltd.
13. **<Insert manufacturer>**
14. or approved equal.

Revise option in paragraph below to specify cables of other than 25-pair binder groups.

- B. Description: 100-ohm, four-pair UTP[, **formed into 25-pair binder groups covered with a blue thermoplastic jacket**].

1. Comply with ICEA S-90-661 for mechanical properties.
2. Comply with TIA/EIA-568-B.1 for performance specifications.
3. Comply with TIA/EIA-568-B.2, [**Category 5e**] [**Category 6**].
4. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as

complying with UL 444 and NFPA 70 for the following types:

Type requirements in subparagraphs below are minimum requirements and may be revised to suit Project. Retain options if "permitted substitutions," as defined in NFPA 70, are appropriate for this Project.

- a. Communications, General Purpose: Type CM or Type CMG[; or Type **MPP, Type CMP, Type MPR, Type CMR, Type MP, or Type MPG**].
- b. Communications, Plenum Rated: Type CMP[or Type **MPP**], complying with NFPA 262.
- c. Communications, Riser Rated: Type CMR[; or Type **MPP, Type CMP, or Type MPR**]; complying with UL 1666.
- d. Communications, Limited Purpose: Type CMX[; or Type **MPP, Type CMP, Type MPR, Type CMR, Type MP, Type MPG, Type CM, or Type CMG**].
- e. Multipurpose: Type MP or Type MPG[; or Type **MPP or Type MPR**].
- f. Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
- g. Multipurpose, Riser Rated: Type MPR[or Type **MPP**], complying with UL 1666.

2.4 UTP CABLE HARDWARE

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. American Technology Systems Industries, Inc.
 2. Dynacom Corporation.
 3. Hubbell Premise Wiring.
 4. KRONE Incorporated.
 5. Leviton Voice & Data Division.
 6. Molex Premise Networks; a division of Molex, Inc.
 7. Nordex/CDT; a subsidiary of Cable Design Technologies.
 8. Panduit Corp.
 9. Siemon Co. (The).
 10. Tyco Electronics/AMP Netconnect; Tyco International Ltd.
 11. <Insert manufacturer>
 12. or approved equal.

Type of connecting hardware depends on the equipment to which cable is connected. Retain first paragraph below if UTP cable terminations are not specified with connected equipment. Specifying connecting hardware permits testing of cables before they are connected to the equipment.

- B. UTP Cable Connecting Hardware: IDC type, using modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of the same category or higher.

Revise paragraph below to match equipment requirements; delete if connecting blocks are specified with the equipment.

- C. Connecting Blocks: 110 style for Category 5e 110 style for Category 6 66 style for Category 5e. Provide blocks for the number of cables terminated on the block, plus percent spare; integral with connector bodies, including plugs and jacks where indicated.

2.5 OPTICAL FIBER CABLE

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Berk-Tek; a Nexans company.
 2. CommScope, Inc.
 3. Corning Cable Systems.
 4. General Cable Technologies Corporation.
 5. Mohawk; a division of Belden CDT.
 6. Nordex/CDT; a subsidiary of Cable Design Technologies.
 7. Optical Connectivity Solutions Division; Emerson Network Power.
 8. Superior Essex Inc.
 9. SYSTIMAX Solutions; a CommScope, Inc. brand.
 10. 3M.
 11. Tyco Electronics/AMP Netconnect; Tyco International Ltd.
 12. <Insert manufacturer>
 13. or approved equal.
- B. Description: Multimode, 50/125 62.5/125-micrometer, -fiber, tight buffer, optical fiber cable.
1. Comply with ICEA S-83-596 for mechanical properties.
 2. Comply with TIA/EIA-568-B.3 for performance specifications.

Retain first option in first subparagraph below for 50/125-micrometer cable; retain second option for 62.5/125-micrometer cable.

3. Comply with [TIA/EIA-492AAAA-B] [TIA/EIA-492AAAA-A] for detailed specifications.
4. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:

Type requirements in first six subparagraphs below are minimum requirements and may need to be revised to suit Project. Types OFC, OFCR, OFCG, and OFCP are conductive optical fiber cables that might have application in industrial settings. Retain options if "permitted substitutions," as defined in NFPA 70, are appropriate for this Project.

- a. General Purpose, Nonconductive: Type OFN or OFNG[, or Type OFNR or Type OFNP].
- b. Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
- c. Riser Rated, Nonconductive: Type OFNR[or Type OFNP], complying with UL 1666.

- d. General Purpose, Conductive: Type OFC or Type OFCG[; **or Type OFNG, Type OFN, Type OFCR, Type OFNR, Type OFCP, or Type OFNP**].
- e. Plenum Rated, Conductive: Type OFCP[**or Type OFNP**], complying with NFPA 262.
- f. Riser Rated, Conductive: Type OFCR[; **or Type OFNR, Type OFCP, or Type OFNP**]; complying with UL 1666.

Retain first subparagraph below even if nonconductive cable is specified in subparagraphs above. If both conductive and nonconductive cables are specified, indicate locations of each on Drawings.

5. Conductive cable shall be [**steel**] [**aluminum**]-armored type.
6. Maximum Attenuation: [**3.5**] **<Insert number>** dB/km at 850 nm; [**1.5**] **<Insert number>** dB/km at 1300 nm.
7. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.

C. Jacket:

1. Jacket Color: [**Aqua for 50/125**] [**Orange for 62.5/125**]-micrometer cable.
2. Cable cordage jacket, fiber, unit, and group color shall be according to TIA/EIA-598-B.
3. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed **40 inches** (1000 mm).

2.6 OPTICAL FIBER CABLE HARDWARE

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. ADC.
 2. American Technology Systems Industries, Inc.
 3. Berk-Tek; a Nexans company.
 4. Corning Cable Systems.
 5. Dynacom Corporation.
 6. Hubbell Premise Wiring.
 7. Molex Premise Networks; a division of Molex, Inc.
 8. Nordex/CDT; a subsidiary of Cable Design Technologies.
 9. Optical Connectivity Solutions Division; Emerson Network Power.
 10. Siemon Co. (The).
 11. **<Insert manufacturer>**
 12. or approved equal.

Type of connecting hardware depends on the equipment to which cable is connected. Retain paragraph below if optical fiber cable terminations are not specified with connected equipment. Specifying connecting hardware permits testing of cables before they are connected to the equipment.

- B. Cable Connecting Hardware: Comply with the Fiber Optic Connector Intermateability Standards (FOCIS) specifications of TIA/EIA-604-2, TIA/EIA-604-3-A, and

TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.

Type SC is a subscriber connector; Type ST is a straight-tip, single-fiber connector; both are commonly used. Recently developed connectors are Type LC, which is an upgraded version of either Type SC or ST connector with a lower insertion loss, and Type MT-RJ, which is a no-epoxy, no-polish connector.

1. Quick-connect, simplex and duplex, [**Type SC**] [**Type ST**] [**Type LC**] [**Type MT-RJ**] connectors. Insertion loss not more than 0.75 dB.
2. Type SFF connectors may be used in termination racks, panels, and equipment packages.

2.7 RS-232 CABLE

RS-232 communications require three conductors with an overall shield. Circuit is limited to a distance of not more than 50 feet (15 m).

A. Standard Cable: NFPA 70, Type CM.

1. Paired, two pairs, No. 22 AWG, stranded (7x30) tinned-copper conductors.
2. Polypropylene insulation.
3. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
4. PVC jacket.
5. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned-copper drain wire.
6. Flame Resistance: Comply with UL 1581.

B. Plenum-Rated Cable: NFPA 70, Type CMP.

1. Paired, two pairs, No. 22 AWG, stranded (7x30) tinned-copper conductors.
2. Plastic insulation.
3. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
4. Plastic jacket.
5. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned-copper drain wire.
6. Flame Resistance: Comply with NFPA 262.

2.8 RS-485 CABLE

RS-485 communications require two twisted pairs. Circuit is limited to a distance of not more than 4000 feet (1220 m).

A. Standard Cable: NFPA 70, Type CM[**or Type CMG**].

1. Paired, two pairs, twisted, No. 22 AWG, stranded (7x30) tinned-copper conductors.
2. PVC insulation.
3. Unshielded.

4. PVC jacket.
5. Flame Resistance: Comply with UL 1581.

B. Plenum-Rated Cable: NFPA 70, Type CMP.

1. Paired, two pairs, No. 22 AWG, stranded (7x30) tinned-copper conductors.
2. Fluorinated ethylene propylene insulation.
3. Unshielded.
4. Fluorinated ethylene propylene jacket.
5. Flame Resistance: NFPA 262, Flame Test.

2.9 LOW-VOLTAGE CONTROL CABLE

Retain one or more of four paragraphs below; difference in paragraphs is the conductor size and insulation type. Other conductor sizes and insulation types are available.

A. Paired Cable: NFPA 70, Type CMG.

1. One pair, twisted, No. 16 AWG, stranded (19x29) tinned-copper conductors.
2. PVC insulation.
3. Unshielded.
4. PVC jacket.
5. Flame Resistance: Comply with UL 1581.

B. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.

1. One pair, twisted, No. 16 AWG, stranded (19x29) tinned-copper conductors.
2. PVC insulation.
3. Unshielded.
4. PVC jacket.
5. Flame Resistance: Comply with NFPA 262.

C. Paired Cable: NFPA 70, Type CMG.

1. One pair, twisted, No. 18 AWG, stranded (19x30) tinned-copper conductors.
2. PVC insulation.
3. Unshielded.
4. PVC jacket.
5. Flame Resistance: Comply with UL 1581.

D. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.

1. One pair, twisted, No. 18 AWG, stranded (19x30) tinned-copper conductors.
2. Fluorinated ethylene propylene insulation.
3. Unshielded.
4. Plastic jacket.
5. Flame Resistance: NFPA 262, Flame Test.

2.10 CONTROL-CIRCUIT CONDUCTORS

Retain option for UL 44 in first two paragraphs below if retaining option for Type XHHN.

- A. Class 1 Control Circuits: Stranded copper, [Type THHN-THWN] [Type XHHN], in raceway, complying with [UL 83] [UL 44].
- B. Class 2 Control Circuits: Stranded copper, [Type THHN-THWN, in raceway] [Type XHHN, in raceway] [power-limited cable, concealed in building finishes] [power-limited tray cable, in cable tray], complying with [UL 83] [UL 44].
- C. Class 3 Remote-Control and Signal Circuits: Stranded copper, Type TW or Type TF, complying with UL 83.

2.11 IDENTIFICATION PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Brady Corporation.
 - 2. HellermannTyton.
 - 3. Kroy LLC.
 - 4. Panduit Corp.
 - 5. <Insert manufacturer>
 - 6. or approved equal.
- B. Comply with UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.
- C. Comply with requirements in Section 260553 "Identification for Electrical Systems."

2.12 SOURCE QUALITY CONTROL

Retain first paragraph below if required. Independent certification may be acceptable to authorities having jurisdiction without further monitoring of plant's quality-control and testing program by Owner.

- A. Testing Agency: Engage a qualified testing agency to evaluate cables.
- B. Factory test UTP and optical fiber cables on reels according to TIA/EIA-568-B.1.
- C. Factory test UTP cables according to TIA/EIA-568-B.2.
- D. Factory test multimode optical fiber cables according to TIA/EIA-526-14-A and TIA/EIA-568-B.3.

See Division 01 Section "Quality Requirements" for retesting and reinspecting requirements and Division

01 Section "Execution" for requirements for correcting the Work.

- E. Cable will be considered defective if it does not pass tests and inspections.
- F. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 INSTALLATION OF PATHWAYS

- A. Cable Trays: Comply with NEMA VE 2 and TIA/EIA-569-A-7.
- B. Comply with TIA/EIA-569-A for pull-box sizing and length of conduit and number of bends between pull points.
- C. Comply with requirements in Division 26 Section "Raceway and Boxes for Electrical Systems" for installation of conduits and wireways.
- D. Install manufactured conduit sweeps and long-radius elbows if possible.
- E. Pathway Installation in Equipment Rooms:
 - 1. Position conduit ends adjacent to a corner on backboard if a single piece of plywood is installed or in the corner of room if multiple sheets of plywood are installed around perimeter walls of room.
 - 2. Install cable trays to route cables if conduits cannot be located in these positions.
 - 3. Secure conduits to backboard if entering room from overhead.
 - 4. Extend conduits [3 inches (75 mm)] <Insert dimension> above finished floor.
 - 5. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.
- F. Backboards: Install backboards with 96-inch (2440-mm) dimension vertical. Butt adjacent sheets tightly and form smooth gap-free corners and joints.

3.2 INSTALLATION OF CONDUCTORS AND CABLES

- A. Comply with NECA 1.
- B. General Requirements for Cabling:

Retain one of first two subparagraphs below for UTP and optical fiber cabling.

- 1. Comply with TIA/EIA-568-B.1.
- 2. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."
- 3. Terminate all conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, and cross-connect and patch panels.
- 4. Cables may not be spliced. Secure and support cables at intervals not exceeding

- 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
5. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
 6. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
 7. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
 8. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.
- C. UTP Cable Installation:
1. Comply with TIA/EIA-568-B.2.
 2. Install 110-style IDC termination hardware unless otherwise indicated.
 3. Do not untwist UTP cables more than 1/2 inch (12 mm) from the point of termination to maintain cable geometry.
- D. Installation of Control-Circuit Conductors:
1. Install wiring in raceways. Comply with requirements specified in Section 260553 "Raceway and Boxes for Electrical Systems."
- E. Optical Fiber Cable Installation:
1. Comply with TIA/EIA-568-B.3.
 2. Cable shall be terminated on connecting hardware that is rack or cabinet mounted.
- F. Open-Cable Installation:
1. Open-Cable installation is prohibited. All cables shall be installed in an approved raceway.
- G. Installation of Cable Routed Exposed under Raised Floors:
1. Install plenum-rated cable only.
 2. Install cabling after the flooring system has been installed in raised floor areas.
 3. Coil cable [72 inches (1830 mm)] <Insert size> long shall be neatly coiled not less than [12 inches (305 mm)] <Insert size> in diameter below each feed point.
- See Editing Instruction No. 3 in the Evaluations for discussion of EMI.
- H. Separation from EMI Sources:
1. Comply with BICSI TDMM and TIA/EIA-569-A recommendations for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.

2. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: A minimum of **5 inches** (127 mm).
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **12 inches** (305 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **24 inches** (600 mm).
3. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: A minimum of **2-1/2 inches** (64 mm).
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **6 inches** (150 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **12 inches** (305 mm).
4. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: No requirement.
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **3 inches** (75 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **6 inches** (150 mm).
5. Separation between Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of **48 inches** (1200 mm).
6. Separation between Cables and Fluorescent Fixtures: A minimum of **5 inches** (127 mm).

3.3 REMOVAL OF CONDUCTORS AND CABLES

- A. Remove all abandoned conductors and cables.

3.4 CONTROL-CIRCUIT CONDUCTORS

- A. Minimum Conductor Sizes:
 1. Class 1 remote-control and signal circuits, **[No 14]** <Insert wire size> AWG.
 2. Class 2 low-energy, remote-control, and signal circuits, **[No. 16]** <Insert wire size> AWG.
 3. Class 3 low-energy, remote-control, alarm, and signal circuits, **[No 12]** <Insert

wire size> AWG.

3.5 FIRESTOPPING

- A. Comply with requirements in Section 078413 "Penetration Firestopping."
- B. Comply with TIA/EIA-569-A, Annex A, "Firestopping."
- C. Comply with BICSI TDMM, "Firestopping Systems" Article.

3.6 GROUNDING

Retain one or both paragraphs below.

- A. For data communication wiring, comply with ANSI-J-STD-607-A and with BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
- B. For low-voltage wiring and cabling, comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

- A. Identify system components, wiring, and cabling according to TIA/EIA-606-A. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.8 FIELD QUALITY CONTROL

Retain first paragraph below to require Contractor to perform tests and inspections.

- A. Perform tests and inspections.

Retain first paragraph below to describe tests and inspections to be performed.

Coordinate inspection and testing requirements with DEN Project Manager.

- B. Tests and Inspections:
 - 1. Visually inspect UTP and optical fiber cable jacket materials for UL or third-party certification markings. Inspect cabling terminations to confirm color-coding for pin assignments, and inspect cabling connections to confirm compliance with TIA/EIA-568-B.1.
 - 2. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.

Retain first subparagraph below if verification of quality is to be performed before completion of the cabling. Delete if not retaining cable connecting hardware in "UTP Cable Hardware" Article.

- 3. Test UTP cabling for DC loop resistance, shorts, opens, intermittent faults, and

polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not after cross connection.

- a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.

Retain subparagraph below if verification of quality is to be performed before completion of the cabling. Delete if not retaining cable connecting hardware in "Optical Fiber Cable Hardware" Article.

4. Optical Fiber Cable Tests:

- a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
- b. Link End-to-End Attenuation Tests:
 - 1) Multimode Link Measurements: Test at 850 or 1300 nm in one direction according to TIA/EIA-526-14-A, Method B, One Reference Jumper.
 - 2) Attenuation test results for links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.

- C. Document data for each measurement. Print data for submittals in a summary report that is formatted using Table 10.1 in BICSI TDMM as a guide, or transfer the data from the instrument to the computer, save as text files, print, and submit.

See Division 01 Section "Quality Requirements" for retesting and reinspecting requirements and Division 01 Section "Execution" for requirements for correcting the Work.

- D. End-to-end cabling will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260523

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SECTION 260526 - GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

NFPA 70 and IEEE C2 include basic grounding requirements for electrical safety. This Section supplements those requirements with additional grounding requirements and with optional grounding methods and materials for both power and electronic systems that go beyond basic minimum safety requirements.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Retain one of two paragraphs below.

- A. Section Includes: Grounding systems and equipment.
- B. Section includes grounding systems and equipment, plus the following special applications:

Retain one or more subparagraphs below for special grounding applications.

- 1. Overhead-line grounding.
- 2. Underground distribution grounding.
- 3. Ground bonding common with lightning protection system.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 SYSTEM DESCRIPTION

- A. Ground the electrical service system neutral at service entrance equipment to the metallic water pipe service on building side only and to supplementary grounding electrodes, as required by the contract documents and as required by the NEC.
- B. External (underground) metal pipes, water, gas, fuel, drain/sewer etc., are not available for electrical grounding. This is due to extensive cathodic protection and isolation joints of all underground metal pipes at DEN. These systems shall be bonded to the grounding system on the building side only.
- C. Ground each separately derived system neutral to nearest building steel or referenced ground plate in the electrical room.
- D. Provide a 2/0 minimum building perimeter-grounding conductor buried thirty inches (30") below finished grade thirty-six inches (36") from foundation.
- E. Provide a minimum of three inch by twelve inch by one-quarter inch (3" x 12" x ¼") copper ground bar in the electrical room for connecting the grounding systems.
- F. An insulated equipment ground conductor shall be installed continuous from the main switchgear or service entrance to all branch panelboards, motor control centers, transformers and all motors. This conductor shall be bonded to the conduit and metal enclosures that it passes through utilizing bonding bushings and terminal devices.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN ELECTRICAL ENGINEER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
- C. Submit shop drawings, coordination drawings and product data in accordance with provisions of Division 1. Submit all required information under a given specification section together. Do not split out submittals under the same specification section.
 - 1. Clearly mark each shop drawing as follows for purposes of identification:
 - a. Shop Drawing
 - b. Equipment Identification Used on Contract Drawings

- c. Date
 - d. Name of Project
 - e. Branch of Work
 - f. Project Manager's Name
 - g. Contractor's Name
2. Indicate layout of ground ring, location of system grounding electrode connections, and routing of grounding electrode conductors.
- D. Prior to submission, shop drawings, material lists and catalog cut sheets or manufacturer's printed data shall be thoroughly checked for compliance with contract requirements, compatibility with equipment being furnished by the Contractor or Owner, accuracy of dimensions, coordination with work of other trades, and conformance with sound and safe practice as to erection of installation. Each submittal shall bear Contractor's signed statement evidencing such checking.
- E. Clearly mark printed material, catalog cut sheets, pamphlets or specification sheets, and shop drawings with the same designation shown on the Contract Document schedules.

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph below to require Contractor to provide Drawings that locate significant grounding features. Division 01 Sections "Project Record Documents" and "Operation and Maintenance Data" require submittals to be included in those documents for use by maintenance forces throughout the life of the Project.

- A. Informational Submittals: Plans showing dimensioned as-built locations of grounding features specified in "Field Quality Control" Article, including the following:
1. Test wells.
 2. Ground rods.
 3. Ground rings.
 4. Grounding arrangements and connections for separately derived systems.
 5. Grounding for sensitive electronic equipment.
 6. **<Insert items>**.

Coordinate first paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For qualified testing agency and testing agency's field supervisor.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

Retain paragraph below if specifying test wells, separately derived systems, or ground ring or other

grounding for sensitive electronic equipment.

- A. Operation and Maintenance Data: For grounding to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

Retain subparagraph below for projects requiring a high reliability for electrical systems. NETA MTS provides more easily interpreted recommendations for frequency of tests and inspections than NFPA 70B.

1. Instructions for periodic testing and inspection of grounding features at [**test wells**] [**ground rings**] [**grounding connections for separately derived systems**] <Insert locations> based on [**NETA MTS**] [**NFPA 70B**] <Insert reference>.
2. Tests shall determine if ground-resistance or impedance values remain within specified maximums, and instructions shall recommend corrective action if values do not.
3. Include recommended testing intervals.

B. Record Documents

1. Maintain a contract set of electrical drawings and specifications at the site. Neatly mark all changes, discoveries and deviations from the original drawings. Use a reproducible color that contrasts with the prints. This shall be a separate set of drawings, not used for construction purposes, and shall be updated daily as the job progresses and shall be made available for inspection by the DEN Project Manager at all times. Upon completion of the contract, this set of record drawings shall be delivered to the DEN Project Manager. Follow DEN CADD standards, to be furnished to the successful bidder. Record documents to be provided by the Contractor shall clearly and accurately show the following:
 - a. Provide horizontal and vertical dimensions for all raceway systems, size and location, for both exterior and interior; locations of control devices; distribution and branch electrical circuitry; and fuse and circuit breaker size and arrangements.
 - b. Equipment locations (exposed and concealed), dimensioned from prominent building lines.
 - c. Approved substitutions, Contract Modifications, and actual equipment and materials installed.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Comply with UL 467 for grounding and bonding materials and equipment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CONDUCTORS

Retain first paragraph below to require one of the two preferred conductor materials permitted by NFPA 70; delete to allow Contractor to retain any material that complies with Code. See "Grounding Products" Article in the Evaluations for discussion on alternative materials.

- A. Insulated Conductors: Copper or tinned-copper wire or cable insulated for 600 V unless otherwise required by applicable Codes.
- B. All ground wires shall be copper, sized according to the NEC or as shown on the drawings which ever is larger.
- C. Bare Copper Conductors:
1. Solid Conductors: ASTM B 3.
 2. Stranded Conductors: ASTM B 8.
 3. Tinned Conductors: ASTM B 33.

Sizes and types of conductors in four subparagraphs below are typical examples. 28-kcmil bonding cable in first subparagraph is slightly larger than No. 6 AWG.

4. Bonding Cable: 28 kcmil, 14 strands of No. 17 AWG conductor, 1/4 inch (6 mm) in diameter.
5. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
6. Bonding Jumper: Copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches (41 mm) wide and 1/16 inch (1.6 mm) thick.
7. Tinned Bonding Jumper: Tinned-copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches (41 mm) wide and 1/16 inch (1.6 mm) thick.

Retain first paragraph below if Project includes overhead-line work.

- D. Bare Grounding Conductor and Conductor Protector for Wood Poles:
1. No. 4 AWG minimum, soft-drawn copper.
 2. Conductor Protector: Half-round PVC or wood molding; if wood, use pressure-treated fir, cypress, or cedar.

Retain paragraph below if size of grounding bus and mounting details are not indicated on Drawings. The default dimension is recommended by BICSI for telecommunications bus bar.

- E. Grounding Bus: Predrilled rectangular bars of annealed copper, [1/4 by 4 inches (6.3 by 100 mm)] <Insert dimensions> in cross section, with 9/32-inch (7.14-mm) holes spaced

1-1/8 inches (28 mm) apart. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600 V. Lexan or PVC, impulse tested at 5000 V.

2.2 CONNECTORS

- A. Listed and labeled by an NRTL acceptable to authorities having jurisdiction for applications in which used and for specific types, sizes, and combinations of conductors and other items connected.
- B. Bolted Connectors for Conductors and Pipes: Copper or copper alloy, pressure type with at least two bolts.
 - 1. Pipe Connectors: Clamp type, sized for pipe.
- C. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions. Exothermic welded connections are required where grounding conductors connect to underground grounding conductors and to underground grounding electrodes, and for bonding to steel. All underground connections shall be exothermic welded.
- D. Bus-bar Connectors: Mechanical type, cast silicon bronze, solderless compression exothermic-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.
- E. Grounding Connection Accessories:
 - 1. Electrical insulating tape, heat-shrinkable insulating tubing, welding materials, bonding straps, as recommended by accessories manufacturers for type of service required.

2.3 GROUNDING ELECTRODES

NFPA 70 allows alternative types of grounding electrodes including ground rods, ground rings, metal underground water pipes, metal building frames, Ufer grounds, and pipe and plate electrodes. Retain "Applications" and "Installation" articles to specify where these items are required; coordinate with Drawings.

Copper-clad steel ground rods are the most common grounding electrode. See Evaluations for discussion on alternative materials. Sectional rods are used when electrodes longer than 10 feet (3 m) are required.

- A. Ground Rods: [**Copper-clad**] [**Zinc-coated**] [**Stainless steel**]; [**sectional type**]; 3/4 inch by 10 feet (19 mm by 3 m) in diameter.
- B. Ground Rods in manholes ground rods shall be stainless steel 3/4-inch diameter and a minimum length of 10 feet.

Retain paragraph below if allowed by authorities having jurisdiction to enhance grounding performance. See Evaluations.

- C. Chemical-Enhanced Grounding Electrodes: Copper tube, straight or L-shaped,

charged with [nonhazardous electrolytic chemical salts] <Insert enhancement material>.

1. Termination: Factory-attached No. 4/0 AWG bare conductor at least 48 inches (1200 mm) long.
2. Backfill Material: Electrode manufacturer's recommended material.

PART 3 - EXECUTION

3.1 APPLICATIONS

- A. Conductors: Install solid conductor for No. [12] <Insert size> AWG and smaller, and stranded conductors for No. [10] <Insert size> AWG and larger unless otherwise indicated.

Coordinate first paragraph below with Drawings and with Division 26 Section "Underground Ducts and Raceways for Electrical Systems."

- B. Underground Grounding Conductors: Install bare [tinned-]copper conductor, No. [2/0] <Insert size> AWG minimum.

1. Bury at least 30 inches (750 mm) below grade.

Retain subparagraph below to require duct-bank grounding conductor to be installed with, but external to, duct bank.

2. Duct-Bank Grounding Conductor: Bury 12 inches (300 mm) above duct bank when indicated as part of duct-bank installation.

- C. Isolated Grounding Conductors: Green-colored insulation with continuous yellow stripe. On feeders with isolated ground, identify grounding conductor where visible to normal inspection, with alternating bands of green and yellow tape, with at least three bands of green and two bands of yellow.

Retain first paragraph below if grounding bus is required. Coordinate with Drawings.

- D. Grounding Bus: Install in electrical and telephone equipment rooms, in rooms housing service equipment, and elsewhere as indicated.

1. Install bus on insulated spacers 2 inches (50 mm) minimum from wall, 6 inches (150 mm) above finished floor unless otherwise indicated.
2. Where indicated on both sides of doorways, route bus up to top of door frame, across top of doorway, and down to specified height above floor; connect to horizontal bus.

- E. Conductor Terminations and Connections:

1. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors.
2. Underground Connections: Welded connectors except at test wells and as otherwise indicated.

3. Connections to Ground Rods at Test Wells: Bolted connectors.
4. Connections to Structural Steel: Welded connectors.

3.2 GROUNDING OVERHEAD LINES

- A. Comply with IEEE C2 grounding requirements.

Grounding practices of the local utility company may differ from requirements in six paragraphs below. Although overhead-line grounding specified in this article is not for the utility company's use and does not have to comply with its standards, it is possible the utility company may be requested to repair or maintain the line in the future. For this reason, it may be desirable to design some grounding features according to the utility company's standards. Utility companies, for economic reasons, often design to a standard lower than what is appropriate for Project requirements. Alternatively, because of their experience with wind, ice, and lightning conditions in their service area, utility companies may design to a higher standard than is required by Code. In addition to Project requirements, evaluate the local utility company's practice and revise paragraphs accordingly. This evaluation is particularly important if Project's overhead lines connect with utility lines. Coordinate with Drawings and with Division 33 Section "Overhead Medium-Voltage Wiring."

- B. Install [**two (2)**] <Insert number> parallel ground rods if resistance to ground by a single, ground-rod electrode exceeds 25 ohms.
- C. Drive ground rods until tops are 12 inches (300 mm) below finished grade in undisturbed earth.
- D. Ground-Rod Connections: Install bolted connectors for underground connections and connections to rods.
- E. Lightning Arrester Grounding Conductors: Separate from other grounding conductors.
- F. Secondary Neutral and Transformer Enclosure: Interconnect and connect to grounding conductor.
- G. Protect grounding conductors running on surface of wood poles with molding extended from grade level up to and through communication service and transformer spaces.

3.3 GROUNDING UNDERGROUND DISTRIBUTION SYSTEM COMPONENTS

- A. Comply with IEEE C2 grounding requirements.

Grounding practices of the local utility company may differ from requirements in three paragraphs below. Although grounding specified in this article is not for the utility company's use and does not have to comply with its standards, it is possible the utility company may be requested to repair or maintain the line in the future. For this reason, it may be desirable to design some grounding features according to the utility company's standards. Utility companies, for economic reasons, often design to a standard lower than what is appropriate for Project requirements. Alternatively, because of their experience with conditions in their service area, utility companies may design to a higher standard than is required by Code. In addition to Project requirements, evaluate the local utility company's practices and revise paragraphs accordingly. This evaluation is particularly important if Project's underground lines connect with utility lines. Coordinate with Drawings and with Division 26 Section "Underground Ducts and Raceways for Electrical Systems."

- B. Grounding Manholes and Handholes: Install a driven ground rod through manhole or handhole floor, close to wall, and set rod depth so 4 inches (100 mm) will extend above finished floor. If necessary, install ground rod before manhole is placed and provide No. 1/0 AWG bare, tinned-copper conductor from ground rod into manhole through a waterproof sleeve in manhole wall. Protect ground rods passing through concrete floor with a double wrapping of pressure-sensitive insulating tape or heat-shrunk insulating sleeve from 2 inches (50 mm) above to 6 inches (150 mm) below concrete. Seal floor opening with waterproof, nonshrink grout.
- C. Grounding Connections to Manhole Components: Bond exposed-metal parts such as inserts, cable racks, pulling irons, ladders, and cable shields within each manhole or handhole, to ground rod or grounding conductor. Make connections with No. 4 AWG minimum, stranded, hard-drawn copper bonding conductor. Train conductors level or plumb around corners and fasten to manhole walls. Connect to cable armor and cable shields according to written instructions by manufacturer of splicing and termination kits.

Retain and revise paragraph below to exceed NFPA 70 requirements. If concrete pad is for equipment to be supplied by utility company, revise paragraph to comply with utility company's grounding standards or delete and detail on Drawings.

- D. Pad-Mounted Transformers and Switches: Install two ground rods and ground ring around the pad. Ground pad-mounted equipment and noncurrent-carrying metal items associated with substations by connecting them to underground cable and grounding electrodes. Install tinned-copper conductor not less than No. 2 AWG for ground ring and for taps to equipment grounding terminals. Bury ground ring not less than 6 inches (150 mm) from the foundation.

3.4 EQUIPMENT GROUNDING

NFPA 70 permits two types of equipment grounding conductors: metallic raceway or cable sheath that encloses supply conductors, and a separate grounding conductor of insulated wire or cable installed with supply conductors. Installation of a separate insulated equipment grounding conductor provides an additional degree of safe operation when compared to relying on raceway or cable sheath for ground continuity. NFPA 70 requires separate insulated equipment grounding conductors in some situations and not in others. Retain and revise one of first two paragraphs below to require insulated equipment grounding conductors that exceed NFPA 70 requirements. Coordinate with Drawings.

- A. Install insulated equipment grounding conductors with all feeders and branch circuits.
- B. Install insulated equipment grounding conductors with the following items, in addition to those required by NFPA 70:

Retain applicable subparagraphs below.

1. Feeders and branch circuits.
2. Lighting circuits.
3. Receptacle circuits.
4. Single-phase motor and appliance branch circuits.
5. Three-phase motor and appliance branch circuits.

6. Flexible raceway runs.
 7. Armored and metal-clad cable runs.
 8. Busway Supply Circuits: Install insulated equipment grounding conductor from grounding bus in the switchgear, switchboard, or distribution panel to equipment grounding bar terminal on busway.
 9. Computer and Rack-Mounted Electronic Equipment Circuits: Install insulated equipment grounding conductor in branch-circuit runs from equipment-area power panels and power-distribution units.
 10. X-Ray Equipment Circuits: Install insulated equipment grounding conductor in circuits supplying x-ray equipment.
- C. Air-Duct Equipment Circuits: Install insulated equipment grounding conductor to duct-mounted electrical devices operating at 120 V and more, including air cleaners, heaters, dampers, humidifiers, and other duct electrical equipment.
- D. Water Heater, Heat-Tracing, and Antifrost Heating Cables: Install a separate insulated equipment grounding conductor to each electric water heater and heat-tracing cable. Bond conductor to heater units, piping, connected equipment, and components.
- E. Isolated Grounding Receptacle Circuits: Install an insulated equipment grounding conductor connected to the receptacle grounding terminal. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service unless otherwise indicated.
- F. Isolated Equipment Enclosure Circuits: For designated equipment supplied by a branch circuit or feeder, isolate equipment enclosure from supply circuit raceway with a nonmetallic raceway fitting listed for the purpose. Install fitting where raceway enters enclosure, and install a separate insulated equipment grounding conductor. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service unless otherwise indicated.

Coordinate first paragraph below with Drawings and with Sections for signal and communication equipment. Revise to suit Project.

- G. Signal and Communication Equipment: In addition to grounding and bonding required by NFPA 70, provide a separate grounding system complying with requirements in TIA/ATIS J-STD-607-A.
1. For telephone, alarm, voice and data, and other communication equipment, provide No. 4 AWG minimum insulated grounding conductor in raceway from grounding electrode system to each service location, terminal cabinet, wiring closet, and central equipment location.
 2. Service and Central Equipment Locations and Wiring Closets: Terminate grounding conductor on a 1/4-by-4-by-12-inch (6.3-by-100-by-300-mm) grounding bus.
 3. Terminal Cabinets: Terminate grounding conductor on cabinet grounding terminal.

Paragraph below may supplement equipment grounding conductor and may be in excess of NFPA 70

requirements. Retain if necessary and coordinate with Drawings.

- H. Metal and Wood Poles Supporting Outdoor Lighting Fixtures: Install grounding electrode and a separate insulated equipment grounding conductor in addition to grounding conductor installed with branch-circuit conductors.

3.5 INSTALLATION

- A. Grounding Conductors: Route along shortest and straightest paths possible unless otherwise indicated or required by Code. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.
- B. Ground Bonding Common with Lightning Protection System: Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system. Bond electrical power system ground directly to lightning protection system grounding conductor at closest point to electrical service grounding electrode. Use bonding conductor sized same as system grounding electrode conductor, and install in conduit.
- C. Ground Rods: Drive rods until tops are 2 inches (50 mm) below finished floor or final grade unless otherwise indicated.
 - 1. Interconnect ground rods with grounding electrode conductor below grade and as otherwise indicated. Make connections without exposing steel or damaging coating if any.

Retain subparagraph below if grounding installation requirements are not detailed on Drawings. Subparagraph exceeds NFPA 70 requirements.

- 2. For grounding electrode system, install at least [three (3)] <Insert number> rods spaced at least one-rod length from each other and located at least the same distance from other grounding electrodes, and connect to the service grounding electrode conductor.

Retain first paragraph below to require test wells; delete if detailed on Drawings.

- D. Test Wells: Ground rod driven through drilled hole in bottom of handhole. Handholes are specified in Section 260543 "Underground Ducts and Raceways for Electrical Systems," and shall be at least 12 inches (300 mm) deep, with cover.
 - 1. Test Wells: Install at least one (1) test well for each service unless otherwise indicated. Install at the ground rod electrically closest to service entrance. Set top of test well flush with finished grade or floor.
- E. Bonding Straps and Jumpers: Install in locations accessible for inspection and maintenance except where routed through short lengths of conduit.
 - 1. Bonding to Structure: Bond straps directly to basic structure, taking care not to penetrate any adjacent parts.
 - 2. Bonding to Equipment Mounted on Vibration Isolation Hangers and Supports: Install bonding so vibration is not transmitted to rigidly mounted equipment.
 - 3. Use exothermic-welded connectors for outdoor locations; if a disconnect-type

connection is required, use a bolted clamp.

If connections specified in first paragraph below circumvent dielectric fittings intended to isolate interior piping systems from ground, other action may be necessary to prevent electrolytic corrosion.

F. Grounding and Bonding for Piping:

1. Metal Water Service Pipe: Install insulated copper grounding conductors, in conduit, from building's main service equipment, or grounding bus, to main metal water service entrances to building. Connect grounding conductors to main metal water service pipes; use a bolted clamp connector or bolt a lug-type connector to a pipe flange by using one of the lug bolts of the flange. Where a dielectric main water fitting is installed, connect grounding conductor on street side of fitting. Bond metal grounding conductor conduit or sleeve to conductor at each end.
2. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with a bolted connector.
3. Bond each aboveground portion of gas piping system downstream from equipment shutoff valve.

G. Retain and revise first paragraph below to exceed NFPA 70 requirements, and comply with NFPA 70 recommendations for a higher standard of safety or electromagnetic interference suppression if needed.

H. Bonding Interior Metal Ducts: Bond metal air ducts to equipment grounding conductors of associated fans, blowers, electric heaters, and air cleaners. Install [tinned] bonding jumper to bond across flexible duct connections to achieve continuity.

I. Grounding for Steel Building Structure: Install a driven ground rod at base of each corner column and at intermediate exterior columns at distances not more than 60 feet (18 m) apart.

See Evaluations for discussion on ground rings.

J. Ground Ring: Install a grounding conductor, electrically connected to each building structure ground rod and to each [steel column] [indicated item], extending around the perimeter of [building] [area or item indicated].

1. Install tinned-copper conductor not less than No. [2/0] <Insert size> AWG for ground ring and for taps to building steel.
2. Bury ground ring not less than [24 inches (600 mm)] <Insert dimension> from building's foundation.

Retain paragraph below to require Ufer ground (concrete-encased grounding electrode). 20 feet (6 m) is minimum length of conductor for this item. Coordinate with Drawings. See Evaluations.

K. Ufer Ground (Concrete-Encased Grounding Electrode): Fabricate according to NFPA 70; use a minimum of [20 feet (6 m)] <Insert length> of bare copper conductor not smaller than No. [4] <Insert size> AWG.

1. If concrete foundation is less than [20 feet (6 m)] <Insert dimension> long, coil excess conductor within base of foundation.

2. Bond grounding conductor to reinforcing steel in at least four locations and to anchor bolts. Extend grounding conductor below grade and connect to building's grounding grid or to grounding electrode external to concrete.

3.6 LABELING

- A. Comply with requirements in Section 260553 "Identification for Electrical Systems" Article for instruction signs.
- B. Install labels at the telecommunications bonding conductor and grounding equalizer [**and at the grounding electrode conductor where exposed**].
 1. Label Text: "If this connector or cable is loose or if it must be removed for any reason, notify the facility manager."

3.7 FIELD QUALITY CONTROL

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- B. Tests and Inspections:
 1. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
 2. Inspect physical and mechanical condition. Verify tightness of accessible, bolted, electrical connections with a calibrated torque wrench according to manufacturer's written instructions.
 3. Test completed grounding system at each location where a maximum ground-resistance level is specified, at service disconnect enclosure grounding terminal[, **at ground test wells**] [, **and at individual ground rods**]. Make tests at ground rods before any conductors are connected.
 4. Measure ground resistance no fewer than two full days after last trace of precipitation and without soil being moistened by any means other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
 5. Perform tests by fall-of-potential method according to IEEE 81.

Coordinate subparagraph below with "Informational Submittals" Article; revise to suit Project.

6. Prepare dimensioned Drawings locating each test well, ground rod and ground-rod assembly, and other grounding electrodes. Identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location, and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.

See Division 01 Section "Quality Requirements" for retesting and reinspecting requirements and Division 01 Section "Execution" for requirements for correcting the Work.

- C. Grounding system will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. Report measured ground resistances that exceed the following values:

See Evaluations for discussion on appropriate ground-resistance values. Typical maximum permitted values are listed below for different grounding applications; retain applicable subparagraphs and revise to suit Project. Coordinate with requirements in Sections specifying equipment to be grounded.

1. Power and Lighting Equipment or System with Capacity of 500 kVA and Less: **[10] <Insert value>** ohms.
 2. Power and Lighting Equipment or System with Capacity of 500 to 1000 kVA: **[5] <Insert value>** ohms.
 3. Power and Lighting Equipment or System with Capacity More Than 1000 kVA: **[3] <Insert value>** ohms.
 4. Power Distribution Units or Panelboards Serving Electronic Equipment: **[1] [3] <Insert value>** ohm(s).
 5. Substations and Pad-Mounted Equipment: **[5] <Insert value>** ohms.
 6. Manhole Grounds: **[10] <Insert value>** ohms.
 7. **<Insert application and maximum ground-resistance value>** ohms.
 8. Ground resistance to earth of each ground rod: > 5 ohms.
- F. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify DEN Electrical Engineer promptly and include recommendations to reduce ground resistance.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260526

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SECTION 260529 - HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes the following:

Adjust list below to suit Project.

- 1. Hangers and supports for electrical equipment and systems.
- 2. Construction requirements for concrete bases.

- B. Related Sections include the following:

List below only products and construction that the reader might expect to find in this Section but are specified elsewhere.

- 1. Division 26 Section "Vibration and Seismic Controls for Electrical Systems" for products and installation requirements necessary for compliance with seismic criteria.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviations that remain after this Section has been edited.

- A. EMT: Electrical metallic tubing.
- B. RMC: Rigid metal conduit.

1.4 PERFORMANCE REQUIREMENTS

Retain first paragraph below if Contractor is required to assume responsibility for design.

- A. Delegated Design: Design supports for multiple raceways, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- B. Design supports for multiple raceways capable of supporting combined weight of supported systems and its contents.
- C. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

Consult structural engineer on safety factor to be specified in paragraph below, or delete and let applicable code determine strength. Retain below if strength that exceeds code requirements is desired.

- D. Rated Strength: Adequate in tension, shear, and pullout force.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN ELECTRICAL ENGINEER

1.5 ACTION SUBMITTALS

Retain this Article for large or complex projects.

- A. Product Data: For the following:
 - 1. Steel slotted support systems.
 - 2. Nonmetallic slotted support systems.
 - 3. Include data substantiating that materials comply with requirements.

Retain paragraph and subparagraphs below if supporting systems are required to withstand specific design loads and DEN Project Manager either has delegated design responsibility to Contractor or wants to review structural data as another way to verify supporting system's compliance with performance requirements. Professional engineer qualifications are specified in Division 01 Section "Quality Requirements."

- B. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following:

Adjust list below to suit Project.

1. Trapeze hangers. Include Product Data for components.
2. Steel slotted channel systems. Include Product Data for components.
3. Nonmetallic slotted channel systems. Include Product Data for components.
4. Equipment supports.

1.6 INFORMATIONAL SUBMITTALS

Retain paragraph below if procedures for welder certification are retained in "Quality Assurance" Article.

- A. Welding certificates.

1.7 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 QUALITY ASSURANCE

Delete first paragraph below if no welding. Retain "Welding certificates" Paragraph in "Informational Submittals" Article if retaining below. AWS states that welding qualifications remain in effect indefinitely unless welding personnel have not welded for more than six months or there is a specific reason to question their ability.

- A. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Comply with NFPA 70.

1.9 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.
- B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 SUPPORT, ANCHORAGE, AND ATTACHMENT COMPONENTS

Retain this Article to specify default product requirements for basic supporting devices. Items to be supported include raceways, cables, wireways, cable trays, busways, boxes, cabinets, equipment, and other electrical products. Where support materials or workmanship is unique to a particular product, specify unique features that are the exception to these default requirements in the Section that specifies the product. Coordinate specifications for supporting devices with structural engineer and with Drawings.

- A. Steel Slotted Support Systems: Comply with MFMA-4, factory-fabricated components for field assembly.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Allied Tube & Conduit.
 - b. Cooper B-Line, Inc.; a division of Cooper Industries.
 - c. ERICO International Corporation.
 - d. GS Metals Corp.
 - e. Thomas & Betts Corporation.
 - f. Unistrut; Tyco International, Ltd.
 - g. Wesanco, Inc.
 - h. <Insert manufacturer>
 - i. or approved equal.

Retain one or more coating systems in first three subparagraphs below. If retaining more than one, specify in Part 3 where each coating system is required.

2. Metallic Coatings: Hot-dip galvanized after fabrication and applied according to MFMA-4.
3. Nonmetallic Coatings: Manufacturer's standard PVC, polyurethane, or polyester coating applied according to MFMA-4.
4. Painted Coatings: Manufacturer's standard painted coating applied according to MFMA-4. For use in dry locations only.
5. Channel Dimensions: Selected for applicable load criteria.

If retaining first paragraph and subparagraphs below, coordinate with Part 3 and with Drawings to indicate where nonmetallic channel is to be used.

- B. Nonmetallic Slotted Support Systems: Structural-grade, factory-formed, glass-fiber-resin channels and angles with **9/16-inch** (14-mm) diameter holes at a maximum of **8 inches** (200 mm) o.c., in at least 1 surface.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain first subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Allied Tube & Conduit.
 - b. Cooper B-Line, Inc.; a division of Cooper Industries.
 - c. Fabco Plastics Wholesale Limited.
 - d. Seasafe, Inc.
 - e. **<Insert manufacturer>**
 - f. or approved equal.
 2. Fittings and Accessories: Products of channel and angle manufacturer and designed for use with those items.
 3. Fitting and Accessory Materials: Same as channels and angles[, **except metal items may be stainless steel**].
 4. Rated Strength: Selected to suit applicable load criteria.
- C. Hardware for hangers and supports shall be corrosion-resistant.
- D. Raceway and Cable Supports: As described in NECA 1 and NECA 101.
- E. Conduit and Cable Support Devices: [**Steel**] [**Steel and malleable-iron**] hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.
- F. Support for Conductors in Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug or plugs for non-armored electrical conductors or cables in riser conduits. Plugs shall have number, size, and shape of conductor gripping pieces as required to suit individual conductors or cables supported. Body shall be malleable iron.
- G. Structural Steel for Fabricated Supports and Restraints: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

Coordinate paragraph and subparagraphs below with installation requirements in Part 3.

- H. Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:

Verify suitability of fasteners in subparagraph below for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) thick.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of first two subparagraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Mechanical-Expansion Anchors: Insert-wedge-type, [**zinc-coated**] [**stainless**] steel, for use in hardened Portland cement concrete with tension, shear, and pullout capacities appropriate for supported loads and building materials in which used.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

Retain first subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Cooper B-Line, Inc.; a division of Cooper Industries.
 - 2) Empire Tool and Manufacturing Co., Inc.
 - 3) Hilti Inc.
 - 4) ITW Ramset/Red Head; a division of Illinois Tool Works, Inc.
 - 5) MKT Fastening, LLC.
 - 6) **<Insert manufacturer>**
 - 7) or approved equal.
2. Concrete Inserts: Steel or malleable-iron, slotted support system units similar to MSS Type 18; complying with MFMA-4 or MSS SP-58.
3. Clamps for Attachment to Steel Structural Elements: MSS SP-58, type suitable for attached structural element.
4. Through Bolts: Structural type, hex head, and high strength. Comply with ASTM A 325.
5. Toggle Bolts: All-steel springhead type.
6. Hanger Rods: Threaded steel.
7. Pneumatic-Actuated Fasteners: For use in ceilings only and by approval of DEN Project Manager. Powder-actuated tools are prohibited. Threaded-steel stud, for use in pan deck cement concrete, steel, or wood, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain first subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Hilti Inc.
 - 2) ITW Ramset/Red Head; a division of Illinois Tool Works, Inc.
 - 3) MKT Fastening, LLC.
 - 4) Simpson Strong-Tie Co., Inc.; Masterset Fastening Systems Unit.
 - 5) **<Insert manufacturer>**
 - 6) or approved equal.

2.2 FABRICATED METAL EQUIPMENT SUPPORT ASSEMBLIES

Equipment supports in this Article require calculation of load and strength for each component and detailing of each assembly. Coordinate specifications for each equipment support with structural engineer and with Drawings.

- A. Description: Welded or bolted, structural-steel shapes, shop or field fabricated to fit dimensions of supported equipment.
- B. Materials: Comply with requirements in Division 05 Section "Metal Fabrications" for

steel shapes and plates.

PART 3 - EXECUTION

3.1 APPLICATION

- A. Comply with NECA 1 and NECA 101 for application of hangers and supports for electrical equipment and systems except if requirements in this Section are stricter.

In first paragraph below, support spacings in NECA 1, Table 1, are more detailed and specific and generally stricter than those permitted by NFPA 70 for EMT, IMC, and RMC. Revise to suit Project, and consider retaining reference to NECA table for critical projects.

- B. Maximum Support Spacing and Minimum Hanger Rod Size for Raceway: Space supports for EMT, IMC, and RMC as **[required by] [scheduled in NECA 1, where its Table 1 lists maximum spacings less than stated in]** NFPA 70. Minimum rod size shall be **1/4 inch** (6 mm) in diameter.
- C. Multiple Raceways or Cables: Install trapeze-type supports fabricated with steel slotted **[or other]** support system, sized so capacity can be increased by at least **[25] <Insert number>** percent in future without exceeding specified design load limits.
1. Secure raceways and cables to these supports with **[two-bolt conduit clamps] [single-bolt conduit clamps] [single-bolt conduit clamps using spring friction action for retention in support channel]**.

Retain paragraph below for projects where seismic design requirements do not apply. Consider retaining for light-commercial projects only.

- D. Spring-steel clamps designed for supporting single conduits without bolts may be used for **1-1/2-inch** (38-mm) and smaller raceways serving branch circuits and communication systems above suspended ceilings and for fastening raceways to trapeze supports.

3.2 SUPPORT INSTALLATION

Consult structural engineer for requirements in this Article.

- A. Comply with NECA 1 and NECA 101 for installation requirements except as specified in this Article.

Retain first paragraph below to permit raceways running perpendicular to bar joists and trusses to be supported by letting them rest within the joist or truss openings. NECA 1 does not mention this method. If seismic design requirements apply, consult structural engineer or authorities having jurisdiction before permitting this support method and specify seismic requirements in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

- B. Raceway Support Methods: In addition to methods described in NECA 1, EMT and RMC may be supported by openings through structure members, as permitted in

NFPA 70.

- C. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb (90 kg).
- D. Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:
1. To Wood: Fasten with lag screws or through bolts.
 2. To New Concrete: Bolt to concrete inserts.
 3. To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
 4. To Existing Concrete: Expansion anchor fasteners.
- Retain first subparagraph below if powder-actuated devices are allowed. Consider deleting if Project contains both lightweight and standard-weight concrete or more than one thickness of concrete slab.
5. To Steel: Beam clamps (MSS Type 19, 21, 23, 25, or 27) complying with MSS SP-69 or Spring-tension clamps, as appropriate and with sufficient weight rating for the application.
 6. To Light Steel: Sheet metal screws.
 7. Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices on slotted-channel racks attached to substrate **[by means that meet seismic-restraint strength and anchorage requirements for a seismic zone 1.]**
- E. Drill holes for expansion anchors in concrete at locations and to depths that avoid reinforcing bars.
- F. Do not fasten supports to piping, ductwork, mechanical equipment, cable tray or conduit.
- G. The use of pneumatic-actuated anchors is not allowed except at ceilings. Obtain DEN Project Manager approval prior to ordering materials or performing work.
- H. Do not drill structural steel members.
- I. Install surface-mounted cabinets and panelboards with minimum of four anchors
- J. Suspended conduit or box supports shall not be less than 1/4" diameter steel rod. Rod used as pedestal support is not acceptable. The contractor shall not use tie wire or wire of any type to support conduits, junction boxes or pull boxes.
- K. No more than five (5) 1/2" conduits, three (3) 3/4" conduits or two (2) 1" conduits shall be supported on a single 1/4" diameter steel rod.
- L. All conduits shall be supported by approved hangers. Supports installed and used by other trades such as duct hangers, pipe hangers, ceiling hangers, etc. shall not be

used for conduit support.

- M. All light fixtures shall be independently supported at opposite corners from structure, or from trapeze supported from structure by the electrical contractor.
- N. Wall-mounted fixtures shall be supported from building structure with backing support as approved by the DEN Project Manager to prevent any damage to the wall.
- O. Use vibration isolation pads for vibrating equipment such as transformers.
- P. Plastic or fiber anchors are prohibited.
- Q. Anchoring in overhead cast in place, pre-tensioned or post-tensioned concrete is prohibited unless x-ray or ground penetrating radar study are performed and approved by the DEN Project Manager.
- R. Route conduit through roof openings provided for piping and ductwork where possible; otherwise, route through roof jack with sealant approved by the roofing manufacturer.

3.3 INSTALLATION OF FABRICATED METAL SUPPORTS

Coordinate installation requirements in this Article with structural engineer.

- A. Comply with installation requirements in Section 055000 "Metal Fabrications" for site-fabricated metal supports.
- B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.
- C. Field Welding: Comply with AWS D1.1/D1.1M.

3.4 CONCRETE BASES

Coordinate this Article with Division 03 Section "Cast-in-Place Concrete" or "Miscellaneous Cast-in-Place Concrete."

Coordinate paragraphs and subparagraphs below with Sections specifying supported equipment.

- A. Install all freestanding electrical equipment on a 4" concrete housekeeping pad.
- B. Construct concrete bases of dimensions indicated but not less than 4 inches (100 mm) larger in both directions than supported unit, and so anchors will be a minimum of 10 bolt diameters from edge of the base.
- C. Use [3000-psi (20.7-MPa)] <Insert value>, 28-day compressive-strength concrete. Concrete materials, reinforcement, and placement requirements are specified in Section[s] "[033000 Cast-in-Place Concrete] [033053 Miscellaneous Cast-in-Place Concrete]."

- D. Anchor equipment to concrete base.
1. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 2. Install anchor bolts to elevations required for proper attachment to supported equipment.
 3. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

3.5 PAINTING

Retain paragraph and subparagraph below if a Division 09 painting Section is not in Project Manual.

- A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
1. Apply paint by brush or spray to provide minimum dry film thickness of **2.0 mils** (0.05 mm).

Retain first paragraph below if a Division 09 painting Section is in Project Manual.

- B. Touchup: Comply with requirements in Division 09 [**painting Sections**] [**Section 099600 "High-Performance Coatings"**] for cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
- C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260529

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SECTION 260533 - RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Metal conduits, tubing, and fittings.
 - 2. Nonmetal conduits, tubing, and fittings.
 - 3. Innerduct
 - 4. Metal wireways and auxiliary gutters.
 - 5. Nonmetal wireways and auxiliary gutters.
 - 6. Surface raceways.
 - 7. Boxes, enclosures, and cabinets.
 - 8. Handholes and boxes for exterior underground cabling.
 - 9. Buried conduits in concrete encased duct banks.

- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

Retain first subparagraph below for underground conduits, handholes, and boxes; delete if incidental exterior underground raceways, handholes, and boxes are specified in this Section.

1. Division 26 Section 260543 "Underground Ducts and Raceways for Electrical Systems" for exterior ductbanks, manholes, and underground utility construction.
2. Division 27 Section 270528 "Pathways for Communications Systems" for conduits, wireways, surface pathways, innerduct, boxes, faceplate adapters, enclosures, cabinets, and handholes serving communications systems.
3. Division 28 Section 280528 "Pathways for Electronic Safety and Security" for conduits, surface pathways, innerduct, boxes, and faceplate adapters serving electronic safety and security.
4. Division 26 Section 260526 "Grounding and Bonding for Electrical Systems" for additional grounding and bonding requirements.

C. Prohibited Materials

1. Intermediate conduits.
2. Aluminum conduit.
3. Multi-conductor assemblies, unless written authorization is obtained from DEN Project Manager, or specifically allowed within specification.

D. Project Conditions

1. Verify locations of outlets and small pull-boxes prior to rough in.
2. Electrical and pull boxes are shown on Drawings in approximate locations unless dimensioned. Install at location required for box to serve intended purpose.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. GRC: Galvanized rigid steel conduit.
- B. RMC: Rigid Metallic Conduit.
- C. RNC: Rigid Nonmetallic Conduit.
- D. EMT: Electrical Metallic Conduit.
- E. FMC: Flexible Metallic Conduit.
- F. LFMC: Liquidtight Flexible Metallic Conduit.
- G. HDPE: High Density Polyethelene.

- H. FNC: Flexible Nonmetallic Conduit.
- I. ENT: Electrical non-metallic conduit.
- J. MC: Metal-clad cable.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN ELECTRICAL ENGINEER

1.4 ACTION SUBMITTALS

- A. Product Data: For surface raceways, wireways and fittings, floor boxes, hinged-cover enclosures, and cabinets.
 - 1. Include data substantiating that materials comply with requirements.

Retain subparagraphs below only if project is pursuing LEED certification

- B. LEED Submittals (if required):

"Product Data for Credit IEQ 4.1" Subparagraph below applies to LEED-NC, LEED-CI, and LEED-CS; coordinate with requirements for solvent cements and adhesive primers.

- 1. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.

"Laboratory Test Reports for Credit IEQ 4" Subparagraph below applies to LEED for Schools.

- 2. Laboratory Test Reports for Credit IEQ 4: For solvent cements and adhesive primers, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

Retain "Shop Drawings" Paragraph below for custom enclosures only.

- C. Shop Drawings: For custom enclosures and cabinets. Include plans, elevations, sections, and attachment details.

Coordinate sample requirements with DEN Project Manager.

- D. Samples: Per request.

1.5 INFORMATIONAL SUBMITTALS

The Designer shall model conduit routing per BIM requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Conduit routing plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of items

involved:

1. Structural members in paths of conduit groups with common supports.
2. HVAC and plumbing items and architectural features in paths of conduit groups with common supports.

Retain "Qualification Data" Paragraph below if source quality-control tests are required to be certified by a professional engineer. Coordinate with qualification requirements in Division 01 Section "Quality Requirements."

- B. Qualification Data: For professional engineer.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Division 26 Section "Vibration and Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Seismic Qualification Certificates: For enclosures, cabinets, and conduit racks and their mounting provisions, including those for internal components, from manufacturer.
- D. Source quality-control reports.

1.6 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.7 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Division 01 Section "Product Requirements."

2.1 METAL CONDUITS, TUBING, AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. AFC Cable Systems, Inc.
 2. Allied Tube & Conduit; a Tyco International Ltd. Co.
 3. Anamet Electrical, Inc.
 4. Electri-Flex Company.
 5. O-Z/Gedney; a brand of EGS Electrical Group.
 6. Picoma Industries, a subsidiary of Mueller Water Products, Inc.
 7. Republic Conduit.
 8. Robroy Industries.
 9. Southwire Company.
 10. Thomas & Betts Corporation.
 11. Western Tube and Conduit Corporation.
 12. Wheatland Tube Company; a division of John Maneely Company.
 13. or approved equal.
- B. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. GRC: Comply with ANSI C80.1 and UL 6.
- D. PVC-Coated Steel Conduit: PVC-coated rigid steel conduit.
1. Comply with NEMA RN 1.
 2. Coating Thickness: 0.040 inch (1 mm), minimum.
- E. EMT: Galvanized tubing. Comply with ANSI C80.3 and UL 797.
- F. FMC: Comply with UL 1; zinc-coated steel.
- G. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.
- H. Fittings for Metal Conduit: Comply with NEMA FB 1 and UL 514B.

In "FMC" Paragraph below, zinc-coated steel is most common type and provides some additional protection from physical damage. .

Coordinate "Conduit Fittings for Hazardous (Classified) Locations" Subparagraph below with Drawings.

1. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 886 and NFPA 70.
2. Fittings for EMT:
 - a. Material: Steel.
 - b. Type: Set screw or compression.
 - c. Provide throated connectors where entering junction boxes.
3. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external

- bonding jumper.
4. Coating for Fittings for PVC-Coated Conduit: Minimum thickness of 0.040 inch (1 mm), with overlapping sleeves protecting threaded joints.

I. Innerduct:

1. Inner duct, meeting or exceeding the following requirements, shall be used to partition conduit.
 - a. Melting point: 260 degrees F., minimum.
 - b. Tensile yield strength: 3600 psi/sq. in., minimum
 - c. Brittleness temperature, maximum: -140 degrees F.
 - d. Heat distortion temperature: 170 degrees F minimum.

Retain "Joint Compound for GRC" Paragraph below to require some threaded joints of GRC, or ARC, or their fittings, to be treated with joint compound for improved conductivity, resistance to oxidation, or ease of assembly and disassembly.

- J. Joint Compound for GRC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.

2.2 NONMETALLIC CONDUITS AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. AFC Cable Systems, Inc.
 2. Anamet Electrical, Inc.
 3. Arnco Corporation.
 4. CANTEX Inc.
 5. CertainTeed Corp.
 6. Condux International, Inc.
 7. Electri-Flex Company.
 8. Kraloy.
 9. Lamson & Sessions; Carlon Electrical Products.
 10. Niedax-Kleinhuis USA, Inc.
 11. RACO; a Hubbell company.
 12. Thomas & Betts Corporation.
 13. or approved equal.
- B. Listing and Labeling: Nonmetallic conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

See Evaluations for descriptions of nonmetallic conduit types.

- C. RNC: Type EPC-40-PVC, complying with NEMA TC 2 and UL 651 unless otherwise indicated.

Retain one or more of three HDPE paragraphs below. See Evaluations for a discussion of the three types.

- D. Rigid HDPE: Comply with UL 651A.
- E. Continuous HDPE: Comply with UL 651B.
- F. Coilable HDPE: Preassembled with conductors or cables, and complying with ASTM D 3485.
- G. RTRC: Comply with UL 1684A and NEMA TC 14.
- H. Fittings for RNC: Comply with NEMA TC 3; match to conduit or tubing type and material.

Retain first paragraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1. VOC limit is that for PVC welding compounds and adhesive primers for plastic.

- I. Solvent cements and adhesive primers shall have a VOC content of 510 and 550 g/L or less, respectively, when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain paragraph below if required for LEED for Schools Credit IEQ 4.

- J. Solvent cements and adhesive primers shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.3 METAL WIREWAYS AND AUXILIARY GUTTERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Cooper B-Line, Inc.
 2. Hoffman; a Pentair company.
 3. Mono-Systems, Inc.
 4. Square D; a brand of Schneider Electric.
 5. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 6. or approved equal.
- B. Description: Sheet metal, complying with UL 870 and NEMA 250, Type 1, Type 3R or Type 4x, and sized according to NFPA 70.

1. Metal wireways installed outdoors shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Fittings and Accessories: Include covers, couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for complete system.

Retain one or more options in "Wireway Covers" Paragraph below. If retaining more than one type, indicate locations of each type on Drawings.

- D. Wireway Covers: Hinged type or screw cover.
- E. Finish: Manufacturer's standard enamel finish.

2.4 NONMETALLIC WIREWAYS AND AUXILIARY GUTTERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Allied Moulded Products, Inc.
 2. Hoffman; a Pentair company.
 3. Lamson & Sessions; Carlon Electrical Products.
 4. Niedax-Kleinhuis USA, Inc.
 5. or approved equal.
- B. Listing and Labeling: Nonmetallic wireways and auxiliary gutters shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain one of two "Description" paragraphs below.

- C. Description: Fiberglass polyester, extruded and fabricated to required size and shape, without holes or knockouts. Cover shall be gasketed with oil-resistant gasket material and fastened with captive screws treated for corrosion resistance. Connections shall be flanged and have stainless-steel screws and oil-resistant gaskets.
- D. Description: Schedule 40 PVC, extruded and fabricated to required size and shape, and having snap-on cover, mechanically coupled connections, and plastic fasteners.
- E. Fittings and Accessories: Couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings shall match and mate with wireways as required for complete system.

Retain first paragraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1. VOC limit is that for PVC welding compounds and adhesive primers for plastic.

- F. Solvent cements and adhesive primers shall have a VOC content of 510 and 550 g/L or less, respectively, when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain paragraph below if required for LEED for Schools Credit IEQ 4.

- G. Solvent cements and adhesive primers shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.5 SURFACE RACEWAYS

Insert requirements for finish-coat paint color, if applicable, in "Surface Metal Raceways" Paragraph below. See Division 09 for optional field-finish coats.

- A. Listing and Labeling: Surface raceways shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Surface Metal Raceways: Galvanized steel with snap-on covers complying with UL 5. **Manufacturer's standard enamel finish in color selected by the DEN Project Manager.**

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- a. Mono-Systems, Inc.
 - b. Panduit Corp.
 - c. Wiremold / Legrand.
 - d. or approved equal.
- C. Surface Nonmetallic Raceways: Two- or three-piece construction, complying with UL 5A, and manufactured of rigid PVC with texture and color selected by DEN Project Manager from **manufacturer's standard** colors. Product shall comply with UL 94 V-0 requirements for self-extinguishing characteristics.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- a. Hubbell Incorporated; Wiring Device-Kellems Division.
 - b. Mono-Systems, Inc.
 - c. Panduit Corp.
 - d. Wiremold / Legrand.
 - e. **<Insert manufacturer>**

f. or approved equal.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

2.6 BOXES, ENCLOSURES, AND CABINETS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Adalet.
 2. Cooper Technologies Company; Cooper Crouse-Hinds.
 3. EGS/Appleton Electric.
 4. Erickson Electrical Equipment Company.
 5. FSR Inc.
 6. Hoffman; a Pentair company.
 7. Hubbell Incorporated; Killark Division.
 8. Kraloy.
 9. Milbank Manufacturing Co.
 10. Mono-Systems, Inc.
 11. O-Z/Gedney; a brand of EGS Electrical Group.
 12. RACO; a Hubbell Company.
 13. Robroy Industries.
 14. Spring City Electrical Manufacturing Company.
 15. Stahlin Non-Metallic Enclosures; a division of Robroy Industries.
 16. Thomas & Betts Corporation.
 17. Wiremold / Legrand.
 18. <Insert manufacturer>
 19. or approved equal.
- B. General Requirements for Boxes, Enclosures, and Cabinets: Boxes, enclosures, and cabinets installed in wet locations shall be listed for use in wet locations.
- C. Sheet Metal Outlet and Device Boxes: Galvanized steel. Comply with NEMA OS 1 and UL 514A.
- In "Cast-Metal Outlet and Device Boxes" Paragraph below, type FD is a device box with extra depth. Many other configurations are available.
- D. Cast-Metal Outlet and Device Boxes: Comply with NEMA FB 1, **ferrous alloy**, Type FD, with gasketed cover. Provide threaded hubs.
- E. Nonmetallic Outlet and Device Boxes: Prohibited, unless specifically allowed in writing by the DEN Project Manager.

See Editing Instruction No. 2 in the Evaluations for a discussion of floor boxes.

- F. Metal Floor Boxes:
1. Material: **Cast metal**.
 2. Type: Fully adjustable.
 3. Shape: [Rectangular] [round] <Insert shape>.
 4. Listing and Labeling: Metal floor boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- G. Nonmetallic Floor Boxes: Prohibited, unless specifically allowed by the DEN Project Manager.
1. Listing and Labeling: Nonmetallic floor boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- H. Luminaire Outlet Boxes: Nonadjustable, designed for attachment of luminaire weighing **50 lb (23 kg)**. Outlet boxes designed for attachment of luminaires weighing more than **50 lb (23 kg)** shall be listed and marked for the maximum allowable weight.
- I. Paddle Fan Outlet Boxes: Nonadjustable, designed for attachment of paddle fan weighing **70 lb (32 kg)**.
1. Listing and Labeling: Paddle fan outlet boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- J. Small Sheet Metal Pull and Junction Boxes: Galvanized steel. NEMA OS 1.
- K. Cast-Metal Access, Pull, and Junction Boxes: Comply with NEMA FB 1 and UL 1773, **galvanized, cast iron** with gasketed cover.
- L. Box extensions used to accommodate new building finishes shall be of same material as recessed box.
- M. Device Box Dimensions: **4 inches square by 2-1/8 inches deep** (100 mm square by 60 mm deep) or as approved by DEN Project Manager.
- N. Gangable boxes are allowed.
- Coordinate "Hinged-Cover Enclosures" Paragraph below with Drawings if hinged-cover enclosures other than NEMA 250, Type 1 are required, such as for very dusty areas; or if consideration should be given to use of NEMA 250, Type 3R or Type 12 enclosures.
- O. Hinged-Cover Enclosures: Comply with UL 50 and NEMA 250, Type 1, Type 3R or Type 4x as appropriate, with continuous-hinge cover with flush latch unless otherwise indicated. Screw cover enclosures: VL50 & NEMA 1.
1. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
 2. Nonmetallic Enclosures: Plastic or Fiberglass.

3. Interior Panels: Steel; 14 gage steel, 12 gage if floor mounted, all sides finished with manufacturer's standard enamel, white.
4. Large Pull Boxes: Boxes larger than 100 cubic inches in volume or 12 inches in any dimension.
 - a. Interior Dry Locations: Use hinged or screw covered enclosure.
 - b. Interior damp or wet locations: Use nema 3R hinged cover boxes.

P. Cabinets:

1. NEMA 250, **[Type 1]** **[Type 3R]** **[Type 12]** <Insert type> galvanized-steel box with removable interior panel and removable **[front][end walls]**, finished inside and out with manufacturer's standard enamel, gray.
2. Cabinet Fronts: Steel, flush or surface type as indicated, with concealed trim clamps, concealed hinge and flush lock keyed to match branch circuit panelboard; finish in gray baked enamel.
3. Provide 3/4-inch thick fire retardant plywood backboard or galvanized steel back plate painted matte white, for mounting terminal blocks.
4. Metal barriers to separate wiring of different systems and voltage.
5. Accessory feet where required for freestanding equipment.
6. Nonmetallic cabinets shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
7. Fabrication:
 - a. Shop assemble enclosures and cabinets housing terminal blocks or electrical components in accordance with ANSI/NEMA ICS 6.
 - b. Provide knockouts on enclosures.
 - c. Provide protective pocket inside front cover with schematic diagram, connection diagram, and layout drawing of control wiring and components within enclosure.

Q. Terminal blocks and accessories:

1. All terminal Blocks: ANSI/NEMA ICS 4; UL listed.
2. Power Terminals: Unit construction type, closed-back type, with tubular pressure screw terminals, rated 600 volts.
3. Signal and Control Terminals: Modular construction type, channel mounted; tubular pressure screw terminals, rated 300 volts.
4. Power and signal/control wiring will use separate terminal blocks.

2.7 HANDHOLES AND BOXES FOR EXTERIOR UNDERGROUND WIRING

See Editing Instruction No. 3 in the Evaluations. Verify with manufacturers that units of types specified are available in sizes required. Indicate the size of each enclosure on Drawings, and use a symbol or other notation to differentiate between handholes and pull boxes.

A. General Requirements for Handholes and Boxes:

1. Boxes and handholes for use in underground systems shall be designed and identified as defined in NFPA 70, for intended location and application.

2. Boxes installed in wet areas shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain one or more of three paragraphs below to select enclosure type(s) for areas not subject to traffic by vehicles. Indicate location of each type in "Raceway Application" Article. For enclosures with cover options, verify that selected cover is available with load rating specified in "Raceway Application" Article. If retaining more than one type of box and cover combination, indicate location of each type on Drawings.

- B. Polymer-Concrete Handholes and Boxes with Polymer-Concrete or stainless steel Cover: Molded of sand and aggregate, bound together with polymer resin, and reinforced with steel, fiberglass, or a combination of the two.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armorcast Products Company.
 - b. Carson Industries LLC.
 - c. CDR Systems Corporation; Hubbell Power Systems.
 - d. NewBasis.
 - e. Oldcastle Precast, Inc.; Christy Concrete Products.
 - f. Synertech Moulded Products; a division of Oldcastle Precast, Inc.
 - g. or approved equal.
2. Standard: Comply with SCTE 77.

First option in "Configuration" Subparagraph below facilitates bottom conduit entry. Second option may be provided by a separate slab placed in the excavation under an open-bottom enclosure; third option is obtained by molding or fabricating the bottom integrally with the body of unit.

3. Configuration: Designed for flush burial with **[open] [closed] [integral closed]** bottom unless otherwise indicated.
4. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure and handhole location.
5. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
6. Cover Legend: Molded lettering, **["ELECTRIC."] <Insert legend>**.

Retain "Conduit Entrance Provisions" Subparagraph below if conduit enters enclosure through the side. Otherwise, entry is made through an open bottom or through side openings cut in the field, as specified in "Installation of Underground Handholes and Boxes" Article. Coordinate with Drawings.

7. Conduit Entrance Provisions: Conduit-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
8. Handholes **[12 Inches Wide by 24 Inches Long (300 mm Wide by 600 mm Long)] <Insert dimensions>** and Larger: Have inserts for cable racks and pulling-in irons installed before concrete is poured.

- C. Fiberglass Handholes and Boxes: Molded of fiberglass-reinforced polyester resin, with frame and covers of polymer concrete or stainless steel.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armorcast Products Company.
 - b. Carson Industries LLC.
 - c. CDR Systems Corporation; Hubbell Power Systems.
 - d. NewBasis.
 - e. Nordic Fiberglass, Inc.
 - f. Oldcastle Precast, Inc.; Christy Concrete Products.
 - g. Synertech Moulded Products; a division of Oldcastle Precast, Inc.
 - h. or approved equal.
2. Standard: Comply with SCTE 77.

Retain "Color of Frame and Cover" Subparagraph below if choosing a metal frame and cover; otherwise, delete.

3. Color of Frame and Cover: **[Gray] [Green]**.

First option in "Configuration" Subparagraph below facilitates bottom conduit entry. Second option may be provided by a separate slab placed in the excavation under an open-bottom enclosure; third option is obtained by molding or fabricating the bottom integrally with the body of unit.

4. Configuration: Designed for flush burial with **[open] [closed] [integral closed]** bottom unless otherwise indicated.
5. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure and handhole location.
6. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
7. Cover Legend: Molded lettering, **["ELECTRIC."] <Insert legend>**.

Retain "Conduit Entrance Provisions" Subparagraph below if conduit enters enclosure through the side. Otherwise, entry is made through an open bottom or through side openings cut in the field, as specified in "Installation of Underground Handholes and Boxes" Article. Coordinate with Drawings.

8. Conduit Entrance Provisions: Conduit-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
9. Handholes **[12 Inches Wide by 24 Inches Long (300 mm Wide by 600 mm Long)] <Insert dimensions>** and Larger: Have inserts for cable racks and pulling-in irons installed before concrete is poured.

2.8 SOURCE QUALITY CONTROL FOR UNDERGROUND ENCLOSURES

Retain this article for underground handholes and pull boxes. Delete if handholes and pull boxes are specified only in Division 26 Section "Underground Ducts and Raceways for Electrical Systems." See Evaluations.

- A. Handhole and Pull-Box Prototype Test: Test prototypes of handholes and boxes for compliance with SCTE 77. Strength tests shall be for specified tier ratings of products supplied.

Retain one of first two subparagraphs below; retain first subparagraph to require an independent testing agency to test for compliance with SCTE requirements; retain second subparagraph to require testing by manufacturers' laboratories. See Evaluations for a discussion of testing.

1. Tests of materials shall be performed by an independent testing agency.
2. Strength tests of complete boxes and covers shall be by either an independent testing agency or manufacturer. A qualified registered professional engineer shall certify tests by manufacturer.
3. Testing machine pressure gages shall have current calibration certification complying with ISO 9000 and ISO 10012 and traceable to NIST standards.

PART 3 - EXECUTION

3.1 RACEWAY APPLICATION

Retain this article to specify type of raceway to be installed. Coordinate with conductor and cable wiring methods specified in Division 26 Section "Low-Voltage Electrical Power Conductors and Cables" and in other Sections in Divisions 26, 27, and 28. See "Writing Guide" Article in the Evaluations for instructions on editing this article.

- A. Raceways shall not be installed in stairways or on the exterior of any building, unless specifically allowed by DEN Project Manager.
- B. Outdoors: Apply raceway products as specified below unless otherwise indicated:
 1. Exposed Conduit: RMC.
 2. Concealed Conduit, Aboveground: RMC.
 3. Underground Conduit: Encased in concrete per Section 260543, "Underground Ducts and Raceways for Electrical Systems."
 - a. Direct buried conduits are not allowed unless specifically allowed by the DEN Project Manager.
 4. Exposed Conduit in Parking Garages or other covered structures open to environment:
 - a. Below 8'-0" AFF or within 10'-0" of extent of covered area: Galvanized RMC.
 - b. Above 8'-0" AFF and more than 10'-0" from extent of covered area: EMT with compression-type weatherproof/rain-tight connectors.

Retain first option in first subparagraph below if raceway may be exposed to physical damage.

5. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): LFMC.
 6. Boxes and Enclosures, Aboveground: NEMA 250, Type 3R Type 4.
- C. Indoors: Apply raceway products as specified below unless otherwise indicated:
 1. Exposed, Not Subject to Physical Damage: EMT.
 2. Exposed, Not Subject to Severe Physical Damage: EMT.
 3. Exposed and Subject to Severe Physical Damage: GRC . Raceway locations include the following:

- a. Loading dock.
 - b. Baggage tunnels
 - c. **<Insert designations of applicable spaces or locations>**
4. Concealed in Ceilings and Interior Walls and Partitions: EMT.
 5. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): FMC, except use LFMC in damp or wet locations.
 6. Wet Locations: GRC.
 7. Boxes and Enclosures: NEMA 250, Type 1, except use NEMA 250, Type 4 stainless steel in institutional and commercial kitchens and damp or wet locations.

D. CONDUIT INSTALLATION SCHEDULE

1. Underground Installations More Than Five Feet From Foundation Wall: Polyvinyl Chloride (PVC) conduit Schedule 40. All bends greater than 45 degrees in non-metallic conduit shall be galvanized rigid steel conduit with a factory coating of polyvinyl chloride (PVC).
2. Installation In Concrete Slab: Not allowed.
 - a. All buried conduits containing cabling shall be installed in concrete encased duct banks.
3. In Slab Above Grade: Not allowed.
4. Wet Interior Locations: Rigid steel.
5. Concealed Dry Interior Locations: Electrical metallic tubing.
6. In Existing Walls of Existing Structure: Electrical metallic tubing or MC Cable.

Select minimum raceway size. 3/4-inch shall be the minimum raceway size for all projects unless 1/2-inch is specifically approved in writing by the DEN Project Manager.

E. Minimum Raceway Size: [1/2-inch (16-mm)] [3/4-inch (19-mm)] trade size.

F. Raceway Fittings: Compatible with raceways and suitable for use and location.

1. Rigid Steel Conduit: Use threaded rigid steel conduit fittings unless otherwise indicated. Comply with NEMA FB 2.10.
2. PVC Externally Coated, Rigid Steel Conduits: Use only fittings listed for use with this type of conduit. Patch and seal all joints, nicks, and scrapes in PVC coating after installing conduits and fittings. Use sealant recommended by fitting manufacturer and apply in thickness and number of coats recommended by manufacturer.
3. EMT: Use setscrew, or compression, steel fittings. Comply with NEMA FB 2.10.
 - a. Setscrew fittings to be used for indoor applications in dry locations only.
 - b. Compression fittings may be used in indoor or outdoor locations for damp or wet locations.
4. Flexible Conduit: Use only fittings listed for use with flexible conduit. Comply with NEMA FB 2.20.

Retain first paragraph below for high-frequency installation.

Install nonferrous conduit for circuits operating above 60 Hz. Coordinate first paragraph below with Drawings.

- G. Install surface raceways only where indicated on Drawings.
- H. Do not install nonmetallic conduit where ambient temperature exceeds 120 deg F (49 deg C).
- I. Unless otherwise indicated and where not otherwise restricted, use the conduit type indicated for the specified applications. Where more than one listed application applies, comply with the most restrictive requirements. Where conduit type for a particular application is not specified, use Galvanized Rigid Conduit.

3.2 INSTALLATION

- A. Comply with NECA 1 and NECA 101 for installation requirements except where requirements on Drawings or in this article are stricter. Comply with NFPA 70 limitations for types of raceways allowed in specific occupancies and number of floors.
- B. Maintain a minimum of 6 inches (150 mm) between conduit and other piping. Maintain twelve inches (12") clearance between conduit and a heat source such as heating pipes, exhaust flues and heating appliances. Install horizontal raceway runs above water and steam piping.
- C. Complete raceway installation before starting conductor installation.
- D. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for hangers and supports.
- E. Arrange stub-ups so curved portions of bends are not visible above finished slab.

First paragraph below is more restrictive than NFPA 70, which permits up to four quarter bends in a conduit run. Retain paragraph for more conservative design, with less stress being placed on conductors being pulled in.

- F. Install no more than the equivalent of three 90-degree bends in any conduit run except for control wiring conduits, for which fewer bends are allowed. Support within 24 inches (610 mm) of changes in direction.
- G. Conceal conduit and EMT within finished walls, ceilings, and floors unless otherwise indicated. Install conduits parallel or perpendicular to building lines. Use conduit bodies to make changes in direction around beams or columns.
- H. Support conduit within 24 inches (610 mm) of enclosures to which attached. Support conduit at a maximum of 8 feet on center, within two (2) feet of a box or fitting.

Some authorities having jurisdiction may not permit nonmetallic tubing in fire-rated slabs in subparagraph below.

- I. Use only factory cast hubs for fastening conduit to cast boxes, and use steel or malleable iron hubs for fastening conduit to sheet metal boxes or equipment in damp or wet locations.
- J. Avoid moisture traps where possible; where unavoidable, provide junction box with drain fitting at conduit low point.
- K. Use suitable conduit caps to protect installed conduit against entrance of dirt and moisture during construction.
- L. Use PVC-coated rigid steel factory elbows for bends greater than 45 degrees in plastic conduit runs.
- M. Exposed conduits subject to physical damage to be rigid steel to 6'-0" above floor, deck or grating except in electrical, communications and mechanical rooms.
- N. Conduit stubbed up shall be two inches above slab or housekeeping pad and the empty conduits shall be capped. Under freestanding equipment conduits with conductors shall be sealed with duct seal.
- O. Flexible steel conduit runs shall not exceed 6' in length when connecting equipment, 6' in length when connecting light fixtures or when fished in hollow spaces with written approval by DEN Project Manager and shall contain a grounding conductor.
- P. Stub-ups to Above Recessed Ceilings:
 - 1. Use EMT or RMC for raceways.
 - 2. Use a conduit bushing or insulated fitting to terminate stub-ups not terminated in hubs or in an enclosure.

Retain "Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions" Paragraph below to require application of protective joint compound to threads of rigid steel conduit and to their fittings where these raceways are installed outdoors or in wet, damp, or corrosive conditions. This optional requirement exceeds NFPA 70 rules. If retaining, coordinate with Drawings indicating wet, damp, or corrosive indoor locations.

- Q. Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions: Apply listed compound to threads of raceway and fittings before making up joints. Follow compound manufacturer's written instructions.
- R. Coat field-cut threads on PVC-coated raceway with a corrosion-preventing conductive compound prior to assembly.

Retain one of first two paragraphs below to exceed NFPA 70 requirements. NFPA 70 requires insulated bushings or other smooth, rounded entry provisions for conduit terminations at all locations where conductors are No. 4 AWG and larger, regardless of the environment. NFPA 70 requires bonding of all service conductors, but does not require bonding to be accomplished with grounding bushings. See Evaluations for further discussion.

- S. Raceway Terminations at Locations Subject to Moisture or Vibration: Use insulating bushings to protect conductors including conductors smaller than No. 4 AWG.

- T. Terminate threaded conduits into threaded hubs or with locknuts on inside and outside of boxes or cabinets. Install bushings on conduits up to **1-1/4-inch (35mm)** trade size and insulated throat metal bushings on **1-1/2-inch (41-mm)** trade size and larger conduits terminated with locknuts. Install insulated throat metal grounding bushings on service conduits.
- U. Install raceways square to the enclosure and terminate at enclosures with locknuts. Install locknuts hand tight plus 1/4 turn more.
- V. Do not rely on locknuts to penetrate nonconductive coatings on enclosures. Remove coatings in the locknut area prior to assembling conduit to enclosure to assure a continuous ground path.
- W. Cut conduit perpendicular to the length. For conduits **2-inch (53-mm)** trade size and larger, use roll cutter or a guide to make cut straight and perpendicular to the length.
- X. Install pull wires in empty raceways. Use polypropylene or monofilament plastic line with not less than **160-lb (72-kg)** tensile strength. Leave at least **12 inches (300 mm)** of slack at each end of pull wire. Cap underground raceways designated as spare above grade alongside raceways in use.

Retain "Surface Raceways" Paragraph below if applicable.

- Y. Surface Raceways:
 - 1. Install surface raceway with a minimum **2-inch (50-mm)** radius control at bend points.
 - 2. Secure surface raceway with screws or other anchor-type devices at intervals not exceeding **48 inches (1200 mm)** and with no less than two supports per straight raceway section. Support surface raceway according to manufacturer's written instructions. Tape and glue are not acceptable support methods.
- Z. Install raceway sealing fittings at accessible locations according to NFPA 70 and fill them with listed sealing compound. For concealed raceways, install each fitting in a flush steel box with a blank cover plate having a finish similar to that of adjacent plates or surfaces. Install raceway sealing fittings according to NFPA 70.

See Evaluations for discussion of types of and locations for raceway seals.

- AA. Install devices to seal raceway interiors at accessible locations. Locate seals so no fittings or boxes are between the seal and the following changes of environments. Seal the interior of all raceways at the following points:
 - 1. Where conduits pass from warm to cold locations, such as boundaries of refrigerated spaces.
 - 2. Where an underground service raceway enters a building or structure.
 - 3. Where otherwise required by NFPA 70.
- BB. Comply with manufacturer's written instructions for solvent welding RNC and fittings.

Retain "Expansion-Joint Fittings" Paragraph below unless locations for expansion fittings for RNC are

indicated on Drawings. See Evaluations.

CC. Expansion-Joint Fittings:

1. Install in each run of aboveground RNC that is located where environmental temperature change may exceed **30 deg F (17 deg C)** and that has straight-run length that exceeds **25 feet (7.6 m)**. Install in each run of aboveground RMC **and EMT** conduit that is located where environmental temperature change may exceed **100 deg F (55 deg C)** and that has straight-run length that exceeds **100 feet (30 m)**.
2. Install type and quantity of fittings that accommodate temperature change listed for each of the following locations:

Revise list below to include all locations in Project with environmental conditions that require considering expansion-joint fittings in conduit runs. For each Project, consider only locations with PVC conduit with straight-run length exceeding 25 feet (7.6 m) or metal conduit in lengths over 100 feet (30 m). Also revise temperature change for each location so it safely represents conditions anticipated. Temperature-change figures below are examples of maximum total swings from the lowest to the highest environmental temperatures at the indicated types of locations and must be revised to represent temperature swings or changes that may occur at Project locations.

- a. Outdoor Locations Not Exposed to Direct Sunlight: **125 deg F (70 deg C)** temperature change.
- b. Outdoor Locations Exposed to Direct Sunlight: **155 deg F (86 deg C)** temperature change.
- c. Indoor Spaces Connected with Outdoors without Physical Separation: **125 deg F (70 deg C)** temperature change.

Formula in first subparagraph below provides about 15 percent safety factor (extra expansion-contraction capability).

3. Install fitting(s) that provide expansion and contraction for at least **0.00041 inch per foot of length of straight run per deg F (0.06 mm per meter of length of straight run per deg C)** of temperature change for PVC conduits. Install fitting(s) that provide expansion and contraction for at least **0.000078 inch per foot of length of straight run per deg F (0.0115 mm per meter of length of straight run per deg C)** of temperature change for metal conduits.
4. Install expansion fittings at all locations where conduits cross building or structure expansion joints.
5. Install each expansion-joint fitting with position, mounting, and piston setting selected according to manufacturer's written instructions for conditions at specific location at time of installation. Install conduit supports to allow for expansion movement.
6. Provide external bonding jumper for all expansion fittings..

Retain option in "Flexible Conduit Connections" Paragraph below if flexible connections are required for recessed and semirecessed luminaires.

- DD. Flexible Conduit Connections: Comply with NEMA RV 3. Use a maximum of **72 inches (1830 mm)** of flexible conduit for **recessed and semirecessed luminaires**, equipment subject to vibration, noise transmission, or movement; and for transformers and

motors. All vibrating equipment such as motors, transformers, and generators shall be connected with flexible steel conduit, not to exceed six feet in length.

1. Use LFMC in damp or wet locations subject to severe physical damage.
2. Use LFMC or LFNC in damp or wet locations not subject to severe physical damage.

- EE. Size conduit for conductor type installed or for Type THHN conductors, whichever is larger.
- FF. Arrange conduit to maintain headroom and present a neat appearance. Certain existing conditions may allow a waiver to this item.
- GG. Arrange conduit supports to prevent distortion of alignment by wire pulling operations. Fasten conduit using galvanized straps, lay-in adjustable hangers, clevis hangers, or bolted split stamped galvanized hangers.
- HH. Group conduit in parallel runs where practical and use conduit rack constructed of steel channel with conduit straps or clamps. Provide space for 25 percent additional conduit.
- II. Do not support conduit from cable tray or cable tray supports.
- JJ. Flexible conduit shall not be less than one-half (1/2) inch except when supplied with lighting fixtures. MC Cable shall be allowed in lieu of flexible conduit for light fixtures in lengths of 6 feet or less.
- KK. When anchoring to a dual sheet metal pan deck and concrete, anchors of any type when placed from below the deck shall be placed only in the lower pan form. No anchors shall be installed in the upper (high) pan.

X-ray is the preferred option. GPR is only allowed if specifically approved by the DEN Project Manager.

- LL. X-ray [or ground penetrating radar] studies shall be made of concrete floors, walls or CMU walls.
- MM. Mount boxes at heights indicated on Drawings. Install boxes with height measured to **center** of box unless otherwise indicated. Coordinate mounting heights and locations of boxes or outlets so as not to be interfered with by grounding systems, electrical panels, or any other building accessory.
- NN. Coordinate installation of outlet or equipment boxes for systems or products furnished under other sections.
- OO. Recessed Boxes in Masonry Walls: Saw-cut opening for box in center of cell of masonry block, and install box flush with surface of wall. Prepare block surfaces to provide a flat surface for a raintight connection between box and cover plate or supported equipment and box.
- PP. Horizontally separate boxes mounted on opposite sides of walls so they are not in the same vertical channel. Provide minimum 8 inch separation.

- QQ. Locate boxes so that cover or plate will not span different building finishes.
- RR. Support boxes of three gangs or more from more than one side by spanning two framing members or mounting on brackets specifically designed for the purpose.
- SS. Fasten junction and pull boxes to or support from building structure. Do not support boxes by conduits.
- TT. Set metal floor boxes level and flush with finished floor surface.
- UU. Set nonmetallic floor boxes level. Trim after installation to fit flush with finished floor surface.
- VV. Install electrical boxes as shown on Drawings, and as required for equipment, terminal strips, splices, taps, wire pulling, equipment connections and compliance with regulatory requirements.
- WW. Inaccessible Ceiling Areas: Install outlet and junction boxes no more than 6 inches from ceiling access panel or from removable recessed light fixture.
- XX. Align adjacent wall-mounted outlet boxes for switches, thermostats, and similar devices with each other.
- YY. Use adjustable steel channel fasteners or all thread for hanging ceiling outlet box, support box from structure.
- ZZ. Support boxes in the ceiling with ¼" threaded rod as a minimum.
- AAA. Use appropriate gang box where more than one device is mounted together.
- BBB. Use 4 inch square box with plaster ring for single device outlets.
- CCC. Use malleable iron outlet box when surface mounted: on exterior of building, in wet location or damp location.
- DDD. Minimum junction and pull box size 4-11/16" x 4-11/16" x 2-1/8" .
- EEE. Minimum outlet box size 4" x 4" x 2-1/8" including feed through outlet boxes.
- FFF. Minimum junction box size for fire alarm pull stations, control module, monitor module, 4" x 4" x 2-1/8". Provide plaster ring at all pull station locations.
- GGG. Use flush mounting outlet boxes in finished areas.
- HHH. Install knockout closure in unused box openings.
- III. Install cabinets and enclosures plumb; anchor securely to wall and structural supports at each corner, minimum.
- JJJ. All floor-mounted equipment shall be on a 4" nominal concrete housekeeping pad.

KKK. No cabinet shall be supported on slab or grade.

3.3 INSTALLATION OF UNDERGROUND CONDUIT

- A. Refer to Division 26 Section "Underground Ducts and Raceways for Electrical Systems" for underground conduit installation requirements.

3.4 INSTALLATION OF UNDERGROUND HANDHOLES AND BOXES

- A. Refer to Division 26 Section "Underground Ducts and Raceways for Electrical Systems" for underground handhole and box installation requirements

3.5 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.6 FIRESTOPPING

- A. Install firestopping at penetrations of fire-rated floor and wall assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.7 PROTECTION

- A. Protect coatings, finishes, and cabinets from damage and deterioration.
 - 1. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
 - 2. Repair damage to PVC coatings or paint finishes with matching touchup coating recommended by manufacturer.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260533

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SECTION 260536 - CABLE TRAYS FOR ELECTRICAL SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Ladder cable trays.
 - 2. Trough cable trays.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN ELECTRICAL ENGINEER

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data indicating dimensions and finishes for each type of cable tray indicated.

2. Include data indicating dimensions and finishes for each type of cable tray indicated.
- B. Shop Drawings: For each type of cable tray.
1. Show fabrication and installation details of cable trays, including plans, elevations, and sections of components and attachments to other construction elements. Designate components and accessories, including clamps, brackets, hanger rods, splice-plate connectors, expansion-joint assemblies, straight lengths, and fittings.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

- C. Delegated-Design Submittal: For seismic restraints.
1. Seismic-Restraint Details: Signed and sealed by a qualified professional engineer, licensed in the state where Project is located, who is responsible for their preparation.
 2. Design Calculations: Calculate requirements for selecting seismic restraints.
 3. Detail fabrication, including anchorages and attachments to structure and to supported cable trays.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans and sections, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Include scaled cable tray layout and relationships between components and adjacent structural, electrical, and mechanical elements.
 2. Vertical and horizontal offsets and transitions.
 3. Clearances for access above and to side of cable trays.
 4. Vertical elevation of cable trays above the floor or below bottom of ceiling structure.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Division 26 Section "Vibration and Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For cable trays, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.5 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.6 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Division 01 Section "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

- A. Delegated Design: Engage a qualified professional engineer, as defined in Division 01 Section "Quality Requirements," to design cable tray supports and seismic bracing.

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

- B. Seismic Performance: Cable trays and supports shall withstand the effects of earthquake motions determined according to **ASCE/SEI 7**.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification.

1. The term "withstand" means, "Cable trays will remain in place without separation

of any parts when subjected to the seismic forces specified."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: **1.0**.

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. **<Insert requirements for Component Amplification Factor and Component Response Modification Factor>**.

- C. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes in cable tray installed outdoors.

Differential values in "Temperature Change" Subparagraph below (for aluminum in particular) are suitable for most of the U.S.

1. Temperature Change: **120 deg F (67 deg C), ambient; 180 deg F (100 deg C), material surfaces.**

2.2 GENERAL REQUIREMENTS FOR CABLE TRAYS

If cable trays are identified for use via listing, then follow listing requirements. This may require that all interconnected cable trays be from single manufacturer. Some tray types may not be capable of being interconnected.

- A. Cable Trays and Accessories: Identified as defined in NFPA 70 and marked for intended location, application, and grounding.
 1. Source Limitations: Obtain cable trays and components from single manufacturer.

If using multiple types, sizes, or ratings of cable trays on a project, consider adding a table to Drawings.

- B. Sizes and Configurations: See the Cable Tray Schedule on Drawings for specific requirements for types, materials, sizes, and configurations.
- C. Structural Performance: See articles on individual cable tray types for specific values for the following parameters:

See "Load/Span Classification System" Article in the Evaluations.

1. Uniform Load Distribution: Capable of supporting a uniformly distributed load on the indicated support span when supported as a simple span and tested according to NEMA VE 1.
2. Concentrated Load: A load applied at midpoint of span and centerline of tray.
3. Load and Safety Factors: Applicable to both side rails and rung capacities.

- D. Circuit requirements: Electrical circuits of less than 50 volts can be installed in approved cable tray systems. Electrical circuits of less than 50 volts shall not be installed in cable tray systems.

2.3 LADDER CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Allied Tube & Conduit; a Tyco International Ltd. Co.
2. Chalfant Manufacturing Company.
3. Cope.
4. Cooper B-Line, Inc.
5. Mono-Systems, Inc.
6. MP Husky.
7. Niedax-Kleinhuis USA, Inc.
8. or approved equal.

- B. Description:

1. Configuration: Two I-beam side rails with transverse rungs welded to side rails.
2. Rung Spacing: 6 inches (150 mm) o.c.
3. Radius-Fitting Rung Spacing: 12 inches (300 mm) at center of tray's width.
4. Minimum Cable-Bearing Surface for Rungs: 7/8-inch (22-mm) width with radius edges.
5. No portion of the rungs shall protrude below the bottom plane of side rails.
6. Structural Performance of Each Rung: Capable of supporting a maximum cable load, with a safety factor of 1.5, plus a 200-lb (90-kg) concentrated load, when tested according to NEMA VE 1.
7. Minimum Usable Load Depth: 4 inches (100 mm).
8. Straight Section Lengths: 10 feet (3 m), except where shorter lengths are required to facilitate tray assembly.

Select required cable tray width.

9. Width: [6 inches (150 mm)] [9 inches (225 mm)] [12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)] [30 inches (750 mm)] [36 inches (900 mm)] unless otherwise indicated on Drawings.
10. Fitting Minimum Radius: 12 inches (300 mm).

The maximum uniform load and the support span are indicated by the cable tray class.

11. Class Designation: Comply with NEMA VE 1, Class 12C.
12. Splicing Assemblies: Bolted type using serrated flange locknuts.
13. Hardware and Fasteners: ASTM F 593 and ASTM F 594 stainless steel, Type 316 Steel, zinc plated according to ASTM B 633.
14. Splice Plate Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.

2.4 TROUGH CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, [provide products by the following] [provide products by one of the following]:
1. Allied Tube & Conduit; a Tyco International Ltd. Co.
 2. Chalfant Manufacturing Company.
 3. Cope.
 4. Cooper B-Line, Inc.
 5. Mono-Systems, Inc.
 6. MP Husky.
 7. Niedax-Kleinhuis USA, Inc.
 8. or approved equal.
- B. Description:
1. Configuration: Two (2) longitudinal members (side rails) with a solid sheet over rungs exposed on the interior of the trough, or corrugated sheet with both edges welded to the side rails.
 2. Rung Spacing: Rungs or corrugations shall be spaced a maximum of **6 inches (150 mm)** o.c. and have a minimum flat bearing surface of **2 inches (50 mm)**.
 3. Radius-Fitting Rung Spacing: **12 inches (300 mm)** at center of tray's width.
 4. Structural Performance: Capable of supporting a maximum cable load, with a safety factor of 1.5, plus a **200-lb (90-kg)** concentrated load, when tested according to NEMA VE 1.
 5. Minimum Usable Load Depth: **4 inches (100 mm)**.
 6. Straight Section Lengths: [**10 feet (3 m)**] except where shorter lengths are required to facilitate tray assembly.

Select required width.

7. Width: [**6 inches (150 mm)**] [**9 inches (225 mm)**] [**12 inches (300 mm)**] [**18 inches (450 mm)**] [**24 inches (600 mm)**] [**30 inches (750 mm)**] [**36 inches (900 mm)**] unless otherwise indicated on Drawings.
8. Fitting Minimum Radius: **12 inches (300 mm)**.

The maximum uniform load and the support span are indicated by the cable tray class.

9. Class Designation: Comply with NEMA VE 1, Class 12C.
10. Splicing Assemblies: Bolted type using serrated flange locknuts.
11. Splicing Assembly Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.
12. Hardware and Fasteners: ASTM F 593 and ASTM F 594 stainless steel, Type 316 Steel, zinc plated according to ASTM B 633.

2.5 VERTICAL (BACKBONE) COMMUNICATIONS PATHWAYS - CABLE TRAY

- A. Cable trays shall utilize dual side rails with 6-inch maximum rung spacing or solid bottom construction. When rung construction is utilized, the top of each rung shall be flat (required for fiber-optic cable). Cable tray covers are generally not required (or desired), however, when the use of covers is mandated, covers shall be hinged. Cable tray systems should be installed with a minimum number of horizontal bends and vertical transitions. Where such transitions are required, provide transition pieces manufactured for the purpose by the cable tray manufacturer. Field fabricated transitions or sections of tray abutting without transition pieces shall not be acceptable. The radius of all transitions for vertical communications pathways shall be a minimum of nine (9) feet measured to the inside rail of the tray.
- B. Cable tray size and supporting system shall be designed for the initial cabling requirements with spare capacity to support 100 percent future growth.
- C. Cable tray shall be installed with as much clearance as possible from other building facilities. A minimum clearance of 8-inches shall be maintained above any cable tray. Maintain 12-inches clearance on both sides of tray.
- D. Cable tray should generally not be installed above inaccessible hard ceiling locations. Where such conditions are unavoidable, person sized access panels shall be provided at 20 foot intervals and at any change of direction greater than 15 degrees. A complete cable tray rope and pulley system shall be installed in tray segments above inaccessible ceiling systems. Where used in plenum areas, pulley cord shall be constructed of plenum rated material.
- E. Cable tray shall terminate at the outside wall of communications room. The communications room penetration shall be made with a group of 4-inch metallic conduits equivalent in cross sectional area to the tray. Conduits shall be secured to both sides of the equipment room wall with unistrut and 4-inch unistrut clamps. Bonding bushings shall be provided on both sides of penetrating sleeves and bonded to tray / cable ladder on both sides. Firesafe between conduits and wall.
- F. When complete, tray shall be free and clear of all obstructions and free of burrs, sharp edges and protrusions. Label tray "DEN Telecommunications at 6'-0" intervals.

2.6 MATERIALS AND FINISHES

Retain one or more of "Steel," "Aluminum," and "Stainless Steel" paragraphs below. If using more than one type of cable tray material for Project, consider using a schedule to detail the specific requirements in each area. See "Cable Tray Materials" Article in the Evaluations.

A. Steel:

ASTM A 1011/A 1011M is for 14 gage and thicker; ASTM A 1008/A 1008M is for 16 gage and thinner. Both have structural-steel (SS) and high-strength, low-alloy-steel (HSLAS) designations.

1. Straight Section and Fitting Side Rails and Rungs: Steel complies with the minimum mechanical properties of [**ASTM A 1011/A 1011M, SS, Grade 33**]

[ASTM A 1008/A 1008M, Grade 33, Type 2].

2. Steel Tray Splice Plates: ASTM A 1011/A 1011M, HSLAS, Grade 50, Class 1.
3. Fasteners: Steel complies with the minimum mechanical properties of ASTM A 510/A 510M, Grade 1008.

Retain one of six "Finish" subparagraphs below or insert a different finish.

4. Finish: Mill galvanized before fabrication.
 - a. Standard: Comply with ASTM A 653/A 653M, **G90 (Z275)**.

Retain one option in "Hardware" Subparagraph below.

- b. Hardware: [**Galvanized, ASTM B 633**] [**Chromium-zinc plated, ASTM F 1136**].
5. Finish: Electrogalvanized before fabrication.
 - a. Standard: Comply with ASTM B 633.
 - b. Hardware: Galvanized, ASTM B 633.
6. Finish: Hot-dip galvanized after fabrication.
 - a. Standard: Comply with ASTM A123/A123 M, Class B2.

Retain one option in "Hardware" Subparagraph below.

- b. Hardware: [**Chromium-zinc plated, ASTM F 1136**] [**Stainless steel, Type 316**].
7. Finish: Epoxy-resin Powder-coat enamel paint.
 - a. Powder-Coat Enamel: Cable tray manufacturer's recommended primer and corrosion-inhibiting treatment, with factory-applied powder-coat paint.
 - b. Epoxy-Resin Prime Coat: Cold-curing epoxy primer, MPI# 101.
 - c. Epoxy-Resin Topcoat: Epoxy, cold-cured, gloss, MPI# 77.

Retain one option in "Hardware" Subparagraph below.

- d. Hardware: [**Chromium-zinc plated, ASTM F 1136**] [**Stainless steel, Type 316, ASTM F 593 and ASTM F 594**].
8. Finish: Factory-standard primer, ready for field painting, with chromium-zinc-plated hardware according to ASTM F 1136.
9. Finish: Black oxide finish for support accessories and miscellaneous hardware according to ASTM D 769.
10. **<Insert finish>**.

B. Aluminum:

1. Materials: Alloy 6063-T6 according to ANSI H35.1/H 35.1M for extruded components, and [**Alloy 5052-H32**] [**or**] [**Alloy 6061-T6**] according to ANSI H35.1/H 35.1M for fabricated parts.
2. Hardware: Chromium-zinc-plated steel, ASTM F 1136 Stainless steel, Type 316, ASTM F 593 and ASTM F 594.

3. Hardware for Aluminum Cable Tray Used Outdoors: Stainless steel, Type 316, ASTM F 593 and ASTM F 594.

C. Stainless Steel:

1. Materials: Low-carbon, passivated, stainless steel, [Type 304L] [or] [Type 316L], ASTM F 593 and ASTM F 594.
2. Hardware for Stainless-Steel Cable Tray Used Outdoors: Stainless steel, Type 316, ASTM F 593 and ASTM F 594.

2.7 CABLE TRAY ACCESSORIES

- A. Fittings: Tees, crosses, risers, elbows, and other fittings as indicated, of same materials and finishes as cable tray.

If more than one cable tray cover type is required, delete "Covers" Paragraph below and indicate type on Drawings or in a schedule. Retain paragraph if cable tray covers are required. See "Cable Tray Covers" Article in the Evaluations.

- B. Covers: [Solid] [Louvered] [Ventilated-hat] [2-in-3 pitch] type made of same materials and with same finishes as cable tray.

Indicate required locations for barrier strips on Drawings.

- C. Barrier Strips: Same materials and finishes as for cable tray.
- D. Cable tray supports and connectors, including bonding jumpers, as recommended by cable tray manufacturer.

2.8 WARNING SIGNS

Insert different lettering size in "Lettering" Paragraph below to suit 25-foot (7.6-m) viewing distance.

- A. Lettering: 1-1/2-inch- (40-mm) high, black letters on yellow background with legend "Warning! Not To Be Used as Walkway, Ladder, or Support for Ladders or Personnel."
- B. Comply with requirements for fasteners in Section 260553 "Identification for Electrical Systems."

2.9 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect cable trays according to NEMA VE 1.

PART 3 - EXECUTION

3.1 CABLE TRAY INSTALLATION

NEMA FG 1 applies to fiberglass cable trays only. NEMA VE 2 applies to all metallic cable trays.

- A. Install cable trays according to NEMA VE 1.
- B. Install cable trays as a complete system, including fasteners, hold-down clips, support systems, barrier strips, adjustable horizontal and vertical splice plates, elbows, reducers, tees, crosses, cable dropouts, adapters, covers, and bonding.
- C. Install cable trays so that the tray is accessible for cable installation and all splices are accessible for inspection and adjustment.
- D. Cut standard straight sections to length in field.
- E. Remove burrs and sharp edges from cable trays.
- F. Join aluminum cable tray with splice plates; use four square-neck carriage bolts and locknuts.
- G. Fasten cable tray supports to building structure and install seismic restraints.

Retain first paragraph below if deleting "Delegated Design" Paragraph in "Performance Requirements" Article. Delete below if retaining "Delegated Design" Paragraph.

- H. Design fasteners and supports to carry cable tray, the cables, and a concentrated load of 200 lb (90 kg). Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems." Comply with seismic-restraint details according to Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- I. Support cable tray at each connection point, at the end of each run, and at other points to maintain maximum spacing between supports of 10 feet (3 m) for ladder cable tray.
- J. Place supports so that spans do not exceed maximum spans on schedules and provide clearances shown on Drawings. Install intermediate supports when cable weight exceeds the load-carrying capacity of the tray rungs.
- K. Construct supports from channel members, threaded rods, and other appurtenances furnished by cable tray manufacturer. Arrange supports in trapeze or wall-bracket form as required by application.
- L. Support bus assembly to prevent twisting from eccentric loading.
- M. Install center-hung supports for single-rail trays designed for 60 versus 40 percent eccentric loading condition, with a safety factor of 3.
- N. Do not install more than one cable tray splice between supports.

Retain first paragraph below if cable trays connect to equipment.

- O. Make connections to equipment with flanged fittings fastened to cable trays and to equipment. Support cable trays independent of fittings. Do not carry weight of cable trays on equipment enclosure.

Retain first paragraph below if expansion fittings are required.

- P. Install expansion connectors where cable trays cross building expansion joints.
- Q. Make changes in direction and elevation using manufacturer's recommended fittings.
- R. Make cable tray connections using manufacturer's recommended fittings.
- S. Seal penetrations through fire and smoke barriers. Comply with requirements in Division 07 Section "Penetration Firestopping."

If cable trays are sized for future cables, specify provisions for penetrations with sleeves through fire-rated partitions or use "repairable" firestop-sealing material. Include this Section's specific firestopping requirements in a schedule developed in Division 07 Section "Penetration Firestopping."

- T. Install capped metal sleeves for future cables through firestop-sealed cable tray penetrations of fire and smoke barriers.
- U. Install cable trays with enough workspace to permit access for installing cables.

Retain first paragraph below if systems are mixed in a single cable tray.

- V. Install barriers to separate cables of different systems, such as power, communications, and data processing; or of different insulation levels, such as 600, 5000, and 15 000 V.

See "Cable Tray Covers" Article in the Evaluations.

- W. Install permanent covers, if used, after installing cable. Install cover clamps according to NEMA VE 2.
- X. Covers with hold down clamps shall be installed on all cable trays installed under open metal grates.
- Y. Clamp covers on cable trays installed outdoors with heavy-duty clamps.
- Z. Install warning signs in visible locations on or near cable trays after cable tray installation.
- AA. X-ray or ground penetrating radar studies shall be made of concrete floors, walls or CMU walls and an interpretation of the findings shall be provided to the DEN Project Manager prior to any core drilling or saw cutting.
- BB. When anchoring to a dual sheet metal pan deck and concrete, anchors of any type when placed below the deck shall be placed only in the lower pan form. No anchors

shall be installed in the upper (high) pan. All concrete type anchors shall be installed in drilled holes.

3.2 CABLE TRAY GROUNDING

- A. Ground cable trays according to NFPA 70 unless additional grounding is specified. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems.
- B. Cable trays with electrical power conductors shall be bonded together with splice plates listed for grounding purposes or with listed bonding jumpers.
- C. Install equipment ground bond between conduit and cable tray.

Verify that cable tray system is specified for grounding and bonding the largest power conductor in the tray. If system is not specified, retain first paragraph below and revise to suit Project.

- D. Cable trays with single-conductor power conductors shall be bonded together with a grounding conductor run in the tray along with the power conductors and bonded to the tray at 72-inch (1800-mm) intervals. The grounding conductor shall be sized according to NFPA 70, Article 250.122, "Size of Equipment Grounding Conductors," and Article 392, "Cable Trays."
- E. When using epoxy- or powder-coat painted cable trays as a grounding conductor, completely remove coating at all splice contact points or ground connector attachment. After completing splice-to-grounding-bolt attachment, repair the coated surfaces with coating materials recommended by cable tray manufacturer.
- F. Bond cable trays to power source for cables contained within with bonding conductors sized according to NFPA 70, Article 250.122, "Size of Equipment Grounding Conductors."

3.3 CABLE INSTALLATION

- A. Install cables only when each cable tray run has been completed and inspected.

Fastening cables on horizontal runs is beyond the requirements of NFPA 70 in most cases. See Evaluations.

- B. Fasten cables on horizontal runs with cable clamps or cable ties according to NEMA VE 2. Tighten clamps only enough to secure the cable, without indenting the cable jacket. Install cable ties with a tool that includes an automatic pressure-limiting device.
- C. Fasten cables on vertical runs to cable trays every 18 inches (450 mm).

Length of unsupported cable is dependent on the cable diameter. See "Cable Installations" Article in Evaluations.

- D. Fasten and support cables that pass from one cable tray to another or drop from cable

trays to equipment enclosures. Fasten cables to the cable tray at the point of exit and support cables independent of the enclosure. The cable length between cable trays or between cable tray and enclosure shall be no more than **72 inches** (1800 mm).

- E. Tie MI cables down every **36 inches** (900 mm) where required to provide a 2-hour fire rating and every **72 inches** (1800 mm) elsewhere.
- F. In existing construction, remove inactive or dead cables from cable trays.

3.4 CONNECTIONS

- A. Remove paint from all connection points before making connections. Repair paint after the connections are completed.
- B. Connect raceways to cable trays according to requirements in NEMA VE 2.
- C. All conduits to be attached and bonded to cable tray with approved fittings.

3.5 FIELD QUALITY CONTROL

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following tests and inspections **with the assistance of a factory-authorized service representative**:
 1. After installing cable trays and after electrical circuitry has been energized, survey for compliance with requirements.
 2. Visually inspect cable insulation for damage. Correct sharp corners, protuberances in cable trays, vibrations, and thermal expansion and contraction conditions, which may cause or have caused damage.
 3. Verify that the number, size, and voltage of cables in cable trays do not exceed that permitted by NFPA 70. Verify that communications or data-processing circuits are separated from power circuits by barriers or are installed in separate cable trays.
 4. Verify that there are no intruding items such as pipes, hangers, or other equipment in the cable tray.
 5. Remove dust deposits, industrial process materials, trash of any description, and any blockage of tray ventilation.
 6. Visually inspect each cable tray joint and each ground connection for mechanical continuity. Check bolted connections between sections for corrosion. Clean and retorque in suspect areas.
 7. Check for improperly sized or installed bonding jumpers.
 8. Check for missing, incorrect, or damaged bolts, bolt heads, or nuts. When found, replace with specified hardware.
 9. Perform visual and mechanical checks for adequacy of cable tray grounding; verify that all takeoff raceways are bonded to cable trays. Test entire cable tray

system for continuity. Maximum allowable resistance is 1 ohm.

- B. Prepare test and inspection reports.

3.6 PROTECTION

- A. Protect installed cable trays and cables.
 1. Install temporary protection for cables in open trays to safeguard exposed cables against falling objects or debris during construction. Temporary protection for cables and cable tray can be constructed of wood or metal materials and shall remain in place until the risk of damage is over.
 2. Repair damage to galvanized finishes with zinc-rich paint recommended by cable tray manufacturer.
 3. Repair damage to paint finishes with matching touchup coating recommended by cable tray manufacturer.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260536

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SECTION 260539 - UNDERFLOOR RACEWAYS FOR ELECTRICAL SYSTEMS

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes the following:
 - 1. Flat-top, single-channel, underfloor raceways.
 - 2. Flat-top, multichannel, underfloor raceways.
 - 3. Flush, flat-top underfloor raceways.
 - 4. Cellular metal underfloor raceways.
 - 5. Trench-type underfloor raceways.

Coordinate first two subparagraphs below with structural deck Drawings and Specifications. Cellular concrete floor decks are specified in Division 03 Section "Precast Structural Concrete," and cellular steel floor decks are specified in Division 05 Section "Steel Decking."

- 6. Electrical connection components for precast concrete, hollow-core, floor decks.
- 7. Electrical connection components for electrified cellular steel floor decks.
- 8. Service fittings.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

The following definitions are for terms used in this Section. Retain terms that remain after this Section has

been edited.

- A. Flush Outlet: Underfloor raceway outlet installed so the top of the fixed portions of the receptacles, jacks, and connector assemblies is located approximately at the surface of the floor or floor covering, and with the bodies of connected plugs exposed above the surface of the floor.
- B. Flush Underfloor Raceway: Rectangular cross-section, flat-top raceway installed with the top of the raceway flush with the surface of the concrete in which it is embedded.
- C. Header Raceway: Rectangular cross-section, single-channel or multichannel, underfloor raceway arranged as feeder raceway to bring wires and cables to service raceways from panelboards and communication terminal components.
- D. Recessed Outlet: Underfloor raceway outlet installed with the top of the fixed portion of the connector assemblies located below the surface of the floor or floor covering and arranged to receive plug connectors with the bodies of the plugs concealed below the floor level.
- E. Service Raceway: Underfloor distribution raceway providing direct connection to service fittings using preset or afterset inserts.
- F. Trench Header: Trench-type raceway arranged as feeder raceway to bring wires and cables to service raceways from panelboards and communication terminal equipment.
- G. Underfloor Raceway: A conduit, duct, or cell assembly, or trench located within the floor material or with its top at the floor surface.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For underfloor raceway components, fittings, and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For underfloor raceways. Include floor plans, assembly drawings, sections, and details.
 - 1. Identify components and accessories such as expansion-joint assemblies, straight raceway lengths, preset and afterset inserts, and service fittings.
 - 2. Provide dimensions locating raceway header and distribution elements. Include spacing between preset inserts and between preset inserts and ends of duct runs, walls, columns, junction boxes, and header duct connections.
 - 3. Show connections between raceway elements and relationships between components and adjacent structural and architectural elements including slab reinforcement, floor finish work, permanent partitions[, **architectural module lines**] [, and **pretensioning or post-tensioning components**].
 - 4. Indicate height of preset inserts, junction boxes, and raceways coordinated with

- depth of concrete slab and floor fill.
5. Indicate thickening of slabs where required for adequate encasement of raceway components.
 6. Document coordination of exposed components with floor-covering materials to ensure that fittings and trim are suitable for indicated floor-covering material.
 7. Revise locations from those indicated in the Contract Documents, as required to suit field conditions and to ensure a functioning layout. Identify proposed deviations from the Contract Documents.
 8. Show details of connections and terminations of underfloor raceways at panelboards and communication terminal equipment in equipment rooms, wire closets, and similar spaces.

Retain subparagraph and associated subparagraphs below if Project includes electrified cellular floor deck.

9. Identify those cells of cellular floor deck that are to be connected and fitted for the following underfloor distribution:

Retain one or more of six subparagraphs below.

- a. Power.
- b. Voice.
- c. Data.
- d. Signal.
- e. Communications.
- f. <Insert system>.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: For typical underfloor raceway products, in specified finish, including the following:

Retain subparagraphs below required for approval of exposed finishes or other critical features.

1. Service fittings and flush and recessed outlet and junction-box covers.
2. A section of each service raceway configuration with specified preset insert and service fitting installed.
3. A junction box of each size and type for use with underfloor raceway.
4. A section of each header raceway configuration, complete with provisions for connection with service raceway.
5. A section of trench-type raceway, complete with cover and required trim.
6. A junction box of each size and type, complete with cover and trim.

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- A. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For underfloor raceways, to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:
1. Manufacturer's written instructions for locating preset inserts and for installing afterset inserts.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Retain one of first two subparagraphs below. Retain first subparagraph for cellular concrete floor installations; retain second for steel underfloor raceway or cellular steel floor installations.

1. Afterset Inserts: Furnish quantity equal to **[10] <Insert number>** percent of service fittings installed.
2. Afterset Inserts: Furnish quantity equal to **[5] <Insert number>** percent of each type of preset insert installed.
3. Service Fittings: Furnish **[3] <Insert number>** of each type of service fitting indicated for each **100 feet (30 m)** of distribution raceway or active-floor-cell length.
4. Outlet Blanking Covers: Furnish quantity equal to **[10] <Insert number>** percent of each type of floor opening installed for outlets.
5. **<Insert item and quantity>**.

Retain two paragraphs and associated subparagraphs below to provide tools for Owner's maintenance staff.

- B. Furnish **[one (1)] <Insert number>** electronic instrument(s) as recommended by underfloor raceway manufacturer for detecting and locating preset inserts in metal raceway under floor covering and up to **3/8 inch (10 mm)** of concrete fill.
- C. Furnish **[one (1)] <Insert number>** set(s) of tools needed for installing afterset inserts in underfloor service raceway, including the following:

1. Electric Drill: Variable speed, 1/2-inch (13-mm) capacity.

Afterset inserts for multiple-system service fittings in multichannel or multicell raceways may require hole saw larger than 2 inches (50-mm). Coordinate with underfloor raceways specified.

2. Hole Saw: Diamond bit, [2-inch (50-mm)] <Insert dimension> size.
3. Insert installation tool.
4. <Insert name of tool>.

1.8 QUALITY ASSURANCE

Retain paragraph and subparagraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Division 01 Section "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

Retain one of first two paragraphs below. Retain first paragraph for electrified cellular steel floor-deck applications; retain second for all other underfloor raceway installations.

- A. Source Limitations for Electrified Cellular Steel Floor-Deck Components: Obtain electrical components such as preset inserts, afterset inserts, service fittings, header ducts, and trench header ducts from the cellular steel floor-deck manufacturer.
- B. Source Limitations: Obtain underfloor raceway components for each system through one source from single manufacturer.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with NFPA 70.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Retain one of first five articles below to specify underfloor raceways. Delete all five articles and retain either the sixth or seventh article to specify electrical fittings, accessories, and connection products used to electrify hollow cells of structural precast concrete or steel cellular floor decks that are specified in Divisions 03 and 05, respectively.

2.1 FLAT-TOP, SINGLE-CHANNEL, UNDERFLOOR RACEWAYS

Retain this Article to specify steel, rectangular, flat-top, single-channel raceways, sometimes called "conventional underfloor raceways" or "single-compartment underfloor ducts." Use service raceways with rectangular preset inserts for flush duplex receptacle and dual telecommunications service fittings. Use round preset inserts for projects with flush service fittings limited to either single-power or single-communication connections, and surface-mounted service fittings limited to single-system, pedestal type.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of three paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Square D; Schneider Electric.
 2. Thomas & Betts Corporation; Steel City Division.
 3. Walker Systems, Inc.; a Wiremold company.
 4. **<Insert manufacturer>**
 5. or approved equal.

Indicate quantity and arrangement of underfloor raceways on Drawings.

- B. Description:
1. Material: Steel.
 2. Cross-Section Shape: Rectangular.

Two-level arrangement in subparagraph below may not be available from all listed manufacturers.

3. Number of Levels: [**One (1)**] [**Two (2)**].

Retain subparagraph below if fiber-optic or Category 5, 5e, or 6 cables may be installed in communication raceways. Verify capability of achieving minimum bending radius with manufacturers.

4. Minimum Bending Radius for Communication Cables: Combination of raceways, fittings, inserts, junction boxes, service fittings, and mounting and connection arrangements for wiring devices and jacks shall provide a **2-inch-** (50-mm-) minimum bending radius for communication cables.

- C. Service Raceways: Fitted with preset inserts.

1. Nominal Raceway Dimensions:
 - a. Depth: **1-1/2 inches** (38 mm).
 - b. Power Service Raceway Width: **3-1/2 inches** (90 mm).
 - c. Communication Service Raceway Width: [**3-1/2 inches** (90 mm)] [**6-1/2 inches** (165 mm)].

Retain first subparagraph below to establish default arrangement of service raceway runs and to establish default configuration of junction boxes. Delete if number of single-channel raceways per run is indicated on Drawings.

2. Number of Single-Channel Raceways per Run: **[One]** **[Two]** **[Three]** **[Four]** **[Five]** unless otherwise indicated.
3. Preset Inserts: **[Rectangular]** **[Round]**.
 - a. Spacing: **[24 inches (600 mm)]** **[12 inches (300 mm)]** o.c.

Retain one of first two subparagraphs below. Retain first subparagraph for rectangular inserts; retain second for round inserts.

- b. Size: Rectangular dimensions as required to accommodate mounting and connection of flush-mounted, duplex receptacle or dual communication-jack or connector service fitting.
- c. Size: **[2 inches (50 mm)]** **<Insert dimension>** in diameter.
- d. Equip each insert with a disposable cover and select insert height so cover is **1/8 inch (3 mm)** below surface of concrete.
- e. Arrange insert for optional attachment of flush-, surface-, or wiring-extension service fitting to replace disposable cover.

Retain paragraph and subparagraphs below if flat-top, single-channel raceway is used as header raceway for either single- or two-level arrangement of raceway. 3-1/2-inch- (90-mm-) wide raceways may be adequate for some power and communication header applications. Indicate header location and arrangements on Drawings.

D. Header Raceways: Single channel, without preset inserts (blank raceway).

1. Nominal Raceway Dimensions:
 - a. Depth: **1-1/2 inches (38 mm)**.

See Evaluations for selecting dimensions of raceways for underfloor raceway layouts. Retain two subparagraphs below if nominal width of raceways is not indicated on Drawings. If widths of header raceways vary, delete two subparagraphs below and indicate widths on Drawings.

- b. Power Header Raceway Width: **3-1/2 inches (90 mm)**.
- c. Communication Header Raceway Width: **[3-1/2 inches (90 mm)]** **[6-1/2 inches (165 mm)]**.

Retain first option in first subparagraph below for single-level arrangement.

2. Arrangement: **[In same plane as]** **[Below]** service raceways.
3. Connections: Arranged to connect with service raceways at **[single]** **[two]**-level junction boxes.

2.2 FLAT-TOP, MULTICHANNEL, UNDERFLOOR RACEWAYS

Retain this Article for underfloor raceway systems capable of providing a grid of multigang, multiple-system outlets that are flush with the floor throughout the area served. Raceways in this Article can also serve single- or multiple-system, surface-mounted outlets and can be connected to raceways that feed wall-mounted outlets. See Evaluations for discussion.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of three paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Square D; Schneider Electric.
 2. Thomas & Betts Corporation; Steel City Division.
 3. **<Insert manufacturer>**
 4. or approved equal.

If the number of channels varies among service raceways, revise first paragraph and subparagraphs below and indicate the number of channels in each service raceway on Drawings.

Verify with manufacturers the number of channels available.

- B. Description:
1. Material: Steel.
 2. Cross-Section Shape: Rectangular.
 3. Number of Longitudinal Channels: **[Two] [Three] [Four]**, separated by steel wall(s).

Verify with manufacturers the number of levels available.

4. Number of Levels: **[One] [Two]**.

Retain subparagraph below if fiber-optic or Category 5, 5e, or 6 cables may be installed in communication raceways. Verify capability of achieving minimum bending radius with manufacturers.

5. Minimum Bending Radius for Communication Cables: Combination of raceways, fittings, inserts, junction boxes, service fittings, and mounting and connection arrangements for wiring devices and jacks shall provide a **2-inch-** (50-mm-) minimum bending radius for communication cables.

- C. Service Raceways: Fitted with preset inserts.

1. Nominal Raceway Dimensions:
 - a. Depth: **1-3/8 inches** (35 mm).

See Evaluations for selecting dimensions of raceways for underfloor raceway layouts. Retain first two subparagraphs below if nominal width of raceways is not indicated on Drawings.

- b. Power Service Channel Width: **[3-1/2 inches** (90 mm)] **[4-3/8-inches** (111 mm)] **<Insert dimension>**.
- c. Communication Service Channel Width: **[3-1/2 inches** (90 mm)] **[4 inches** (102 mm)] **[6-1/2 inches** (165 mm)] **<Insert dimension>**.

2. Preset Inserts:
 - a. Spacing: **[24 inches** (600 mm)] **[12 inches** (300 mm)] o.c.
 - b. Size: Dimensions as required to accommodate mounting and connection of flush- and surface-mounted, single- and multiple-system service fittings or to connect to wiring extensions for feeding wall outlets for **[power] [communications] [power and communications] <Insert system>**.
 - c. Equip each insert with a disposable cover arranged for installation with top

- 1/8 inch (3 mm)** below surface of concrete.
- d. Arrange inserts for optional attachment of flush-, surface-, or wiring-extension service fitting to replace disposable cover. Arrange brackets, mountings, barriers, and floor access covers to support, isolate, and provide access to **[flush] [or] [surface]** outlet-mounting connector, jack, and receptacle devices.

Retain paragraph and subparagraphs below if flat-top, multichannel raceway is used as header raceway for either single- or two-level arrangements of distribution raceway.

D. Header Raceways: Multichannel, without preset inserts (blank raceway).

1. Nominal Raceway Dimensions:

See Evaluations for selecting dimensions of raceways. Retain subparagraph below only if extra header raceway capacity is required beyond that provided by nominal 1-3/8-inch (35-mm) depth. Selection of nominal depth more than 1-3/8 inches (35 mm) may result in a proprietary specification because only one manufacturer catalogs extra-deep header raceway of this type. Consult manufacturers.

- a. Header Raceway Depth: [Same as service raceways] **[2-1/2 inches (64 mm)] [2-3/4 inches (70 mm)] [3 inches (76 mm)] [3-1/2 inches (90 mm)]**.

Retain first two subparagraphs below if nominal width of channels is not indicated on Drawings.

- b. Power Header Channel Width: **[3-1/2 inches (90 mm)] [4-3/8-inches (111 mm)] <Insert dimension>**.
- c. Communication Header Channel Width: **[3-1/2 inches (90 mm)] [4 inches (102 mm)] [6-1/2 inches (165 mm)] <Insert dimension>**.

2. Arrangement: **[In same plane as] [Below]** service raceways.
3. Connections: Arranged to connect with service raceways at **[single] [two]**-level junction boxes.

2.3 FLUSH, FLAT-TOP UNDERFLOOR RACEWAYS

Retain this Article for single-channel or multichannel underfloor raceways to be installed on floor slab with top of raceway flush with concrete topping added thereafter, and then covered with finish material. See Evaluations for additional application considerations.

Only one manufacturer now catalogs these products, so they may be proprietary.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of first three paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Walker Systems, Inc.; a Wiremold company.
 2. **<Insert manufacturer>**
 3. or approved equal.

- B. Description:
1. Material: Steel.
 2. Cross-Section Shape: Rectangular, [**single channel**] [**and**] [**multichannel, separated by steel wall(s)**].
 3. Listed and labeled for installation with top flush with concrete floor.
 4. Number of Levels: One.
- C. Service Raceways: Fitted with preset inserts.

Retain subparagraph below for flush, multichannel raceway installations.

1. Number of Longitudinal Channels per Multichannel Raceway: [**Two**] [**Three**].

Retain first subparagraph below for flush, single-channel raceway installations.

2. Number of Single-Channel Raceways per Run: [**One**] [**Two**] [**Three**] unless otherwise indicated.
 3. Nominal Channel Dimensions: **3 inches** (76 mm) wide by **1-1/4 inches** (32 mm) deep.
 4. Preset Inserts: Threaded opening with removable steel plug that is flush with top of raceway when screwed in place.
 - a. Spacing: [**24 inches** (600 mm)] [**12 inches** (300 mm)] o.c., full length of each service raceway.
 - b. Arrangement: Stagger insert locations on parallel raceways or channels to accommodate placement of adjacent service fittings.
 - c. Size: **1-5/8-inch** (41-mm) diameter.
- D. Header Raceways: Raceways same as service raceways except without preset inserts (blank raceway).
1. Nominal Channel Dimensions: Same as service raceways.
 2. Arrangement: In same plane as service raceways.
 3. Connections: Arranged to connect with service raceways at junction boxes.

2.4 CELLULAR METAL UNDERFLOOR RACEWAYS

Retain this Article for longitudinal runs of multichannel underfloor service raceways that have the appearance of three-cell sections cut from sheets of cellular floor decking, and to specify raceway layouts similar to those for flat-top, rectangular, multichannel raceways specified above. Also retain this Article for other products required for header and feeder raceways. See Evaluations for application considerations.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of first three paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. HH Robertson; Division of CENTRIA.

2. Walker Systems, Inc.; a Wiremold company.
3. <Insert manufacturer>
4. or approved equal.

B. Service Raceways: Fitted with preset inserts.

1. Material: Steel.
2. Number of Longitudinal Cells: Three, separated by steel walls.
3. Nominal Dimensions of Cells:
 - a. Overall Depth: 1-1/4 inches (32 mm) unless otherwise indicated.
 - b. Cross-Sectional Area of Cells: Power cells: 5-1/2 sq. in. (35.5 sq. cm); communication system cells: 16 sq. in. (103 sq. cm).

Retain subparagraph below if fiber-optic or Category 5, 5e, or 6 cables are to be installed in communication raceways. Verify capability of achieving minimum bending radius with manufacturers.

4. Minimum Bending Radius for Communication Cables: Combination of raceways, fittings, inserts, junction boxes, service fittings, and mounting and connection arrangements for wiring devices and jacks shall provide a 2-inch- (50-mm-) minimum bending radius for communication cables.

Indicate types and locations of service fittings on Drawings.

5. Preset Inserts: Rectangular-shaped metal housing assemblies arranged to provide electrical outlet access to each cell of each raceway designated for service raceway use. Inserts shall be provided throughout the entire length of each such raceway.
 - a. Spacing: [30 inches (762 mm)] [24 inches (600 mm)] [12 inches (300 mm)] o.c.
 - b. Include housing and connecting provisions for a flush or recessed, single-, double-, or triple-system service fitting.
 - c. Include mounting and connecting provisions for a surface, single- or multiple-system service fitting.
 - d. Include connecting provisions for a wiring-extension service fitting to feed wall outlets.
 - e. Equip each insert with a disposable cover plate arranged for installation with top 1/8 inch (3 mm) below surface of concrete. Arrange insert to receive a flush-, recessed-, or wiring-extension service fitting to replace disposable top.

Retain paragraph and applicable subparagraphs below if trench-type raceway is not used or is not the sole product to be employed as header raceway to feed the cellular service raceways. See Evaluations. Indicate arrangement of header raceways on Drawings.

C. Header Assembly: A junction box and raceway arrangement arranged to feed wires and cables to service raceways.

Retain one of two subparagraphs and associated subparagraphs below.

1. Three-compartment junction box connecting blank, multicell cellular header

raceway (no inserts) with cellular service raceways.

Indicate location of junction boxes on Drawings.

- a. Arrange junction box in the center of a [60-inch (152-cm)] <Insert dimension> length of header raceway.
 - b. Cellular header raceway shall have same dimensions as service raceways.
 - c. Provide capability for service raceways to be run in both directions from intersection with header raceway.
2. Three-compartment junction box preassembled with blank, flat-top, multichannel header raceway (no inserts) and fitted to connect with cellular service raceway at right angles to header raceway.

Indicate location of junction boxes on Drawings.

- a. Arrange junction box in the center of a [60-inch (152-cm)] <Insert dimension> length of header raceway.
- b. Provide capability for service raceways to be run in both directions from intersection with header raceway.

2.5 TRENCH-TYPE UNDERFLOOR RACEWAYS

Retain this Article for trench-type raceway, sometimes called "trench duct," used as header or feeder raceway to serve service raceways. See Evaluations for application discussion and comparison with alternative types of header raceway.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. HH Robertson; Division of CENTRIA.
 2. Square D; Schneider Electric.
 3. Thomas & Betts Corporation; Steel City Division.
 4. Walker Systems, Inc.; a Wiremold company.
 5. <Insert manufacturer>
 6. or approved equal.

Indicate sizes and locations of trench raceways on Drawings.

- B. Trench: Steel, shop or factory welded and fabricated to indicated sizes. Include the following features:
1. Slab Depth Adjustment: Minimum of minus 1/8 inch (3 mm) to plus 5/8 inch (16 mm) before and during concrete placement.
 2. Cover Supports: Height adjustable, with leveling screws to rigidly support cover assembly.
 3. Screed Strip: Extruded aluminum along both edges at proper elevation without

- requiring shim material.
- 4. Trim Strip: Select to accommodate floor finish material.
- 5. Partitions: Arranged to separate channels and isolate wiring of different systems.

When used with cellular concrete or cellular steel deck, designate active service raceway cells on Drawings to facilitate provision of grommets openings required in first subparagraph below.

- 6. Grommets openings in active floor cells or service raceways.
 - 7. Manufacturer's standard corrosion-resistant finish, applied after fabrication.
- C. Cover Plates: Removable, steel plates, 1/4 inch (6 mm) thick, each weighing 60 lb (27 kg) or less with full gasket attached to side units. Fabricate intermediate supports to limit unsupported spans to [15 inches (380 mm)] <Insert dimension> or less. Fabricate covers with appropriate depth recess to receive indicated floor finish.

2.6 ELECTRICAL CONNECTION COMPONENTS FOR CELLULAR STEEL FLOOR DECK

Retain this Article with articles for header and feeder raceways for use with electrified structural cellular steel floor deck specified in Division 05 Section "Steel Decking." Coordinate with Structural and Electrical Drawings.

- A. Preset Inserts: Rectangular metal-housing assemblies.
- 1. Spacing: [30 inches (762 mm)] [24 inches (600 mm)] [12 inches (300 mm)] o.c.
 - 2. Size: As required to provide electrical outlet access to each cell of each group of three cells that is designated for electrical service raceway use.
 - 3. Equip each insert with a disposable cover arranged for installation with top 1/8 inch (3 mm) below surface of concrete. Arrange insert to receive a flush-, recessed-, or wiring-extension service fitting to replace disposable cover.

Retain one of first two subparagraphs below.

- 4. Include housing and connecting provisions for a flush or recessed, single-, double-, or triple-system service fitting.
- 5. Include mounting and connecting provisions for a surface, single-, double-, or triple-system service fitting.
- 6. Include connecting provisions for a wiring-extension service fitting to feed wall outlets.

2.7 ELECTRICAL CONNECTION COMPONENTS FOR CELLULAR CONCRETE FLOOR DECK

Retain this Article with articles for header and feeder raceways for use with electrified structural cellular concrete floor deck specified in Division 03 Section "Precast Structural Concrete." Coordinate with Structural and Electrical Drawings.

- A. Afterset Inserts: Round metal-nipple assembly with internal and external threading, arranged to screw into plug driven into 1-7/8-inch (48-mm) hole drilled through floor fill, where present, and deck-cell wall into floor raceway cell.

Indicate location and type of afterset inserts on Drawings.

1. Inserts shall be compatible with floor-mounting service fittings.
2. Inserts shall provide wiring path from cell to [power] [communication] [power and communication] <Insert system> [wall] [and] [ceiling] outlets.
3. Inserts shall provide wiring path from cell to header raceway.

2.8 SUPPORTS, FITTINGS, AND HARDWARE

- A. Supports, fittings, and hardware shall be compatible with raceway and outlet system and shall be listed for use with raceway systems and components specified.
- B. Supports: Adjustable for height and arranged to maintain alignment and spacing of raceways during concrete placement. Include hold-down straps.
- C. Raceway Fittings: Couplings, expansion-joint sleeves, cross-under offsets, vertical and horizontal elbows, grounding screws, adapters, end caps, and other fittings suitable for use with basic components to form a complete installation.

2.9 JUNCTION BOXES

Retain this Article for all types of underfloor raceways that include junction boxes.

- A. Description: Manufacturer's standard enclosure for indicated type, quantity, arrangement, and configuration of raceways at each raceway junction, intersection, and access location. Include the following accessories and features:
 1. Mounting brackets.
 2. Escutcheons and holders to accommodate surrounding floor covering.
 3. Means for leveling and height adjustment more than 3/8 inch (10 mm) before and after concrete is placed.
 4. Raceway Openings: For underfloor raceways and conduits arranged to accommodate raceway layout.

Coordinate first subparagraph below with indicated floor finish material.

5. Covers shall have appropriate depth recess to receive specific floor finish material.
6. Partitions to separate wiring of different systems.

2.10 SERVICE FITTINGS

- A. Exposed Parts Finish: [Brass] [Brushed Aluminum] <Insert finish>.

Retain paragraph and subparagraphs below for flush service fittings in flat-top, single-channel, underfloor raceway with round inserts. Indicate type and location on Drawings.

- B. Flush, Single-System Service Fitting for Round Inserts: Include mounting and cover to support and provide access to single connector, jack, or receptacle device; mounted

flush with floor within body of insert.

1. Connector, Jack, and Receptacle Devices: Single modular type; complying with Section 262726 "Wiring Devices" and Section 271500 "Communications Horizontal Cabling."
2. Power Receptacle Outlet: Suitable for 20-A device.

Retain paragraph and subparagraphs below for flush service fittings in underfloor raceways with rectangular preset inserts, including flat-top, single-channel and multichannel, two- and three-cell, cellular underfloor raceway and cellular steel deck.

- C. Flush, [**Single-**] [**or**] [**Multiple-**] System Service Fitting for Rectangular Inserts: Include mounting, hinged cover, and trim to support and provide access to connector, jack, or receptacle devices mounted flush with floor within insert.
1. Connector, Jack, and Receptacle Devices: Modular type; complying with Division 26 Section "Wiring Devices" and Section 271500 "Communications Horizontal Cabling."
 2. Power Receptacle Rating: 20 A, 120 V unless otherwise indicated.

Retain first paragraph and subparagraphs below for recessed service fittings in three-cell, cellular underfloor raceway and cellular steel deck.

- D. Recess-Mounted Service Fitting: Modular fittings compatible with preset inserts and shall include covers; provisions for receptacles, jacks, and connectors; and associated device plates for indicated systems. Include hinged flush handhole covers with recessed depth to match thickness of floor finish material. Provide for internally mounted receptacle- and communication-jack and connector assemblies complying with requirements in Section 262726 "Wiring Devices" and Section 271500 "Communications Horizontal Cabling."

Indicate types and locations of devices on Drawings.

1. Duplex receptacle.
 2. Duplex telephone-data jacks.
 3. Double duplex receptacles.
 4. Duplex receptacle and duplex telephone-data jacks.
 5. Double duplex telephone-data jacks, [**Category 5**] [**Category 5e**] [**Category 6**].
 6. Fiber-optic cable connector.
- E. Surface-Mounted Service Fitting: Modular pedestal type, with locking attachment matched to insert floor opening.

Indicate types and locations of fittings on Drawings.

1. Power-outlet, double-faced, surface-mounted unit for duplex receptacle on both sides.
2. Power-outlet, single-faced, surface-mounted unit for duplex receptacle on one side.
3. Communication-outlet, double-faced, surface-mounted unit.

Retain one of first three subparagraphs below to describe provisions for terminating cable from communication equipment at surface-mounted outlets.

- a. Include bushed openings on both sides; 1-inch (25-mm) minimum diameter; insulated with nonconducting material.
 - b. Include provisions for modular dual fiber-optic connector assembly on both sides.
 - c. Include provisions for modular dual jack-connector assembly, rated for **[Category 5] [Category 5e] [Category 6]** on both sides.
4. Communication-outlet, single-faced, surface-mounted unit with bushed opening on one side; 1-inch (25-mm) minimum diameter; insulated with nonconducting material.
 5. Combination surface-mounted unit for duplex receptacle on one side and with communication cable connection provision on opposite side.

Retain one of three subparagraphs below to describe provisions for terminating cable from communication equipment at these outlets.

- a. Communication Side: Include bushed opening; 1-inch (25-mm) minimum diameter; insulated with nonconducting material.
- b. Communication Side: Include provisions for modular dual fiber-optic connector assembly.
- c. Communication Side: Include provisions for modular dual jack-connector assembly, rated for **[Category 5] [Category 5e] [Category 6]**.

Flush service-fitting types described in paragraph and subparagraphs below are used with flat-top, multichannel, underfloor raceway and three-cell, cellular underfloor raceway and cellular steel deck.

- F. Flush-Mounted Service Fittings: Modular fittings compatible with preset inserts and shall include covers, provisions for receptacles jacks and connector assemblies and wiring extensions to wall-mounted outlets, and associated device plates for indicated systems. Include flush handhole covers, recessed to suit floor finish material. Internally mounted, modular, receptacle, jack and connector assemblies shall comply with requirements in Section 262726 "Wiring Devices" and Section 271500 "Communications Horizontal Cabling."

Coordinate with Division 26 Section "Wiring Devices" and Division 27 Section "Communications Horizontal Cabling," and indicate types and locations of devices on Drawings.

1. Duplex convenience receptacle.
2. Duplex telephone-data outlets.
3. Double duplex convenience receptacles.
4. Duplex convenience receptacle and duplex telephone-data outlets.
5. Double duplex telephone-data outlets.
6. Duplex communication jack, rated for **[Category 5] [Category 5e] [Category 6]**.
7. Duplex fiber-optic communication connector.

Indicate locations for wiring-extension service fittings on Drawings.

8. Wiring-Extension Service Fittings: Arrangement of brackets and mountings to support, and provide access to wiring or cabling of a cell, and to connect the

cable or raceway that extends the system to an individual wall outlet. Provide for connection of [FMC] [ENT] [Type MC cable] for power extensions, and [FMC] [ENT] [optical fiber/communication cable raceway] for communication system extensions.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install raceways aligned and leveled and, unless otherwise indicated, parallel or perpendicular to building walls.

Retain first paragraph below if cellular metal raceway is specified but is not to be installed directly on compacted fill or on an existing slab. See Evaluations.

- B. Provide a concrete base for support of cellular metal raceway.
- C. Arrange supports to attain proper elevation, alignment, and spacing of raceways. Install supports securely at ends and at intervals not to exceed 60 inches (1500 mm), to prevent movement during concrete pour.
- D. Level raceway components with finished slab and make adjustments for floor finishes.

Retain first paragraph below except for flush underfloor raceway assemblies.

- E. Adjust supports to maintain a 1/16- to 3/8-inch (1.6- to 10-mm) finished concrete cover over preset inserts.
- F. Remove burrs, sharp edges, dents, and mechanical defects.
- G. Cap or plug boxes, insert- and service-fitting openings, and open ends of raceways.
- H. Seal raceways, cells, junction boxes, and inserts to prevent water, concrete, or foreign matter from entering raceways before and during pouring slab or placing fill. Tape joints, or seal with compound, as recommended in writing by underfloor raceway manufacturer.

Retain paragraph below if junction boxes are indicated for specified underfloor raceways.

- I. Junction Boxes: Install tops level and flush with finished floor. Install blank closure plates or plugs to close unused junction-box openings. Grout boxes in place to prevent

movement during construction. Place top covers in inverted position during construction to prevent damage to surface of cover. Reinstall covers in proper position prior to final acceptance of Work.

Retain first paragraph below for cellular concrete deck installations and other projects requiring afterset inserts.

- J. Afterset Inserts: Cut, hole saw, and drill slab and raceways to allow for installation.
- K. Ground underfloor raceway components.

Retain first paragraph and subparagraphs below to define how NFPA 70 requirement to install a suitable marker "at or near the end of each straight run of raceway to locate the last insert" is to be accomplished. Paragraph also expands the Code requirement to enhance location and identification.

- L. Install a marker at the center of the last insert of each cell and channel of each straight run of metal underfloor service raceway to locate the insert and identify the system.
 - 1. Install markers at last inserts on both sides of permanent walls and at first inserts adjacent to each junction box.
 - 2. Install markers flush at screed line before pouring slab or placing fill. Extend marker with grommited screw when floor covering is placed. Do not extend through carpet.
 - 3. Use slotted-head screw to identify electrical power; use Phillips-head screw to identify conventional communications.
 - 4. Use another distinctive screw head to identify third system such as special-purpose wiring.
- M. Level raceway components with finished slab and make adjustments in raceway component elevation to accommodate indicated floor finishes.

3.3 FIELD QUALITY CONTROL

Retain paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. Perform visual inspection of interior of each junction box section of trench raceway to verify absence of dirt, dust, construction debris, and moisture.

- Replace damaged and malfunctioning components.
2. Perform point-to-point tests of ground continuity and resistance of ground path between the most remote accessible fitting on each branch of each underfloor raceway system and the main electrical distribution grounding system.
 - a. Determine cause and perform correction of any point-to-point resistance value that exceeds 0.05 ohms.
 - b. Comply with NETA Acceptance Testing Specifications about safety, suitability of test equipment, test instrument calibration, and test report and records.

3.4 CLEANING

- A. Clean and swab out underfloor raceways, inserts, and junction boxes after finish has been applied to floor slab, and remove foreign material, dirt, and moisture. Leave interiors clean and dry.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260539

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SECTION 260543 - UNDERGROUND DUCTS AND RACEWAYS FOR ELECTRICAL SYSTEMS

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes the following:

List below includes the most common products and applications for underground site distribution for electrical power and communications.

Edit to suit Project.

- 1. Conduit, ducts, and duct accessories for **[direct-buried] [and] [concrete-encased]** duct banks[, and in single duct runs].
- 2. Handholes and boxes.
- 3. Manholes.

- B. Related Sections:

- 1. Section "033350 "Flowable Backfill Low-Strength Concrete" for flowable backfill concrete.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

- A. RNC: Rigid nonmetallic conduit.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For the following:

1. Duct-bank materials, including separators and miscellaneous components.
2. Ducts and conduits and their accessories, including elbows, end bells, bends, fittings, and solvent cement.
3. Accessories for manholes, handholes, boxes[, **and other utility structures**].
4. Warning tape.
5. Warning planks.
6. Include data substantiating that materials comply with requirements.

Retain paragraph and subparagraphs below for precast utility structures.

- B. Shop Drawings for Precast or Factory-Fabricated Underground Utility Structures: Include plans, elevations, sections, details, attachments to other work, and accessories, including the following:

Coordinate subparagraphs below with manhole and handhole features and components specified in Part 2.

1. Duct entry provisions, including locations and duct sizes.
2. Reinforcement details.
3. Frame and cover design and manhole frame support rings.
4. Ladder details.
5. Grounding details.
6. Dimensioned locations of cable rack inserts, pulling-in and lifting irons, and sumps.
7. Joint details.

Retain paragraph and subparagraphs below for handholes or boxes other than precast concrete.

- C. Shop Drawings for Factory-Fabricated Handholes and Boxes Other Than Precast Concrete: Include dimensioned plans, sections, and elevations, and fabrication and installation details, including the following:

1. Duct entry provisions, including locations and duct sizes.
2. Cover design.
3. Grounding details.
4. Dimensioned locations of cable rack inserts, and pulling-in and lifting irons.

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph and subparagraphs below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Duct-Bank Coordination Drawings: Show duct profiles and coordination with other utilities and underground structures.
 - 1. Include plans and sections, drawn to scale, and show bends and locations of expansion fittings.
 - 2. Drawings shall be signed and sealed by a qualified professional engineer.
- B. Product Certificates: For concrete and steel used in precast concrete [**manholes**] [**and**] [**handholes**], as required by ASTM C 858.

Retain first paragraph below if nonconcrete handholes or boxes are specified and testing is specified in Part 2 "Source Quality Control" Article.

- C. Qualification Data: For professional engineer and testing agency.
- D. Source quality-control test reports.
- E. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

Retain first paragraph below if manufacturer is required to provide services of an independent testing agency in Part 2 "Source Quality Control" Article. Qualification requirements supplement those specified in Division 01 Section "Quality Requirements," which also includes the definition for NRTL (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Qualified according to ASTM E 329 for testing indicated.
- B. Comply with ANSI C2.
- C. Comply with NFPA 70.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver ducts to Project site with ends capped. Store nonmetallic ducts with supports to prevent bending, warping, and deforming.
- B. Store [**precast concrete**] [**and**] [**other factory-fabricated**] underground utility structures at Project site as recommended by manufacturer to prevent physical damage. Arrange so identification markings are visible.
- C. Lift and support precast concrete units only at designated lifting or supporting points.

1.9 PROJECT CONDITIONS

Delete this Article if no interruption of existing electrical service is required.

- A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 - 2. Do not proceed with interruption of electrical service without Owner's written permission.

1.10 COORDINATION

- A. Coordinate layout and installation of ducts, manholes, handholes, and boxes with final arrangement of other utilities, site grading, and surface features as determined in the field.
- B. Coordinate elevations of ducts and duct-bank entrances into manholes, handholes, and boxes with final locations and profiles of ducts and duct banks as determined by coordination with other utilities, underground obstructions, and surface features. Revise locations and elevations from those indicated as required to suit field conditions and to ensure that duct runs drain to manholes and handholes, and as approved by DEN Project Manager.

1.11 EXTRA MATERIALS

Extra materials may not be allowed for publicly funded projects.

Coordinate extra stock requirements with DEN Project Manager.

- A. Furnish extra materials described below that match products installed and that are

packaged with protective covering for storage and identified with labels describing contents.

Delete first option in paragraph below if nonmetallic cable arms are specified for manholes or handholes. See Editing Instruction No. 2 in the Evaluations.

- B. Furnish cable-support stanchions, arms, [insulators,] <Insert other accessories and specialties> and associated fasteners in quantities equal to [10] <Insert number> percent of quantity of each item installed.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CONDUIT

Rigid steel conduit is often used with underground ducts at bends and stub-ups. Coordinate with Part 3 "Underground Duct Application" Article.

- A. Rigid Steel Conduit: Galvanized Rigid Conduit (GRC) with factory bonded 40 mil. PVC coating. Comply with ANSI C80.1.
- B. Rigid metallic conduit used for elbows and sweeps shall be PVC coated, schedule 40 galvanized rigid conduit bent to shape at the factory. All connections to Non-Metallic rigid conduits shall be made with threaded couplings.

Paragraph below specifies Schedule 40 and Schedule 80 weights, respectively, of same RNC specified in Division 26 Section "Raceway and Boxes for Electrical Systems." Coordinate with Part 3 "Underground Duct Application" Article. See Evaluations.

- C. RNC: NEMA TC 2, [Type EPC-40-PVC] [and] [Type EPC-80-PVC], UL 651, with matching fittings by same manufacturer as the conduit, complying with NEMA TC 3 and UL 514B.

2.2 NONMETALLIC DUCTS AND DUCT ACCESSORIES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following::

1. ARNCO Corp.
2. Beck Manufacturing.
3. Cantex, Inc.
4. CertainTeed Corp.; Pipe & Plastics Group.
5. Condux International, Inc.
6. ElecSys, Inc.
7. Electri-Flex Company.
8. IPEX Inc.
9. Lamson & Sessions; Carlon Electrical Products.
10. Manhattan/CDT; a division of Cable Design Technologies.
11. Spiraduct/AFC Cable Systems, Inc.
12. <Insert manufacturer>
13. or approved equal.

Retain one or more of three paragraphs and associated subparagraphs below to match duct types specified in Part 3 "Underground Duct Application" Article. See the Underground Raceway Application Chart and associated discussion in "Product Selection and Application Considerations" Article in the Evaluations.

- B. Underground Plastic Utilities Duct: NEMA TC 6 & 8, Type EB-20-PVC, ASTM F 512, UL 651A, with matching fittings by the same manufacturer as the duct, complying with NEMA TC 9.
- C. Underground Plastic Utilities Duct: NEMA TC 6 & 8, [Type DB-60-PVC] [and] [Type DB-120-PVC], ASTM F 512, with matching fittings by the same manufacturer as the duct, complying with NEMA TC 9.
- D. Duct Accessories:
 1. Duct Separators: Factory-fabricated rigid PVC interlocking spacers, sized for type and sizes of ducts with which used, and selected to provide minimum duct spacings indicated while supporting ducts during concreting or backfilling.
 2. Inner-ducts shall be nominal 1-inch internal diameter with longitudinally fluted (finned) construction to reduce cable pulling friction. Inner-ducts shall be manufactured of high density polyethylene and provided in blue, orange and black. Inner-duct shall be installed in unbroken (no couplings) lengths between Underground Concrete Vaults and pull boxes.
 3. Pull Tape shall be $\frac{3}{4}$ " wide woven Aramid fiber with no more than 4% elongation at yield. Tape shall provide a tensile strength of 2500 lbs. Tape shall be provided with accurate sequential footage marks at one foot intervals.
 4. Flow able backfill shall be 60 to 100 psi, Designed in accordance with ASTM C 94 and ASTM D 4832. Reference Section 033350 "Flowable Backfill Low-Strength Concrete".
 5. Red concrete for encasement shall be 3,000 psi minimum, 28-day compressive strength and 3/8-inch maximum aggregate size. The color shall be Davis Color "Baja Red." Use Davis Color # 160 at a ratio of [two (2) pounds powder dose] for each sack of cement in the mix or equal as determined by the manufacturer and DEN Project Manager to achieve desired color.
 6. Warning Tape: Underground-line warning tape specified in Section 260553 "Identification for Electrical Systems."

7. Concrete Warning Planks: Nominal 12 by 24 by 3 inches (300 by 600 by 76 mm) in size, manufactured from 6000-psi (41-MPa) concrete.
 - a. Color: a specified for encasement concrete above..
 - b. Mark each plank with "ELECTRIC" in 2-inch (50-mm) high, 3/8-inch (10-mm) deep letters.
8. Mortar shall comply with ASTM C 270, Type M, except for quantities less than 2.0 cubic feet where packaged mix complying with ASTM C 387, Type M, may be used.
9. Steel bore casings shall be ASTM A/252 Grade 2
10. Counterpoise conductor shall be #6 bare hard drawn or soft drawn copper. Exothermic welds shall be utilized at all connections.

2.3 PRECAST CONCRETE HANDHOLES AND BOXES

Retain this Article for handholes and pull boxes subject to deliberate vehicular traffic. Also retain if precast concrete handholes and boxes are preferred where not subject to deliberate vehicular traffic. See discussion of handhole and box application in the Evaluations. Structural load ratings for precast concrete and alternative underground enclosures are specified in Part 3 "Underground Enclosure Application" Article.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of first two paragraphs and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Design guidelines for Precast Pull Boxes: Precast pull boxes shall be provided as round units with 4'-0" nominal interior diameter. Boxes shall be of two-piece construction with side walls and base cast as one unit and precast lid as a separate piece. Waffle-board knockout panels shall be provided at a minimum of four (4) equally spaced positions around the perimeter of the pull box to facilitate conduit entry. Pullboxes shall be provided with the following accessories:
 1. Bolt-on UCV step, stainless steel
 2. Embedded eyebolts, stainless steel
 3. Collar ring, cast steel, 30-inch inside diameter
 4. Cover, cast steel, 30-inch diameter (Marked DEN Communications)
 5. Provide plugs on all conduit entering pull boxes. Plugs shall provide a tight seal between conduit and pull tapes and shall withstand a minimum of 15 psi of hydrostatic pressure.
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Carder Concrete Products.
 2. Christy Concrete Products.
 3. Elmhurst-Chicago Stone Co.
 4. Oldcastle Precast Group.
 5. Riverton Concrete Products; a division of Cretex Companies, Inc.

6. Utility Concrete Products, LLC.
7. Utility Vault Co.
8. Wausau Tile, Inc.
9. <Insert manufacturer>
10. or approved equal.

C. Comply with ASTM C 858 for design and manufacturing processes.

If Project requires more than one type of precast handhole or box, give each type a separate designation and copy and edit paragraph and applicable subparagraphs below for each type.

D. Description: Factory-fabricated, reinforced-concrete, monolithically poured walls and bottom unless open-bottom enclosures are indicated. Frame and cover shall form top of enclosure and shall have load rating consistent with that of handhole or box.

Retain one of four subparagraphs and associated subparagraphs below, and edit to specify features of frame and cover assembly. Consult manufacturers for additional frame and cover designs.

1. Manhole and hand hole covers and hinges shall be cast iron or stainless steel unless indicated otherwise.
2. Frame and Cover: Weatherproof cast-iron frame, with cast-iron cover with recessed cover hook eyes and tamper-resistant, captive, cover-securing bolts.

Coordinate remaining subparagraphs and associated subparagraphs below with Drawings.

3. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
4. Cover Legend: Molded lettering, ["ELECTRIC."] ["TELEPHONE."] [As indicated for each service.] <Insert legend.>
5. Configuration: Units shall be designed for flush burial and have [open] [closed] [integral closed] bottom, unless otherwise indicated.
6. Extensions and Slabs: Designed to mate with bottom of enclosure. Same material as enclosure.
 - a. Extension shall provide increased depth of [12 inches (300 mm)] <Insert dimension>.
 - b. Slab: Same dimensions as bottom of enclosure, and arranged to provide closure.

Retain one or both of first two subparagraphs and associated subparagraphs below to specify provisions to be made in the factory to accommodate connections of ducts to handholes in the field. Coordinate with Drawings.

Subparagraph and associated subparagraphs below specify window openings in handhole walls, arranged so duct banks and their terminating fittings can be cast in place in the field after handholes are installed. This method can minimize problems of aligning duct banks with handhole openings in the field.

7. Windows: Precast openings in walls, arranged to match dimensions and elevations of approaching ducts and duct banks plus an additional 12 inches (300 mm) vertically and horizontally to accommodate alignment variations.
 - a. Windows shall be located no less than 6 inches (150 mm) from interior surfaces of walls, floors, or frames and covers of handholes, but close

- enough to corners to facilitate racking of cables on walls.
- b. Window opening shall have cast-in-place, welded wire fabric reinforcement for field cutting and bending to tie in to concrete envelopes of duct banks.
 - c. Window openings shall be framed with at least two additional No. 4 steel reinforcing bars in concrete around each opening.

First subparagraph and associated subparagraphs below specify end-bell or duct-terminating fittings to be factory installed, ready for connection to approaching ducts in the field. This method reduces installation costs but may increase risk of potential alignment problems.

8. Duct Entrances in Handhole Walls: Cast end-bell or duct-terminating fitting in wall for each entering duct.
 - a. Type and size shall match fittings to duct or conduit to be terminated.
 - b. Fittings shall align with elevations of approaching ducts and be located near interior corners of handholes to facilitate racking of cable.
9. Handholes [12 inches wide by 24 inches long (300 mm wide by 600 mm long)] <Insert dimensions> and larger shall have inserts for cable racks and pulling-in irons installed before concrete is poured.

2.4 HANDHOLES AND BOXES OTHER THAN PRECAST CONCRETE

Retain this Article for installations at locations not subject to deliberate traffic paths of vehicles where enclosures lighter and less costly than those of concrete are desired. Enclosures specified in this Article range from those suitable only for pedestrian areas to units able to withstand incidental, nondeliberate heavy-vehicle loading. Coordinate with Part 1 "Action Submittals" and "Quality Assurance" articles and Part 3 "Underground Enclosure Application" Article. Coordinate with Drawings for sizes. See discussion of nonconcrete handhole application in the Evaluations.

A. Description: Comply with SCTE 77.

1. Color: [Gray] [Green].

First option in first subparagraph below facilitates bottom duct entry. Second option may be provided by a separate slab placed in the excavation under an open-bottom enclosure; third option is obtained by molding or fabricating the bottom integrally with the body of the unit.

2. Configuration: Units shall be designed for flush burial and have [open] [closed] [integral closed] bottom, unless otherwise indicated.
3. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure.
4. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
5. Cover Legend: Molded lettering, ["ELECTRIC."] ["TELEPHONE."] [As indicated for each service.] <Insert legend.>

Consider retaining subparagraph below if wires or cables are direct buried and will enter enclosure through the side. Otherwise, entry will be made through an open bottom or through side openings cut in the field as specified in Part 3. Coordinate with Drawings.

6. Direct-Buried Wiring Entrance Provisions: Knockouts equipped with insulated bushings or end-bell fittings, selected to suit box material, sized for wiring

indicated, and arranged for secure, fixed installation in enclosure wall.

Retain first subparagraph below if ducts will enter enclosure through the side. Otherwise, entry will be made through an open bottom or through side openings cut in the field as specified in Part 3. Coordinate with Drawings.

7. Duct Entrance Provisions: Duct-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
8. Handholes 12 inches wide by 24 inches long (300 mm wide by 600 mm long) <Insert dimensions> and larger shall have factory-installed inserts for cable racks and pulling-in irons.

Retain one or more of four paragraphs and associated subparagraphs below to select enclosure type(s) for areas not subject to deliberate traffic by vehicles. Coordinate selection with Part 3 "Underground Enclosure Application" Article. For enclosures with cover options, verify that selected cover is available with the load rating specified in Part 3 "Underground Enclosure Application" Article.

- B. Polymer Concrete Handholes and Boxes with Polymer Concrete Cover: Molded of sand and aggregate, bound together with a polymer resin, and reinforced with steel or fiberglass or a combination of the two.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armorcast Products Company.
 - b. Carson Industries LLC.
 - c. CDR Systems Corporation.
 - d. NewBasis.
 - e. <Insert manufacturer>
 - f. or approved equal.

- C. Fiberglass Handholes and Boxes with Polymer Concrete Frame and Cover: Sheet-molded, fiberglass-reinforced, polyester resin enclosure joined to polymer concrete top ring or frame.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armorcast Products Company.
 - b. Carson Industries LLC.
 - c. Christy Concrete Products.
 - d. Synertech Moulded Products, Inc.; a division of Oldcastle Precast.
 - e. <Insert manufacturer>
 - f. or approved equal.

- D. Fiberglass Handholes and Boxes: Molded of fiberglass-reinforced polyester resin, with

covers of **[polymer concrete] [reinforced concrete] [cast iron] [hot-dip galvanized-steel diamond plate] [fiberglass]**.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Carson Industries LLC.
 - b. Christy Concrete Products.
 - c. Nordic Fiberglass, Inc.
 - d. **<Insert manufacturer>**
 - e. or approved equal.

- E. High-Density Plastic Boxes: Injection molded of high-density polyethylene or copolymer-polypropylene. Cover shall be **[polymer concrete] [hot-dip galvanized-steel diamond plate] [plastic]**.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Carson Industries LLC.
 - b. Nordic Fiberglass, Inc.
 - c. PenCell Plastics.
 - d. **<Insert manufacturer>**
 - e. or approved equal.

2.5 PRECAST MANHOLES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Carder Concrete Products.
 2. Christy Concrete Products.
 3. Elmhurst-Chicago Stone Co.
 4. Oldcastle Precast Group.
 5. Riverton Concrete Products; a division of Cretex Companies, Inc.
 6. Utility Concrete Products, LLC.
 7. Utility Vault Co.
 8. Wausau Tile, Inc.
 9. **<Insert manufacturer>**
 10. or approved equal.

Coordinate first paragraph below with Drawings.

- B. Comply with ASTM C 858[, **with structural design loading as specified in Part 3 "Underground Enclosure Application" Article**] and with interlocking mating sections, complete with accessories, hardware, and features.

Retain one or both subparagraphs and associated subparagraphs below to specify provisions to be made in the factory to accommodate connections of ducts to manholes in the field. Coordinate with Drawings.

Subparagraph and associated subparagraphs below specify window openings in manhole walls, arranged so duct banks and their terminating fittings can be cast in place in the field after manholes are installed. This method can minimize problems of aligning duct banks with manhole openings in the field.

1. Windows: Precast openings in walls, arranged to match dimensions and elevations of approaching ducts and duct banks plus an additional **12 inches** (300 mm) vertically and horizontally to accommodate alignment variations.
 - a. Windows shall be located no less than **6 inches** (150 mm) from interior surfaces of walls, floors, or roofs of manholes, but close enough to corners to facilitate racking of cables on walls.
 - b. Window opening shall have cast-in-place, welded wire fabric reinforcement for field cutting and bending to tie in to concrete envelopes of duct banks.
 - c. Window openings shall be framed with at least two additional No. 4 steel reinforcing bars in concrete around each opening.

Subparagraph and associated subparagraphs below specify end-bell or duct-terminating fittings to be factory installed, ready for connection to approaching ducts in the field. This method reduces installation costs but may increase risk of potential alignment problems.

2. Duct Entrances in Manhole Walls: Cast end-bell or duct-terminating fitting in wall for each entering duct.
 - a. Type and size shall match fittings to duct or conduit to be terminated.
 - b. Fittings shall align with elevations of approaching ducts and be located near interior corners of manholes to facilitate racking of cable.
- C. Concrete Knockout Panels: **1-1/2 to 2 inches** (38 to 50 mm) thick, for future conduit entrance and sleeve for ground rod.
- D. Joint Sealant: Asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground-water level at grade.

2.6 CAST-IN-PLACE MANHOLES

Coordinate this Article with Drawings for manhole designs, indicating locations, dimensions, features, accessories, and installation conditions. See Evaluations.

- A. Description: Underground utility structures, constructed in place, complete with accessories, hardware, and features. Include concrete knockout panels for conduit

entrance and sleeve for ground rod.

- B. Materials: Comply with ASTM C 858 and with Section 033000 "Cast-in-Place Concrete."
- C. Structural Design Loading: As specified in Part 3 "Underground Enclosure Application" Article of this Section.

2.7 PRECAST UNDERGROUND COMMUNICATIONS VAULTS (UCV'S)

- A. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - 1. Amcor Precast (Oldcastle).
 - 2. **<Insert manufacturer>**
 - 3. or approved equal.
- B. Precast underground communications vaults shall be provided in the following sizes:
 - 1. 12'-0"L x 6'-0"W x 7'-0"H nominal interior dimension
 - 2. 6'-0"L x 4'-0"W x 7'-0"H nominal interior dimension
- C. Vaults shall be of two part construction consisting of separate top and bottom sections. Bottom section shall be equipped with four internal lifting points. Top section shall be equipped with four external lifting points. Top section of vault shall contain a 30-inch round opening to receive precast grade rings and UCV collar. Bottom section of vault shall be provided with 12" diameter x 3.5" deep passive sump with removable stainless steel grating.
- D. 12'-0" x 6'-0" vaults shall be provided with forty (40) embedded PVC belled ends to accept standard schedule 40 PVC conduit. 6'-0" x 4'-0" vaults shall be provided with twelve (12) embedded PVC belled ends. All embedded adapters shall be constructed with a break-out PVC diaphragm which shall remain in place on unused openings. Duct conduits shall be attached to adapters using solvent cement.
- E. 12'-0" x 6'-0" vaults shall be equipped with eight (8) stainless steel pulling irons embedded in the precast base section. 6'-0" x 4'-0" vaults shall be provided with four (4) embedded pulling irons.
- F. 12'-0" x 6'-0" vaults shall be provided with the following accessory equipment:
 - 1. Sixteen (16) 47-hole cable support racks, stainless steel.
 - 2. Forty (40) L-Bracket for cable support racks, stainless steel.
 - 3. Four (4) 7'-0" vertical copper bonding ribbon (two per long side)
 - 4. Bolt-on ladder bracket, hot-dip galvanized
 - 5. Hook ladder, stainless steel
 - 6. Grade ring(s), precast, 30-inch inside diameter
 - 7. Collar ring, cast steel, 30-inch inside diameter
 - 8. Cover, cast steel, 30-inch diameter (Marked "DEN Communications")

- G. 6'-0" x 4'-0" vaults shall be provided with the following accessory equipment:
1. Nine (9) 47-hole cable support racks, stainless steel.
 2. Eight (8) L-Bracket for cable support racks, stainless steel.
 3. Two (2) 7'-0" vertical copper bonding ribbon (duct entry side only)
 4. Bolt-on ladder bracket, hot-dip galvanized
 5. Hook ladder, stainless steel
 6. Grade ring(s), precast, 30-inch inside diameter
 7. Collar ring, cast steel, 30-inch inside diameter
 8. Cover, cast steel, 30-inch diameter (Marked "DEN Communications").
- H. Vaults shall be designed for AASHTO HS-20 Loading and according to ASTM C857-87 and ASTM C858-83.
- I. The specified UCV's are manufactured with factory embedded PVC belled ends for all port positions. These fittings contain a break-out plastic diaphragm which must be removed during conduit installation. Diaphragm shall remain in place on all unused ports. Provide rubber expansion plugs on all ports with installed. Plugs shall provide a tight seal between conduit and pull tapes and shall withstand a minimum of 15 psi of hydrostatic pressure.

2.8 AIRCRAFT RATED UCVS

- A. UCVs located in apron or taxiway areas may be either precast or cast in place. All aircraft rated UCVs shall be engineered for aircraft loading. Contact DEN Engineering for required loading values for each location where aircraft rated UCVs will be required.

2.9 UTILITY STRUCTURE ACCESSORIES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Bilco Company (The).
 2. Campbell Foundry Company.
 3. Carder Concrete Products.
 4. Christy Concrete Products.
 5. East Jordan Iron Works, Inc.
 6. Elmhurst-Chicago Stone Co.
 7. McKinley Iron Works, Inc.
 8. Neenah Foundry Company.
 9. NewBasis.
 10. Oldcastle Precast Group.
 11. Osburn Associates, Inc.
 12. Pennsylvania Insert Corporation.

13. Riverton Concrete Products; a division of Cretex Companies, Inc..
14. Strongwell Corporation; Lenoir City Division.
15. Underground Devices, Inc.
16. Utility Concrete Products, LLC.
17. Utility Vault Co.
18. Wausau Tile, Inc.
19. <Insert manufacturer>
20. or approved equal.

Indicate in details on Drawings where accessories specified in this Article are to be installed.

- B. Manhole Frames, Covers, and Chimney Components: Comply with structural design loading specified for manhole.
1. Frame and Cover: Weatherproof, [**gray cast iron complying with ASTM A 48/A 48M, Class 30B**] [**stainless steel**] with milled cover-to-frame bearing surfaces; diameter, [**26 inches** (660 mm)] [**29 inches** (737 mm)].
 - a. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
 - b. Special Covers: Recess in face of cover designed to accept finish material in paved areas.
 2. Cover Legend: Cast in. Selected to suit system.
 - a. Legend: "ELECTRIC-LV" for duct systems with power wires and cables for systems operating at 600 V and less.
 - b. Legend: "ELECTRIC-HV" for duct systems with medium-voltage cables.
 - c. Legend: "SIGNAL" for communications, data, and telephone duct systems.
 3. Manhole Chimney Components: Precast concrete rings with dimensions matched to those of roof opening.
 - a. Mortar for Chimney Ring and Frame and Cover Joints: Comply with ASTM C 270, Type M, except for quantities less than **2.0 cu. ft. (60 L)** where packaged mix complying with ASTM C 387, Type M, may be used.

Most manufacturers' standard precast units have sump consisting of depression in floor only and no frame or grate. 12-1/2-inch- (318-mm-) diameter, 4-inch- (100-mm-) deep thermoplastic sump is also available for casting into the manhole floor.

- C. Manhole Sump Frame and Grate: ASTM A 48/A 48M, Class 30B, gray cast iron.
- D. Pulling Eyes in Concrete Walls: Eyebolt with reinforcing-bar fastening insert, **2-inch** (50-mm) diameter eye, and **1-by-4-inch** (25-by-100-mm) bolt. Stainless steel only.
1. Working Load Embedded in **6-Inch** (150-mm), **4000-psi** (27.6-MPa) Concrete: **13,000-lbf** (58-kN) minimum tension.
- E. Pulling Eyes in Nonconcrete Walls: Eyebolt with reinforced fastening, **1-1/4-inch**

(32-mm) diameter eye, rated [2500-lbf (11-kN)] <Insert rating> minimum tension. Stainless steel only.

F. Pulling-In and Lifting Irons in Concrete Floors: 7/8-inch (22-mm) diameter, hot-dip galvanized, bent steel rod; stress relieved after forming; and fastened to reinforcing rod. Exposed triangular opening.

1. Ultimate Yield Strength: 40,000-lbf (180-kN) shear and 60,000-lbf (270-kN) tension.

G. Bolting Inserts for Concrete Utility Structure Cable Racks and Other Attachments: Flared, threaded inserts of noncorrosive, chemical-resistant, nonconductive thermoplastic material; 1/2-inch (13-mm) ID by 2-3/4 inches (69 mm) deep, flared to 1-1/4 inches (32 mm) minimum at base.

1. Tested Ultimate Pullout Strength: 12,000 lbf (53 kN) minimum.

H. Expansion Anchors for Installation after Concrete Is Cast: Zinc-plated, carbon-steel-wedge type with stainless-steel expander clip with 1/2-inch (13-mm) bolt, 5300-lbf (24-kN) rated pullout strength, and minimum 6800-lbf (30-kN) rated shear strength.

Retain one of two "Cable Rack Assembly" paragraphs and associated subparagraphs below to select type of cable support for use in manholes. Coordinate with Drawings.

I. Cable Rack Assembly: Steel, [hot-rolled] [hot-dip] galvanized, except insulators.

1. Stanchions: T-section or channel; 2-1/4-inch (57-mm) nominal size; punched with 14 holes on 1-1/2-inch (38-mm) centers for cable-arm attachment.
2. Arms: 1-1/2 inches (38 mm) wide, lengths ranging from 3 inches (75 mm) with 450-lb (204-kg) minimum capacity to 18 inches (460 mm) with 250-lb (114-kg) minimum capacity. Arms shall have slots along full length for cable ties and be arranged for secure mounting in horizontal position at any vertical location on stanchions.
3. Insulators: High-glaze, wet-process porcelain arranged for mounting on cable arms.

Nonmetallic alternative in first paragraph below requires no insulators and no grounding.

J. Cable Rack Assembly: Nonmetallic. Components fabricated from nonconductive, fiberglass-reinforced polymer.

1. Stanchions: Nominal 36 inches (900 mm) high by 4 inches (100 mm) wide, with minimum of 9 holes for arm attachment.
2. Arms: Arranged for secure, drop-in attachment in horizontal position at any location on cable stanchions, and capable of being locked in position. Arms shall be available in lengths ranging from 3 inches (75 mm) with 450-lb (204-kg) minimum capacity to 20 inches (508 mm) with 250-lb (114-kg) minimum capacity. Top of arm shall be nominally 4 inches (100 mm) wide, and arm shall have slots along full length for cable ties.

- K. Duct-Sealing Compound: Nonhardening, safe for contact with human skin, not deleterious to cable insulation, and workable at temperatures as low as **35 deg F (2 deg C)**. Capable of withstanding temperature of **300 deg F (150 deg C)** without slump and adhering to clean surfaces of plastic ducts, metallic conduits, conduit coatings, concrete, masonry, lead, cable sheaths, cable jackets, insulation materials, and common metals.

Retain one or both of first two paragraphs below. Coordinate fixed ladder arrangement with manhole details on Drawings.

- L. Fixed Manhole Ladders: Arranged for attachment to **[roof] [or] [wall] [and floor]** of manhole. Ladder and mounting brackets and braces shall be fabricated from **[nonconductive, structural-grade, fiberglass-reinforced resin] [hot-dip galvanized steel]**.
- M. Portable Manhole Ladders: UL-listed, heavy-duty **[wood] [fiberglass]** specifically designed for portable use for access to electrical manholes. Minimum length equal to distance from deepest manhole floor to grade plus **36 inches (900 mm)**. **[One (1)]** <Insert quantity> required.
- N. Cover Hooks: **[Heavy duty, designed for lifts 60 lbf (270 N) and greater] [Light duty, designed for lifts less than 60 lbf (270 N)]**. **[Two (2)]** <Insert quantity> required.
- O. All manhole hardware shall be stainless steel including pulling eyes, inserts.
- P. The ground busbar shall be stainless steel and the ground rod shall be stainless steel. Seal ground rod penetration in the manholes with epoxy.

2.10 SOURCE QUALITY CONTROL

Retain paragraph below for precast concrete utility structures.

- A. Test and inspect precast concrete utility structures according to ASTM C 1037.

Retain paragraph below if underground enclosures of polymer concrete, fiberglass-reinforced polyester resin, high-density plastic, or composites of fiberglass and polymer concrete are specified. See Evaluations.

- B. Nonconcrete Handhole and Pull-Box Prototype Test: Test prototypes of manholes and boxes for compliance with SCTE 77. Strength tests shall be for specified tier ratings of products supplied.

Retain one of first two subparagraphs below. Retain first to require an independent testing agency to test for compliance with SCTE requirements. Retain second to require testing by manufacturers' laboratories. See Evaluations for a discussion about testing.

1. Tests of materials shall be performed by a independent testing agency.
2. Strength tests of complete boxes and covers shall be by either an independent testing agency or the manufacturer. A qualified registered professional engineer shall certify tests by manufacturer.

3. Testing machine pressure gages shall have current calibration certification complying with ISO 9000 and ISO 10012, and traceable to NIST standards.

PART 3 - EXECUTION

3.1 UNDERGROUND DUCT APPLICATION

Products and installation options in this Article are examples only. Coordinate with Drawings and edit to suit Project. See the Underground Raceway Application Chart and "Product Selection and Application Considerations" Article in the Evaluations. Coordinate with products listed in Part 2 "Nonmetallic Ducts and Duct Accessories" Article.

- A. Underground conduits shall be Poly-vinyl Chloride (PVC) schedule 40 or greater, or Galvanized Rigid Conduit (GRC) with factory bonded 40 mil. PVC coating.
- B. All underground duct banks inside and outside of the building shall be encased in red concrete, supported on listed conduit spacers every five (5) feet, with a minimum of three (3) inches of cover on all sides and two (2) inches between conduits at a minimum depth of 36 - inches from top of concrete encasement to finished grade. A 3" wide red metallized foil core detectable warning tape shall be placed over the duct bank at a depth not exceeding the manufacturer's recommendations.
- C. Concrete encased duct banks shall be utilized for all primary duct banks at DEN. Primary duct banks are considered those duct banks that form the main arteries of the DEN duct bank system and those serving any DEN owned facility or structure. Concrete encasement shall also be used on segments of direct buried duct bank that cross under paved roadways or other locations subject to vehicular traffic.
- D. Include a bare #2 copper ground conductor above conduits in all concrete encased duct banks.
- E. A 1-inch minimum size shall be used for underground conduit.
- F. The minimum size of any underground high voltage (above 1,000 volt) conduit shall be 4".
- G. A separate insulated ground wire shall be installed in each conduit. The ground wire shall be sized on the drawings or in accordance with NEC article 250.

Verify application in paragraph below with utility if ducts are for service conductors provided by utility.

- H. Ducts for Electrical Cables Over 600 V: RNC, NEMA Type [EPC-80] [EPC-40] [EB-20]-PVC, in concrete-encased duct bank, unless otherwise indicated.

Retain one of first two paragraphs below for underground feeders rated 600 V and less. First paragraph is for concrete-encased ducts; second is for direct-buried ducts. Verify application with utility if ducts are for service conductors provided by utility. See Evaluations.

- I. Ducts for Electrical Feeders 600 V and Less: RNC, NEMA Type [EPC-80] [EPC-40]

[EB-20]-PVC, in concrete-encased duct bank, unless otherwise indicated.

- J. Ducts for Electrical Feeders 600 V and Less: RNC, NEMA Type [EPC-80] [EPC-40]-PVC, in direct-buried duct bank, unless otherwise indicated.
- K. Ducts for Electrical Branch Circuits: RNC, NEMA Type [EPC-80] [EPC-40]-PVC, in direct-buried duct bank, unless otherwise indicated.

Retain one of two paragraphs below for underground telecommunications service. Edit to suit Project. Verify application with utility if ducts are for utility use for service cables. See Evaluations.

Both options in paragraph below represent listed products in wiring methods that are permitted by NFPA 70 for electrical power work. NFPA 70 has no clear requirements for outside underground raceways for telephone, communications, or data wiring. Verify validity of these applications with authorities having jurisdiction.

- L. Underground Ducts for Telephone, Communications, or Data Utility Service Cables: RNC, NEMA Type [EPC-40] [EB-20]-PVC, in concrete-encased duct bank, unless otherwise indicated.

First option in paragraph below represents a listed product in a wiring method that is permitted by NFPA 70 for electrical power work. Duct types in other options are not listed but are often used for applications like this. Verify validity of these applications with authorities having jurisdiction.

- M. Underground Ducts for Telephone, Communications, or Data Utility Service Cables: [RNC, NEMA Type EPC-40-PVC,] [Underground plastic utilities duct, NEMA Type DB-60-PVC,] [Underground plastic utilities duct, NEMA Type DB-120-PVC,] installed in concrete-encased duct bank, unless otherwise indicated.

Retain one of two paragraphs below for on-site underground telecommunications distribution. Edit to suit Project. See Evaluations.

First option in paragraph below represents a listed product in a wiring method that is permitted by NFPA70 for electrical power work. Duct types in other options are not listed but are often used for applications like this. Verify validity of these applications with authorities having jurisdiction.

- N. Underground Ducts for Telephone, Communications, or Data Circuits: RNC, NEMA Type [EPC-40] [DB-60] [DB-120]-PVC, in direct-buried duct bank, unless otherwise indicated.

Paragraph below represents a listed product in a wiring method that is permitted by NFPA 70 for electrical power conductors and cables. NFPA 70 has no clear requirements for outside underground raceways for telephone, communications, or data wiring. Verify validity of these applications with authorities having jurisdiction.

- O. Underground Ducts for Telephone, Communications, or Data Circuits: RNC, NEMA Type EB-20-PVC, in concrete-encased duct bank, unless otherwise indicated.

Trenchless technology involving horizontal jacking or boring or directional boring is often used for crossing obstructions such as described in paragraph below. Trenchless techniques are not specified in this Section but are described in the Evaluations.

Coordinate paragraph below with Drawings, and consider showing duct-bank reinforcement and backfill and pavement patching requirements on them.

- P. Underground Ducts Crossing [**Paved Paths**] [**Walks**] [**and**] [**Driveways**] [**Roadways**] [**and Railroads**]: RNC, NEMA Type EPC-40-PVC, encased in reinforced concrete.
1. Steel reinforced, concrete encased duct banks shall be utilized for all duct bank segments running under aprons, taxiways and other aircraft movement areas.

3.2 UNDERGROUND ENCLOSURE APPLICATION

- A. The underground concrete vaults (UCV's) and pull boxes used throughout non-aircraft movement areas at DEN are pre-cast units which conform to <Insert telephone provider> regulated telephone company specifications. These units are described more completely in part two of this section.
- B. Mid-sized UCV's (12'-0" L x 6'-0" W x 7'-0" H interior dimension) shall be utilized for all main duct banks at DEN. Main duct banks shall be considered those duct banks serving more than one facility or containing more than four (4) 4-inch conduits. Mid-sized UCV's may contain fiber-optic cabling, copper cabling or both. Many of the mid-sized UCV's will contain splice cases, repeaters and other outside plant devices.
- C. Small UCV's (6'-0" L x 4'-0" W x 7'-0" H interior dimension) may be utilized for branch connections which serve only a single facility and contain four (4) or fewer ducts. These UCV's may contain fiber-optic cabling, copper cabling or a combination of both. These UCV's are not suitable for housing splice cases, repeaters, etc. Small UCV's should be reserved for straight through pulls of copper or fiber cabling.
- D. The standard DEN pull box is a round unit approximately 48-inches in internal diameter and approximately 48-inches deep. This pull box is to be used on duct bank runs containing no more than two conduits and supporting fiber-optic cable only. These boxes do not provide sufficient space for copper splice cases.
- E. UCV's shall be placed within 100-feet of any 90-degree turn in the duct bank and at intervals of approximately 500-feet. Pull boxes on fiber-optic only duct banks may be placed at intervals of approximately 750-feet. Adjust spacing to avoid paved areas and traveled roadways.
- F. The standard DEN UCV contains break out ports for 4-inch schedule 40 PVC on two opposing ends. UCV's should not be placed directly at the corner point for a 90-degree duct bank turn. Do not modify UCV's with sidewall openings where no conduit ports exist as to do so complicates cable racking and splice case placement on larger cable sizes.
- G. The standard DEN pull box contains break-out waffle panels at intervals around the pull box circumference. Arrange ducts to enter and exit the pull box on directly opposite break-out panels to allow for straight-through cable pulls.
- H. When arranging ducts in UCV's and pull boxes, utilize the lower ports first, starting with

the bottom most port and working upward. Ensure that the pattern of ducts (ie:1, 2, 3, 4 etc.) remains the same on both ends of a duct run. For example, on a north-south duct run the lowest duct on the east side leaving one UCV would also be the lowest duct on the east side at the next UCV.

Delete this Article if Drawings indicate type and structural load rating of enclosure to be used for each application. Retain this Article to specify types and structural load ratings of manholes, handholes, and pull boxes for various applications in Project. Options are examples only. Coordinate with Drawings. See the "Product Selection and Application Considerations" Article in the Evaluations. Coordinate with product specifications in Part 2 articles that specify underground enclosures.

Verify with manufacturers that units of types specified are available in sizes required. Indicate on Drawings the size of each enclosure, and use a symbol or other notation to differentiate between manholes and handholes or boxes.

- I. Handholes and Boxes for 600 V and Less[, **Including Telephone, Communications, and Data Wiring**]:
 1. Units in Roadways and Other Deliberate Traffic Paths: Precast concrete. AASHTO HB 17, [**H-10**] [**H-20**] structural load rating.
 2. Units in Driveway, Parking Lot, and Off-Roadway Locations, Subject to Occasional, Nondeliberate Loading by Heavy Vehicles: [**Precast concrete, AASHTO HB 17, H-20**] [**Polymer concrete, SCTE 77, Tier 15**] [**Fiberglass enclosures with polymer concrete frame and cover, SCTE 77, Tier 15**] [**Fiberglass-reinforced polyester resin, SCTE 77, Tier 15**] [**High-density plastic, SCTE 77, Tier 15**] structural load rating.
 3. Units in Sidewalk and Similar Applications with a Safety Factor for Nondeliberate Loading by Vehicles: [**Precast concrete, AASHTO HB 17, H-10**] [**Polymer concrete units, SCTE 77, Tier 8**] [**Heavy-duty fiberglass units with polymer concrete frame and cover, SCTE 77, Tier 8**] [**High-density plastic, SCTE 77, Tier 8**] structural load rating.
 4. Units Subject to Light-Duty Pedestrian Traffic Only: [**Fiberglass-reinforced polyester resin**] [**High-density plastic**], structurally tested according to SCTE 77 with 3000-lbf (13 345-N) vertical loading.
- J. Manholes: [**Precast**] [**or**] [**cast-in-place**] concrete.

Retain one or both subparagraphs below, according to load rating or ratings required for Project manholes. If retaining both, use notations on Drawings to indicate the traffic level in each roadway where a manhole is located.

1. Units Located in Roadways and Other Deliberate Traffic Paths by Heavy or Medium Vehicles: H-20 structural load rating according to AASHTO HB 17.
2. Units Not Located in Deliberate Traffic Paths by Heavy or Medium Vehicles: H-10 load rating according to AASHTO HB 17.

3.3 EARTHWORK

Coordinate this Article with Drawings.

- A. Excavation and Backfill: Comply with Section 312000 "Earth Moving," but do not use heavy-duty, hydraulic-operated, compaction equipment.
- B. After installation of electrical work, backfill with flowable backfill to insure against the possibility of differential settling, then use flowable backfill to within 8 inches of final grade.

Retain three paragraphs below if Project requires restoration of disturbed features and areas.

- C. Restore surface features at areas disturbed by excavation and reestablish original grades, unless otherwise indicated. Replace removed sod immediately after backfilling is completed.
- D. Restore areas disturbed by trenching, storing of dirt, cable laying, and other work. Restore vegetation and include necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging, and mulching. Comply with Section 329200 "Turf and Grasses" and Section 329300 "Plants."
- E. Cut and patch existing pavement in the path of underground ducts and utility structures according to Division 32 Sections.

3.4 DUCT INSTALLATION

For electrical-power duct banks, note that ampacity of cables may be reduced in duct banks of more than two tiers of two ducts each.

- A. Slope: Pitch ducts a minimum slope of 1:300 down toward manholes and handholes and away from buildings and equipment. Slope ducts from a high point in runs between two manholes to drain in both directions.

Manufactured sweep bends in first paragraph below are available in various radii up to 25 feet (7.5 m) for 4- and 5-inch (100- and 125-mm) ducts, although a 48-inch (1220-mm) radius is the largest regularly stocked. To minimize pulling tensions, specify the largest radius possible, consistent with other Project requirements. See Editing Instruction No. 3 in the Evaluations. Coordinate with Drawings.

Stub-ups are specified separately in this Article in paragraphs for concrete-encased and direct-buried ducts and duct banks.

- B. Curves and Bends: Use 5-degree angle couplings for small changes in direction. Use manufactured long sweep bends with a minimum radius of [48 inches (1220 mm)] [12.5 feet (4 m)] [25 feet (7.5 m)], vertically, and [9 feet (2.75 m)] [12.5 feet (4 m)] horizontally, unless otherwise indicated.
- C. Joints: Use solvent-cemented joints in ducts and fittings and make watertight according to manufacturer's written instructions. Stagger couplings so those of adjacent ducts do not lie in same plane.
- D. Duct Entrances to Manholes and Concrete and Polymer Concrete Handholes: Use end bells, spaced approximately 10 inches (250 mm) o.c. for 5-inch (125-mm) ducts, and vary proportionately for other duct sizes.

1. Begin change from regular spacing to end-bell spacing **10 feet (3 m)** from the end bell without reducing duct line slope and without forming a trap in the line.

Retain first subparagraph below if differential settlement is anticipated where duct banks approach manholes or handholes. Expansion and deflection fittings were available in 2-, 3-, and 4-inch (50-, 75-, and 100-mm) sizes when this Section was updated. Consult manufacturers for availability of larger sizes and for installation instructions.

2. Direct-Buried Duct Banks: Install an expansion and deflection fitting in each conduit in the area of disturbed earth adjacent to manhole or handhole.
3. Grout end bells into structure walls from both sides to provide watertight entrances.

Coordinate design of concrete-encased duct banks approaching building wall penetrations with building structural design to support ducts at wall, without reducing structural or watertight integrity of building. Do not use steel conduit in highly corrosive soils. Coordinate with Drawings.

Sleeves and sleeve seals for conduits penetrating building walls below grade are specified in Division 26 Section "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

- E. Building Wall Penetrations: Make a transition from underground duct to rigid PVC coated steel conduit at least **10 feet (3 m)** outside the building wall without reducing duct line slope away from the building, and without forming a trap in the line. Use fittings manufactured for duct-to-conduit transition. Install conduit penetrations of building walls as specified in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."
- F. Waterproofed Wall and Floor Penetrations: Install a watertight entrance-sealing device with sealing gland assembly on the inside. Anchor device into masonry construction with one or more integral flanges. Secure membrane waterproofing to the device to make permanently watertight.
- G. Sealing: Provide temporary closure at terminations of ducts that have cables pulled. Seal spare ducts at terminations. Use sealing compound and plugs to withstand at least **15-psig (1.03-MPa)** hydrostatic pressure.
- H. Pulling Cord: install pulling cord in ducts, including spares.
- I. When concrete encased duct bank or conduit penetrates a foundation wall of a manhole, hand hole, or large pull box, the encasement is required to be structurally attached to the wall. Furnish for approval a shop drawing showing the conduit terminations and how the concrete encasement will be tied into the structure.
- J. No conduits shall be encased in sidewalks, roadways, footings, grade beams and foundations except under special cases approved by the DEN Project Manager.
- K. Conduit penetrating a foundation wall or wall of a handhole or manhole shall be sleeved and continuous (without fittings) from the interior for a minimum of five (5') on the exterior. Conduit penetrating a footer or grade beam shall be sleeved and continuous for five feet (5') on either side of a footer or grade beam using a single ten foot piece of PVC coated GRC. Conduit penetrating a wall, footer or grade beam

below grade shall be plastic coated rigid steel conduit. Conduit penetration of an exterior wall or wall of a handhole or manhole shall be made watertight.

- L. All G.R.C. entering or leaving manholes, hand holes or switch gear shall have a grounding bushing attached to the conduit and the ground wire attached to the bushing.
- M. Bell fittings shall be installed on all PVC conduits entering or leaving manholes or hand holes.
- N. All conduits in manholes and hand holes that contain conductors shall be sealed by duct seal and all empty conduits shall be sealed with an approved fitting.
- O. All cable shall be racked and supported in manholes.
- P. Manholes and hand holes shall be water tight; joints in precast hand holes and manholes shall be filled with non-shrink mortar and finished flush with the adjoining surfaces after being made watertight.
- Q. Concrete-Encased Ducts: Support ducts on duct separators.

To comply with first subparagraph below, Contractor may have to provide additional separators to prevent sagging when temperature is high during construction. Additional separators also reduce chance of floating or other movement during concreting.

1. Separator Installation: Space separators close enough to prevent sagging and deforming of ducts, with not less than [4] [5] spacers per 20 feet (6 m) of duct. Secure separators to earth and to ducts to prevent floating during concreting. Stagger separators approximately 6 inches (150 mm) between tiers. Tie entire assembly together using fabric straps; do not use tie wires or reinforcing steel that may form conductive or magnetic loops around ducts or duct groups.
2. Concreting Sequence: Pour each run of envelope between manholes or other terminations in one continuous operation.
 - a. Start at one end and finish at the other, allowing for expansion and contraction of ducts as their temperature changes during and after the pour. Use expansion fittings installed according to manufacturer's written recommendations, or use other specific measures to prevent expansion-contraction damage.
 - b. If more than one pour is necessary, terminate each pour in a vertical plane and install 3/4-inch (19-mm) reinforcing rod dowels extending 18 inches (450 mm) into concrete on both sides of joint near corners of envelope.
3. Pouring Concrete: Spade concrete carefully during pours to prevent voids under and between conduits and at exterior surface of envelope. Do not allow a heavy mass of concrete to fall directly onto ducts. Use a plank to direct concrete down sides of bank assembly to trench bottom. Allow concrete to flow to center of bank and rise up in middle, uniformly filling all open spaces. Do not use power-driven agitating equipment unless specifically designed for duct-bank application.

Coordinate first subparagraph below with Drawings, and consider showing duct-bank reinforcement requirements on them.

4. Reinforcement: Reinforce concrete-encased duct banks where they cross disturbed earth and where indicated. Arrange reinforcing rods and ties without forming conductive or magnetic loops around ducts or duct groups.
5. Forms: Use walls of trench to form side walls of duct bank where soil is self-supporting and concrete envelope can be poured without soil inclusions; otherwise, use forms.

Delete subparagraph below if dimensioned duct sections are shown on Drawings.

6. Minimum Space between Ducts: 3 inches (75 mm) between ducts and exterior envelope wall, 2 inches (50 mm) between ducts for like services, and 4 inches (100 mm) between power and signal ducts.

Requirements in subparagraph below exceed NFPA 70 and may be considered conservative. If desired, depth (cover) requirements below can be deleted and NFPA 70 requirements will apply.

7. Depth: Install top of duct bank at least 36 inches below finished grade, unless otherwise indicated.

Manufactured PVC duct elbows in first subparagraph below are vulnerable to damage by pulling lines when cable pulling tensions are high. However, concrete encasement, together with reduced pulling tensions, can prevent serious damage. Reduce potential pulling tensions by making duct runs from the closest manhole or handhole as short as possible and arranging stub-up elbows to have the largest possible radius. 5-inch (125-mm) duct is available in standard radii of 24, 36, 48, and 60 inches (300, 900, 1200, and 1500 mm) and greater. If necessary, specify that stub-ups be made with rigid steel conduit elbows as provided in second subparagraph below. Coordinate with Drawings and see Editing Instruction No. 3 in the Evaluations.

Retain one of first two subparagraphs and associated subparagraphs below to specify type of stub-ups for direct-buried ducts in Project.

8. Stub-Ups: Use manufactured duct elbows for stub-ups at poles and equipment and at building entrances through the floor, unless otherwise indicated. Extend concrete encasement throughout the length of the elbow.
9. Stub-Ups: Use manufactured rigid steel conduit elbows for stub-ups at poles and equipment and at building entrances through the floor.
 - a. Couple steel conduits to ducts with adapters designed for this purpose, and encase coupling with 3 inches (75 mm) of concrete.
 - b. Stub-Ups to Equipment: For equipment mounted on outdoor concrete bases, extend steel conduit horizontally a minimum of 60 inches (1500 mm) from edge of base. Install insulated grounding bushings on terminations at equipment.
10. Warning Tape: Bury warning tape approximately 12 inches (300 mm) above all concrete-encased ducts and duct banks. Align tape parallel to and within 3 inches (75 mm) of the centerline of duct bank. Provide an additional warning tape for each 12-inch (300-mm) increment of duct-bank width over a nominal 18 inches (450 mm). Space additional tapes 12 inches (300 mm) apart, horizontally.

R. Special Duct Bank Construction at Corners

1. The duct bank system at DEN supports copper cabling in sizes up to 1800 pairs. The pulling tension required to install these cable requires the use of winches and steel cables. Special provisions are required at corners to prevent these cables from sawing through the sidewall of the ducts.
2. Corners in the duct bank system are required to be made with 4-inch galvanized rigid PVC coated conduit with a radius of at least nine (9) feet. Concrete encasement is required at corners to control stresses and movement in the duct system during cable installation.

S. Duct Bank Provisions for Fiber Optic Cabling

1. Ducts designated for fiber-optic cabling shall be provided with three 1-inch inner-ducts. The three inner-ducts installed in each fiber duct shall be colored blue, orange and black.

T. Direct-Buried Duct Banks:

1. Support ducts on duct separators coordinated with duct size, duct spacing, and outdoor temperature.
2. Space separators close enough to prevent sagging and deforming of ducts, with not less than [4] [5] spacers per 20 feet (6 m) of duct. Secure separators to earth and to ducts to prevent displacement during backfill and yet permit linear duct movement due to expansion and contraction as temperature changes. Stagger spacers approximately 6 inches (150 mm) between tiers.
3. Excavate trench bottom to provide firm and uniform support for duct bank. Prepare trench bottoms as specified in Division 31 Section "Earth Moving" for pipes less than 6 inches (150 mm) in nominal diameter.
4. Install backfill as specified in Division 31 Section "Earth Moving."
5. After installing first tier of ducts, backfill and compact. Start at tie-in point and work toward end of duct run, leaving ducts at end of run free to move with expansion and contraction as temperature changes during this process. Repeat procedure after placing each tier. After placing last tier, hand-place backfill to 4 inches (100 mm) over ducts and hand tamp. Firmly tamp backfill around ducts to provide maximum supporting strength. Use hand tamper only. After placing controlled backfill over final tier, make final duct connections at end of run and complete backfilling with normal compaction as specified in Division 31 Section "Earth Moving."

Delete subparagraph below if dimensioned duct sections are shown on Drawings.

6. Install ducts with a minimum of 3 inches (75 mm) between ducts for like services and 6 inches (150 mm) between power and signal ducts.

Requirements in first subparagraph below exceed NFPA 70. Retain for conservative design.

7. Depth: Install top of duct bank at least 36 inches (900 mm) below finished grade, unless otherwise indicated.
8. Set elevation of bottom of duct bank below the frost line.

Direct-buried, PVC duct elbows in first subparagraph below are particularly vulnerable to damage by pulling lines when cable pulling tensions are high. Rigid steel conduit elbows are sometimes specified for these stub-ups to prevent such damage. However, concrete encasement of PVC duct elbows, together

with reduced pulling tensions, is also used in these situations. Pulling tensions can be reduced by making duct runs from the closest manhole or handhole as short as possible and arranging duct banks so stub-up elbows have the longest possible radius. 5-inch (125-mm) duct elbows are available in standard radii of 24, 36, 48, and 60 inches (300, 900, 1200, and 1500 mm) and greater. Coordinate with Drawings and see Editing Instruction No. 3 in the Evaluations.

Retain one of first two subparagraphs and associated subparagraphs below to specify type of stub-ups for direct-buried ducts in Project.

9. Install manufactured duct elbows for stub-ups at poles and equipment and at building entrances through the floor, unless otherwise indicated. Encase elbows for stub-up ducts throughout the length of the elbow.
10. Install manufactured rigid steel conduit elbows for stub-ups at poles and equipment and at building entrances through the floor.
 - a. Couple steel conduits to ducts with adapters designed for this purpose, and encase coupling with 3 inches (75 mm) of concrete.
 - b. For equipment mounted on outdoor concrete bases, extend steel conduit horizontally a minimum of 60 inches (1500 mm) from edge of equipment pad or foundation. Install insulated grounding bushings on terminations at equipment.
11. Warning Planks: Bury warning planks approximately 12 inches (300 mm) above direct-buried ducts and duct banks, placing them 24 inches (600 mm) o.c. Align planks along the width and along the centerline of duct bank. Provide an additional plank for each 12-inch (300-mm) increment of duct-bank width over a nominal 18 inches (450 mm). Space additional planks 12 inches (300 mm) apart, horizontally.

3.5 INSTALLATION OF CONCRETE MANHOLES, HANDHOLES, AND BOXES

Retain this Article for both cast-in-place and precast manholes and for precast handholes.

A. Cast-in-Place Manhole Installation:

1. Finish interior surfaces with a smooth-troweled finish.

Coordinate first subparagraph below with Drawings.

2. Windows for Future Duct Connections: Form and pour concrete knockout panels 1-1/2 to 2 inches (38 to 50 mm) thick, arranged as indicated.
3. Cast-in-place concrete, formwork, and reinforcement are specified in Division 03 Section "Cast-in-Place Concrete."

B. Precast Concrete Handhole and Manhole Installation:

1. Comply with ASTM C 891, unless otherwise indicated.
2. Install units level and plumb and with orientation and depth coordinated with connecting ducts to minimize bends and deflections required for proper entrances.
3. Unless otherwise indicated, support units on a level bed of crushed stone or

gravel, graded from 1-inch (25-mm) sieve to No. 4 (4.75-mm) sieve and compacted to same density as adjacent undisturbed earth.

Coordinate paragraph and subparagraphs below with Drawings. See Editing Instruction No. 4 in the Evaluations.

C. Elevations:

1. Manhole Roof: Install with rooftop at least 24 inches (610 mm) below finished grade.
2. Manhole Frame: In paved areas and trafficways, set frames flush with finished grade. Set other manhole frames 1 inch (25 mm) above finished grade.
3. Install handholes with bottom below the frost line, <Insert depth of frost line below grade at Project site> below grade.
4. Handhole Covers: In paved areas and trafficways, set surface flush with finished grade. Set covers of other handholes 1 inch (25 mm) above finished grade.
5. Where indicated, cast handhole cover frame integrally with handhole structure.

Retain paragraph below if drain lines for underground structures are provided. Coordinate with site drainage design and Drawings. See Editing Instruction No. 5 in the Evaluations.

- D. Drainage: Install drains in bottom of manholes where indicated. Coordinate with drainage provisions indicated.

Revise paragraph and subparagraphs below if other-than-round, cast-iron frame and cover are used for access to manholes.

E. Manhole Access: Circular opening in manhole roof; sized to match cover size.

1. Manholes with Fixed Ladders: Offset access opening from manhole centerlines to align with ladder.
2. Install chimney, constructed of precast concrete collars and rings to support frame and cover and to connect cover with manhole roof opening. Provide moisture-tight masonry joints and waterproof grouting for cast-iron frame to chimney.

- F. Frame and Cover: Install grade rings centered on UCV top opening to elevate frame and cover to correct elevation. Provide moisture-tight masonry joints and waterproof grouting for cast-iron frame to grade rings. Provide additional steps in UCV throat at any location where the height of the grade rings exceeds 18-inches.

Retain one or both paragraphs below if concrete utility structures are to be waterproofed or dampproofed. See Editing Instruction No. 6 in the Evaluations.

- G. Waterproofing: Apply waterproofing to exterior surfaces of manholes[**and handholes**] after concrete has cured at least three days. Waterproofing materials and installation are specified in Section "[071326 **"Self-Adhering Sheet Waterproofing"**] [071353 **"Elastomeric Sheet Waterproofing"**] [071354 **"Thermoplastic Sheet Waterproofing"**]." After ducts have been connected and grouted, and before backfilling, waterproof joints and connections and touch up abrasions and scars.

Waterproof exterior of manhole chimneys after mortar has cured at least three days.

- H. Dampproofing: Apply dampproofing to exterior surfaces of manholes[**and handholes**] after concrete has cured at least three days. Dampproofing materials and installation are specified in Division 07 Section "Bituminous Dampproofing." After ducts have been connected and grouted, and before backfilling, dampproof joints and connections and touch up abrasions and scars. Dampproof exterior of manhole chimneys after mortar has cured at least three days.

Coordinate paragraph below with Drawings. Delete second option if nonmetallic cable racks are specified.

- I. Hardware: Install removable hardware, including pulling eyes, cable stanchions, [**and**] cable arms, [**and insulators,**] as required for installation and support of cables and conductors and as indicated.

Delete first paragraph below if manhole ladder locations are detailed on Drawings.

- J. Fixed Manhole Ladders: Arrange to provide for safe entry with maximum clearance from cables and other items in manholes.
- K. Field-Installed Bolting Anchors in Manholes and Concrete Handholes: Do not drill deeper than **3-7/8 inches** (98 mm) for manholes and **2 inches** (50 mm) for handholes, for anchor bolts installed in the field. Use a minimum of two anchors for each cable stanchion.
- L. Warning Sign: Install "Confined Space Hazard" warning sign on the inside surface of each manhole cover.

3.6 INSTALLATION OF HANDHOLES AND BOXES OTHER THAN PRECAST CONCRETE

- A. Install handholes and boxes level and plumb and with orientation and depth coordinated with connecting ducts to minimize bends and deflections required for proper entrances. Use box extension if required to match depths of ducts, and seal joint between box and extension as recommended by the manufacturer.
- B. Unless otherwise indicated, support units on a level bed of crushed stone or gravel, graded from **1/2-inch** (12.7-mm) sieve to **No. 4** (4.75-mm) sieve and compacted to same density as adjacent undisturbed earth.
- C. Elevation: In paved areas and trafficways, set so cover surface will be flush with finished grade. Set covers of other handholes **1 inch** (25 mm) above finished grade.
- D. Install handholes and boxes with bottom below the frost line, **<Insert depth of frost line below grade at Project site>** below grade.

First paragraph below requires Contractor to select hardware to install and support cable. If desired, edit paragraph to refer Contractor to Drawings, and show on them specific requirements for each enclosure.

- E. Install removable hardware, including pulling eyes, cable stanchions, cable arms, and insulators, as required for installation and support of cables and conductors and as indicated. Select arm lengths to be long enough to provide spare space for future cables, but short enough to preserve adequate working clearances in the enclosure.
- F. Field-cut openings for ducts and conduits according to enclosure manufacturer's written instructions. Cut wall of enclosure with a tool designed for material to be cut. Size holes for terminating fittings to be used, and seal around penetrations after fittings are installed.

Some manufacturers recommend structural protection similar to that described below for enclosures other than precast concrete, if they will be exposed to occasional nondeliberate loading by heavy-vehicle traffic, and particularly if they are to be installed in asphalt concrete paving. Consult manufacturers and edit paragraph and subparagraphs below to suit Project.

- G. For enclosures installed in [**asphalt paving**] [**and**] <Insert material> and subject to occasional, nondeliberate, heavy-vehicle loading, form and pour a concrete ring encircling, and in contact with, enclosure and with top surface screeded to top of box cover frame. Bottom of ring shall rest on [**compacted earth**] <Insert material>.
 - 1. Concrete: 3000 psi (20 kPa), 28-day strength, complying with Division 03 Section "Cast-in-Place Concrete," with a troweled finish.
 - 2. Dimensions: 10 inches wide by 12 inches deep (250 mm wide by 300 mm deep) <Insert dimensions>.

3.7 GROUNDING

- A. Ground underground ducts and utility structures according to Division 26 Section "Grounding and Bonding for Electrical Systems."

3.8 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following tests and inspections and prepare test reports:
 - 1. Demonstrate capability and compliance with requirements on completion of installation of underground ducts and utility structures.
 - 2. Pull aluminum or wood test mandrel through duct to prove joint integrity and test for out-of-round duct. Provide mandrel equal to 80 percent fill of duct. If obstructions are indicated, remove obstructions and retest.
 - 3. Test manhole [**and handhole**] grounding to ensure electrical continuity of grounding and bonding connections. Measure and report ground resistance as specified in Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Correct deficiencies and retest as specified above to demonstrate compliance.

3.9 CLEANING

- A. Pull leather-washer-type duct cleaner, with graduated washer sizes, through full length of ducts. Follow with rubber duct swab for final cleaning and to assist in spreading lubricant throughout ducts.
- B. Clean internal surfaces of manholes, including sump. Remove foreign material.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260543

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SECTION 260544 - SLEEVES AND SLEEVE SEALS FOR ELECTRICAL RACEWAYS AND CABLING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Sleeves for raceway and cable penetration of non-fire-rated construction walls and floors.
 - 2. Sleeve-seal systems.
 - 3. Sleeve-seal fittings.
 - 4. Grout.
 - 5. Silicone sealants.

- B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 078413 "Penetration Firestopping" for penetration firestopping installed in fire-resistance-rated walls, horizontal assemblies, and smoke barriers, with and without penetrating items.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data substantiating that materials comply with requirements.

Retain the paragraph and sub paragraphs below only if project is pursuing LEED certification.

- B. LEED Submittals:

"Product Data for Credit EQ 4.1" Subparagraph below applies to LEED-NC, LEED-CI, and LEED-CS; coordinate with requirements for sealants.

- 1. Product Data for Credit EQ 4.1: For sealants, documentation including printed statement of VOC content.

"Laboratory Test Reports for Credit EQ 4" Subparagraph below applies to LEED for Schools.

- 2. Laboratory Test Reports for Credit EQ 4: For sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.4 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Division 01 Section "Product Requirements."

2.1 SLEEVES

A. Wall Sleeves:

Retain "Steel Pipe Sleeves" or "Cast-Iron Pipe Sleeves" Subparagraph below for penetrations through exterior walls above and below grade.

1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

Retain "Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies" Paragraph below when required by authorities having jurisdiction. NFPA 70 does not contain requirements for sleeves. The requirement below is from International Building Code, Section 712, "Penetrations."

- ### B. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies:
- Galvanized-steel sheet; 0.0239-inch (0.6-mm) minimum thickness; round tube closed with welded longitudinal joint, with tabs for screw-fastening the sleeve to the board.

PVC sleeves in "PVC-Pipe Sleeves" and "Molded-PVC Sleeves" paragraphs below may be prohibited by authorities having jurisdiction.

- ### C. PVC-Pipe Sleeves:
- ASTM D 1785, Schedule 40.
- ### D. Molded-PVC Sleeves:
- With nailing flange for attaching to wooden forms.
- ### E. Molded-PE or -PP Sleeves:
- Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.
- ### F. Sleeves for Rectangular Openings:
1. Material: Galvanized sheet steel.
 2. Minimum Metal Thickness:
 - a. For sleeve cross-section rectangle perimeter less than 50 inches (1270 mm) and with no side larger than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
 - b. For sleeve cross-section rectangle perimeter 50 inches (1270 mm) or more and one or more sides larger than 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).

2.2 SLEEVE-SEAL SYSTEMS

Sleeve-seal systems in this article are used for conduit penetrations in slabs-on-grade and in below-grade exterior walls.

- ### A. Description:
- Modular sealing device, designed for field assembly, to fill annular space between sleeve and raceway or cable.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advance Products & Systems, Inc.
 - b. CALPICO, Inc.
 - c. Metraflex Company (The).
 - d. Pipeline Seal and Insulator, Inc.
 - e. Proco Products, Inc.
 - f. Link-Seal.
 - g. <Insert manufacturer>
 - h. or approved equal.

Retain first option in "Sealing Elements" Subparagraph below unless Nitrile (Buna N) rubber gasket material is required because hydrocarbons are present in the soil.

2. Sealing Elements: [EPDM] [Nitrile (Buna N)] rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
3. Pressure Plates: [Carbon steel] or [Stainless steel].
4. Connecting Bolts and Nuts: [Carbon steel, with corrosion-resistant coating,] [Stainless steel] of length required to secure pressure plates to sealing elements.

2.3 SLEEVE-SEAL FITTINGS

Sleeve-seal fittings in this article are used for conduit penetrations in slabs-on-grade and in exterior walls. These fittings are made to match conduit OD, so they must be selected to match the penetrating piping size. They are available for NPS 1/2 to 6 (DN 15 to 150) piping.

- A. Description: Manufactured plastic, sleeve-type, waterstop assembly made for embedding in concrete slab or wall. Unit shall have plastic or rubber waterstop collar with center opening to match piping OD.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Presealed Systems.
 - b. <Insert manufacturer>
 - c. or approved equal.

2.4 GROUT

- A. Description: Nonshrink; recommended for interior and exterior sealing openings in

non-fire-rated walls or floors.

- B. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- C. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

Retain "Silicone Sealants" Article below when use of silicone sealants and silicone foams is permitted as an alternative to grout in sealing of conduit or cable penetrations in gypsum wallboard walls.

2.5 SILICONE SEALANTS

- A. Silicone Sealants: Single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below.
 - 1. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces that are not fire rated.

Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit EQ 4.1.

- 2. Sealant shall have VOC content of <Insert value> g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools.

- 3. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- B. Silicone Foams: Multicomponent, silicone-based liquid elastomers that, when mixed, expand and cure in place to produce a flexible, nonshrinking foam.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION FOR NON-FIRE-RATED ELECTRICAL PENETRATIONS

- A. Comply with NECA 1.
- B. Comply with NEMA VE 2 for cable tray and cable penetrations.
- C. Sleeves for Conduits Penetrating Above-Grade Non-Fire-Rated Concrete and Masonry-Unit Floors and Walls:
 - 1. Interior Penetrations of Non-Fire-Rated Walls and Floors:
 - a. Seal annular space between sleeve and raceway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with

- requirements in Division 07 Section "Joint Sealants."
- b. Seal space outside of sleeves with mortar or grout. Pack sealing material solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect material while curing.
2. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
 3. Size pipe sleeves to provide [1/4-inch (6.4-mm)] <Insert dimension> annular clear space between sleeve and raceway or cable unless sleeve seal is to be installed [or unless seismic criteria require different clearance].
 4. Install sleeves for wall penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of walls. Cut sleeves to length for mounting flush with both surfaces of walls. Deburr after cutting.

Retain subparagraph below when unsleeved core-drilled openings in concrete floors are not allowed.

5. Install sleeves for floor penetrations. Extend sleeves installed in floors [2 inches (50 mm)] <Insert dimension> above finished floor level. Install sleeves during erection of floors.
- D. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies:
1. Use circular metal sleeves unless penetration arrangement requires rectangular sleeved opening.
 2. Seal space outside of sleeves with approved joint compound for gypsum board assemblies.
- E. Roof-Penetration Sleeves: Seal penetration of individual raceways and cables with flexible boot-type flashing units applied in coordination with roofing work.
- F. Aboveground, Exterior-Wall Penetrations: Seal penetrations using [steel] [cast-iron] pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
- G. Underground, Exterior-Wall and Floor Penetrations: Install cast-iron pipe sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between raceway or cable and sleeve for installing sleeve-seal system.

3.2 SLEEVE-SEAL-SYSTEM INSTALLATION

Sleeve-seal systems in this article are used in slabs-on-grade and in below-grade exterior concrete walls for a watertight seal around service-piping entries into the building. These systems require installation in a sleeve for proper operation.

- A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at raceway entries into building.
- B. Install type and number of sealing elements recommended by manufacturer for raceway or cable material and size. Position raceway or cable in center of sleeve.

Assemble mechanical sleeve seals and install in annular space between raceway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

3.3 SLEEVE-SEAL-FITTING INSTALLATION

Sleeve-seal fittings in this article are used above and below grade in concrete slabs and in concrete walls for a watertight seal around piping. These fittings do not require a sleeve.

- A. Install sleeve-seal fittings in new walls and slabs as they are constructed.
- B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.
- C. Secure nailing flanges to concrete forms.
- D. Using grout, seal the space around outside of sleeve-seal fittings.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260544

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SECTION 260548 - VIBRATION AND SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes the following:
 - 1. Isolation pads.
 - 2. Spring isolators.
 - 3. Restrained spring isolators.
 - 4. Channel support systems.
 - 5. Restraint cables.
 - 6. Hanger rod stiffeners.
 - 7. Anchorage bushings and washers.

- B. Related Sections include the following:

List below only products that the reader might expect to find in this Section but are specified elsewhere.

- 1. Section 260529 "Hangers and Supports for Electrical Systems" for commonly used electrical supports and installation requirements.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviations that remain after this Section has been edited.

- A. The IBC: International Building Code.
- B. ICC-ES: ICC-Evaluation Service.
- C. OSHPD: Office of Statewide Health Planning and Development for the State of California.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic-Restraint Loading:

Obtain values for items in subparagraphs and associated subparagraphs below from Project structural engineer or from SEI/ASCE 7. If the code at Project site is other than IBC or NFPA 5000, revise parameters to comply with applicable code.

Specify design spectral response acceleration at short periods (0.2 second) and at 1.0 second based on site class in subparagraphs below. Typical values range from 2 to 200 percent. Design spectral response acceleration is required for seismic force calculations to size seismic restraints. For each seismic restraint, include component importance factor, component response modification factor, and component amplification factor in the Electrical Vibration-Control and Seismic-Restraint Device Schedule.

1. Site Class as Defined in the IBC: **[A] [B] [C] [D] [E] [F]**.

In subparagraph below, retain Seismic Use Group or Building Category for Project structure from three classifications defined in the IBC.

2. Assigned Seismic Use Group or Building Category as Defined in the IBC: **[I] [II] [III]**.

Retain first three subparagraphs below if these values are not included in the Electrical Vibration-Control and Seismic-Restraint Device Schedule on Drawings. Factors below often vary among supported equipment. However, it is possible to specify maximum values for these factors for various classes of equipment or for all equipment instead of scheduling each piece of equipment.

- a. Component Importance Factor: **[1.0] [1.5] <Insert value>**.
- b. Component Response Modification Factor: **[1.5] [2.5] [3.5] [5.0] <Insert value>**.
- c. Component Amplification Factor: **[1.0] [2.5] <Insert value>**.
3. Design Spectral Response Acceleration at Short Periods (0.2 Second): **<Insert percent>**.
4. Design Spectral Response Acceleration at 1.0-Second Period: **<Insert percent>**.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

A. Product Data: For the following:

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.

See Evaluations for a discussion on seismic-restraint capacities and rating services.

- a. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by **[an evaluation service member of ICC-ES] [OSHPD] [an agency acceptable to authorities having jurisdiction]**.
- b. Annotate to indicate application of each product submitted and compliance with requirements.

Retain subparagraph below if vibration isolation devices are required for Project.

3. Restrained-Isolation Devices: Include ratings for horizontal, vertical, and combined loads.
4. Include data substantiating that materials comply with requirements.

Paragraph below is defined in Division 01 Section "Submittal Procedures" as a "Delegated-Design Submittal." Retain if Work of this Section is required to withstand specific design loads and design responsibilities have been delegated to Contractor or if structural data are required as another way to verify compliance with performance requirements. Professional engineer qualifications are specified in Division 01 Section "Quality Requirements."

B. Delegated-Design Submittal: For **[vibration isolation and]**seismic-restraint details indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Design Calculations: Calculate static and dynamic loading due to equipment weight and operation, seismic forces required to select vibration isolators and seismic restraints.
 - a. Coordinate design calculations with wind-load calculations required for equipment mounted outdoors. Comply with requirements in other Division 26 Sections for equipment mounted outdoors.
2. Indicate materials and dimensions and identify hardware, including attachment and anchorage devices.
3. Field-fabricated supports.

Retain subparagraph and associated subparagraphs below only if seismic design requirements apply but calculations have not been made and details or schedules on Drawings do not describe seismic restraints in detail. Retaining subparagraph will require Contractor to submit seismic-restraint Shop Drawings prepared by a professional engineer. Revise to suit local requirements.

4. Seismic-Restraint Details:

- a. Design Analysis: To support selection and arrangement of seismic restraints. Include calculations of combined tensile and shear loads.
- b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. [**Indicate association with vibration isolation devices.**]
- c. Preapproval and Evaluation Documentation: By [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**], showing maximum ratings of restraint items and the basis for approval (tests or calculations).

1.6 INFORMATIONAL SUBMITTALS

Retain paragraph below if seismic bracing of conduit racks, cable trays, and other electrical system components will be installed in congested areas.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Show coordination of seismic bracing for electrical components with other systems and equipment in the vicinity, including other supports and seismic restraints.

Coordinate paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For professional engineer.

Retain paragraph below if procedures for welder certification are retained in "Quality Assurance" Article.

- C. Welding certificates.

Retain paragraph below if Contractor is responsible for field quality-control testing.

- D. Field quality-control test reports.

1.7 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 QUALITY ASSURANCE

If an independent testing agency is required, see Division 01 Section "Quality Requirements" for general testing and inspecting agency qualification requirements.

- A. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.

Delete first paragraph below if no welding. Retain "Welding certificates" Paragraph in "Informational Submittals" Article if retaining below. AWS states that welding qualifications remain in effect indefinitely unless welding personnel have not welded for more than six months or there is a specific reason to question their ability.

- B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- C. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.
- D. Comply with NFPA 70.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 VIBRATION ISOLATORS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Ace Mountings Co., Inc.
 2. Amber/Booth Company, Inc.
 3. California Dynamics Corporation.
 4. Isolation Technology, Inc.
 5. Kinetics Noise Control.
 6. Mason Industries.
 7. Vibration Eliminator Co., Inc.
 8. Vibration Isolation.
 9. Vibration Mountings & Controls, Inc.
 10. **<Insert manufacturer>**
 11. or approved equal.

Copy paragraph and subparagraph below for each type of pad configuration required for Project. Use drawing designation and coordinate with the Electrical Vibration-Control and Seismic-Restraint Device Schedule on Drawings.

- B. Pads **<Insert drawing designation>**: Arrange in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.

Verify availability of various pad materials with manufacturers.

1. Resilient Material: Oil- and water-resistant [**neoprene**] [**rubber**] [**hermetically sealed compressed fiberglass**].

Copy paragraph and subparagraphs below for each type of spring isolator configuration required for Project. Use drawing designation and coordinate with the Electrical Vibration-Control and Seismic-Restraint Device Schedule on Drawings.

- C. Spring Isolators **<Insert drawing designation>**: Freestanding, laterally stable, open-spring isolators.
1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
 2. Minimum Additional Travel: 50 percent of the required deflection at rated load.
 3. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
 5. Baseplates: Factory drilled for bolting to structure and bonded to **1/4-inch- (6-mm)** thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to **500 psig (3447 kPa)**.
 6. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

Copy paragraph and subparagraphs below for each type of restrained spring isolator configuration required for Project. Use drawing designation and coordinate with the Electrical Vibration-Control and

Seismic-Restraint Device Schedule on Drawings.

- D. Restrained Spring Isolators **<Insert drawing designation>**: Freestanding, steel, open-spring isolators with seismic or limit-stop restraint.
1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to **1/4-inch-** (6-mm) thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
 2. Restraint: Seismic or limit-stop as required for equipment and authorities having jurisdiction.
 3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
 4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
 5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.2 SEISMIC-RESTRAINT DEVICES

Coordinate specifications for seismic-restraint components in this Article with structural engineer and with Drawings.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Amber/Booth Company, Inc.
 2. California Dynamics Corporation.
 3. Cooper B-Line, Inc.; a division of Cooper Industries.
 4. Hilti Inc.
 5. Loos & Co.; Seismic Earthquake Division.
 6. Mason Industries.
 7. TOLCO Incorporated; a brand of NIBCO INC.
 8. Unistrut; Tyco International, Ltd.
 9. **<Insert manufacturer>**
 10. or approved equal.

See Evaluations for a discussion on seismic-restraint capacities and rating services.

- B. General Requirements for Restraint Components: Rated strengths, features, and application requirements shall be as defined in reports by **[an evaluation service member of ICC-ES] [OSHPD] [an agency acceptable to authorities having jurisdiction]**.
1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least **[four] <Insert number>** times the maximum

seismic forces to which they will be subjected.

Two paragraphs below specify alternative types of seismic restraints for bracing suspended conduit and cable runs, wireways, cable trays, and busways. Retain one or both paragraphs and coordinate with Part 3, with electrical Sections specifying restrained items, and with Drawings. See Evaluations.

- C. Channel Support System: MFMA-3, shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; and rated in tension, compression, and torsion forces.
- D. Restraint Cables: **[ASTM A 603 galvanized]** **[ASTM A 492 stainless]**-steel cables with end connections made of steel assemblies with thimbles, brackets, swivels, and bolts designed for restraining cable service; and with a minimum of two clamping bolts for cable engagement.

Retain first paragraph below for strengthening resistance of hanger rods against seismic forces that may cause buckling of rods; delete if detailed on Drawings. Use with either channel- or cable-type bracing assemblies when required to counter seismic forces. Detail fabrication and indicate locations on Drawings.

- E. Hanger Rod Stiffener: **[Steel tube or steel slotted-support-system sleeve with internally bolted connections]** **[Reinforcing steel angle clamped]** to hanger rod. Do not weld stiffeners to rods.
- F. Bushings for Floor-Mounted Equipment Anchor: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchors and studs.
- G. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices.
- H. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

Expansion-type anchor bolts are not permitted by SEI/ASCE 7 for non-isolated equipment in excess of 10 hp (7.46 kW).

- I. Mechanical Anchor: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchors with strength required for anchor and as tested according to ASTM E 488. Minimum length of eight times diameter.
- J. Adhesive Anchor: Drilled-in and capsule anchor system containing polyvinyl or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

2.3 FACTORY FINISHES

Specify field-painting requirements in Division 09 Sections. Verify compatibility of factory finishes with field-applied coats. Indicate which groups of equipment are to receive various types of finish.

- A. Finish: Manufacturer's standard prime-coat finish ready for field painting.

Edit paragraph and subparagraphs below to include custom colors. Coordinate custom-color requirements with sample submittal requirements.

- B. Finish: Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.
1. Powder coating on springs and housings.
 2. All hardware shall be galvanized. Hot-dip galvanize metal components for exterior use.
 3. Baked enamel or powder coat for metal components on isolators for interior use.
 4. Color-code or otherwise mark vibration isolation and seismic-control devices to indicate capacity range.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and equipment to receive [**vibration isolation and**] seismic-control devices for compliance with requirements for installation tolerances and other conditions affecting performance.
- B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

- A. Multiple Raceways or Cables: Secure raceways and cables to trapeze member with clamps approved for application by [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**].

Indicate on Drawings, by details, schedules, or a combination of both, the locations where hanger rods for individual raceways, bus duct, cable trays, and hanger rods for trapeze hangers require hanger rod stiffeners.

- B. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.
- C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select

sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

3.3 SEISMIC-RESTRAINT DEVICE INSTALLATION

A. Equipment and Hanger Restraints:

Indicate type and quantity of restrained isolators described in first subparagraph below on Drawings or in the Electrical Vibration-Control and Seismic-Restraint Device Schedule on Drawings.

1. Install restrained isolators on electrical equipment.
 2. Install resilient, bolt-isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch (3.2 mm).
 3. Install seismic-restraint devices using methods approved by **[an evaluation service member of ICC-ES] [OSHPD] [an agency acceptable to authorities having jurisdiction]** providing required submittals for component.
- B. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.
- C. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.
- D. Drilled-in Anchors:
1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 2. Anchoring deeper than 1-1/2" in overhead cast in place, pre-tensioned or post-tensioned concrete is prohibited unless x-ray or ground penetrating radar study are performed and approved by the DEN Project Manager.
 3. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 4. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
 5. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
 6. Set anchors to manufacturer's recommended torque, using a torque wrench.
 7. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.
 8. Plastic or fiber anchors are prohibited.

3.4 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

Coordinate this Article with Drawings.

- A. Install flexible connections in runs of raceways, cables, wireways, cable trays, and busways where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where they terminate with connection to equipment that is anchored to a different structural element from the one supporting them as they approach equipment.

3.5 FIELD QUALITY CONTROL

Retain this Article if testing of anchors and supports is required.

Retain paragraph below to require Contractor to perform tests and inspections.

- A. Perform tests and inspections.

Retain paragraph and subparagraphs below to describe tests and inspections to be performed.

- B. Tests and Inspections:
 - 1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
 - 2. Schedule test with Owner, through DEN Project Manager, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven (7) days' advance notice.
 - 3. Obtain DEN Project Manager's approval before transmitting test loads to structure. Provide temporary load-spreading members.
 - 4. Test at least **[four (4)] <Insert number>** of each type and size of installed anchors and fasteners selected by DEN Project Manager.
 - 5. Test to 90 percent of rated proof load of device.

Retain first three subparagraphs below if vibration isolators are required for Project.

- 6. Measure isolator restraint clearance.
 - 7. Measure isolator deflection.
 - 8. Verify snubber minimum clearances.
 - 9. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.
- C. Remove and replace malfunctioning units and retest as specified above.
- D. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Adjust isolators after isolated equipment is at operating weight.

- B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.
- C. Adjust active height of spring isolators.
- D. Adjust restraints to permit free movement of equipment within normal mode of operation.

3.7 ELECTRICAL VIBRATION-CONTROL AND SEISMIC-RESTRAINT DEVICE SCHEDULE

Revise schedule below to suit Project. Do not duplicate requirements in Part 2. Refer to a completed example in the Evaluations for an explanation on how to use schedules. If a schedule is not included on Drawings, retain below to indicate location and type of required vibration isolators and seismic restraints.

Copy and re-edit paragraph and associated subparagraphs below for each piece of supported or suspended equipment required.

- A. Supported or Suspended Equipment: **<Insert name and drawing designation>**.
 - 1. Equipment Location: **<Insert room number>**.
 - 2. Pads:
 - a. Material: **[Neoprene] [Rubber] [Hermetically sealed compressed fiberglass]**.
 - b. Thickness: **<Insert inches (mm)>**.
 - c. Durometer: **<Insert number>**.
 - d. Number of Pads: **<Insert number>** thick.
 - 3. Isolator Type: **<Insert generic name or designation used in Part 2>**.
 - 4. Component Importance Factor: **[1.0] [1.5]**.
 - 5. Component Response Modification Factor: **[1.5] [2.5] [3.5] [5.0]**.
 - 6. Component Amplification Factor: **[1.0] [2.5]**.

PART 4 - METHOD OF MEASUREMENT

- 4.1 No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **260548**

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SECTION 260553 - IDENTIFICATION FOR ELECTRICAL SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES ARE TO BE DELETED FROM FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Identification for raceways.
 - 2. Identification of power and control cables.
 - 3. Identification for conductors.
 - 4. Underground-line warning tape.
 - 5. Warning labels and signs.
 - 6. Instruction signs.
 - 7. Equipment identification labels.
 - 8. Miscellaneous identification products.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each electrical identification product indicated.
 - 1. Include data substantiating that materials comply with requirements.

Retain both paragraphs below if Project requirements are complex.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager.

Coordinate sample requirements with DEN Project Manager.

- B. Samples: For each type of label and sign to illustrate size, colors, lettering style, mounting provisions, and graphic features of identification products.
- C. Identification Schedule: An index of nomenclature of electrical equipment and system components used in identification signs and labels.

1.4 QUALITY ASSURANCE

Retain IEEE C2 in first paragraph below for projects with electrical utility work, including underground and overhead distribution and medium-voltage cabling. By reference, IEEE C2 requires compliance with ANSI Z531.1 through ANSI Z531.5. See Evaluations for additional description of the scope of these standards.

- A. Comply with ANSI A13.1[and IEEE C2].
- B. Comply with NFPA 70.
- C. Comply with 29 CFR 1910.144 and 29 CFR 1910.145.
- D. Comply with ANSI Z535.4 for safety signs and labels.

Retain paragraph below if retaining self-adhesive products in Part 2. See Editing Instruction No. 1 in the Evaluations.

- E. Adhesive-attached labeling materials, including label stocks, laminating adhesives, and inks used by label printers, shall comply with UL 969.

1.5 COORDINATION

- A. Coordinate identification names, abbreviations, colors, and other features with requirements in other Sections requiring identification applications, Drawings, Shop Drawings, manufacturer's wiring diagrams, and the Operation and Maintenance Manual; and with those required by codes, standards, and 29 CFR 1910.145. Use consistent designations throughout Project.
- B. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.

- C. Coordinate installation of identifying devices with location of access panels and doors.
- D. Install identifying devices before installing acoustical ceilings and similar concealment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.6 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Retain products in articles below that are retained in "Identification Schedule" Article. Consider alternatives before specifying self-adhesive identification products. See Editing Instruction No. 1 and "Writing Guide" Article in the Evaluations.

2.1 POWER RACEWAY IDENTIFICATION MATERIALS

Retain this article to require identification exceeding requirements in NFPA 70. See "NFPA Requirements" Article in the Evaluations.

- A. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway size.
- B. Colors for Raceways Carrying Circuits at More Than 600 V:
 - 1. Black letters on an orange field.
 - 2. Legend: "DANGER CONCEALED HIGH VOLTAGE WIRING" with 3-inch (75-mm) high letters on 20-inch (500-mm) centers.

Retain one or more of six paragraphs below. Coordinate with "Identification Schedule" Article. See Editing Instruction No. 1 in the Evaluations for a discussion on self-adhesive products.

- C. Tape and Stencil for Raceways Carrying Circuits More Than 600 V: 4-inch (100-mm-) wide black stripes on 10-inch (250-mm) centers diagonally over orange background that extends full length of raceway or duct and is 12 inches (300 mm) wide. Stop stripes at legends.
- D. Pre-Printed Tags: Polyester tag, [0.010 inch (0.25 mm)] [0.015 inch (0.38 mm)] <Insert dimension> thick, with corrosion-resistant grommet and cable tie for attachment to conductor or cable.
 - 1. Marker for Tags: Machine-printed, permanent, waterproof, black ink marker recommended by printer manufacturer.

2.2 POWER AND CONTROL CABLE IDENTIFICATION MATERIALS

- A. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway and cable size.

Retain one or more of five paragraphs below. Coordinate with "Identification Schedule" Article. See Editing Instruction No. 1 in the Evaluations for a discussion on self-adhesive products.

Specify thicker tags in first paragraph below where exposed to damage or to rough service.

- B. Pre-Printed Tags: Polyester tag, [0.010 inch (0.25 mm)] [0.015 inch (0.38 mm)] **<Insert dimension>** thick, with corrosion-resistant grommet and cable tie for attachment to conductor or cable.
1. Marker for Tags: Machine-printed, permanent, waterproof, black ink marker recommended by printer manufacturer.
- C. Snap-Around Labels: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeve, with diameter sized to suit diameter of cable it identifies and to stay in place by gripping action.
- D. Snap-Around, Color-Coding Bands: Slit, pretensioned, flexible, solid-colored acrylic sleeve, 2 inches (50 mm) long, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.

2.3 CONDUCTOR IDENTIFICATION MATERIALS

Retain this article to require identification exceeding requirements in NFPA 70. See "NFPA Requirements" Article in the Evaluations.

Retain first paragraph below for colored tape used to identify phase or voltage of circuits.

- A. Color-Coding Conductor Tape: Colored, self-adhesive vinyl tape not less than 3 mils (0.08 mm) thick by 1 to 2 inches (25 to 50 mm) wide.
- B. Self-Adhesive Vinyl Labels: Preprinted, flexible label laminated with a clear, weather- and chemical-resistant coating and matching wraparound adhesive tape for securing ends of legend label.
- C. Snap-Around Labels: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeve, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.
- D. Snap-Around, Color-Coding Bands: Slit, pretensioned, flexible, solid-colored acrylic sleeve, 2 inches (50 mm) long, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.
- E. Marker Tapes: Vinyl or vinyl-cloth, self-adhesive wraparound type, with circuit identification legend machine printed by thermal transfer or equivalent process.

Specify thicker tags in first paragraph below where exposed to damage or to rough service.

- F. Pre-Printed Tags: Polyester tag, [0.010 inch (0.25 mm)] [0.015 inch (0.38 mm)] <Insert dimension> thick, with corrosion-resistant grommet and cable tie for attachment to conductor or cable.
 - 1. Marker for Tags: Machine-printed, permanent, waterproof, black ink marker recommended by printer manufacturer.

2.4 FLOOR MARKING TAPE

- A. 2-inch (50-mm) wide, 5-mil (0.125-mm) pressure-sensitive vinyl tape, with black and white stripes and clear vinyl overlay.

2.5 UNDERGROUND-LINE WARNING TAPE

Common trenching and tape laying methods are hand, static plow, and vibratory plow. Revise options in this article if only specific trenching methods are allowed.

- A. Tape:
 - 1. Recommended by manufacturer for the method of installation and suitable to identify and locate underground electrical [**and communications**] utility lines.
 - 2. Printing on tape shall be permanent and shall not be damaged by burial operations.
 - 3. Tape material and ink shall be chemically inert, and not subject to degrading when exposed to acids, alkalis, and other destructive substances commonly found in soils.
- B. Color and Printing:
 - 1. Comply with ANSI Z535.1 through ANSI Z535.5.
 - 2. Inscriptions for Red-Colored Tapes: ELECTRIC LINE, HIGH VOLTAGE, <Insert inscription>.
 - 3. Inscriptions for Orange-Colored Tapes: TELEPHONE CABLE, CATV CABLE, COMMUNICATIONS CABLE, OPTICAL FIBER CABLE, <Insert inscription>.

Use drawing designation in remaining paragraphs below on Drawings. First two paragraphs are generally standard- and extra-strength nonconducting protective tapes. Third and fourth paragraphs are conductive tapes suitable for conductive or inductive tracing to locate and identify the underground utility; the sequence is for standard- and extra-strength tapes. Listed weight, thickness, and strength of tapes is typical for generally available stock.

- C. Tag: [**Type ID**] <Insert drawing designation>:
 - 1. Detectable three-layer laminate, consisting of a printed pigmented polyolefin film, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core, bright-colored, [**continuous-printed on one side with the inscription of the utility**,]compounded for direct-burial service.

2. Overall Thickness: **5 mils** (0.125 mm).
3. Foil Core Thickness: **0.35 mil** (0.00889 mm).
4. Weight: **28 lb/1000 sq. ft.** (13.7 kg/100 sq. m).
5. **3-Inch** (75-mm) Tensile According to ASTM D 882: **70 lbf** (311.3 N), and **4600 psi** (31.7 MPa).

D. Tag: **[Type IID] <Insert drawing designation>**:

1. Reinforced, detectable three-layer laminate, consisting of a printed pigmented woven scrim, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core, bright-colored, **[continuous-printed on one side with the inscription of the utility,**]compounded for direct-burial service.
2. Overall Thickness: **8 mils** (0.2 mm).
3. Foil Core Thickness: **0.35 mil** (0.00889 mm).
4. Weight: **34 lb/1000 sq. ft.** (16.6 kg/100 sq. m).
5. **3-Inch** (75-mm) Tensile According to ASTM D 882: **300 lbf** (1334 N), and **12,500 psi** (86.1 MPa).

2.6 WARNING LABELS AND SIGNS

- A. Comply with NFPA 70 and 29 CFR 1910.145.

Retain one or more of four paragraphs below. Coordinate with "Identification Schedule" Article. See Editing Instruction No. 1 in the Evaluations for a discussion on self-adhesive products.

- B. Self-Adhesive Warning Labels: Factory-printed, multicolor, pressure-sensitive adhesive labels, configured for display on front cover, door, or other access to equipment unless otherwise indicated.
- C. Baked-Enamel Warning Signs:
1. Preprinted 20 gauge steel signs, punched or drilled for fasteners, with colors, legend, and size required for application.
 2. **1/4-inch** (6.4-mm) grommets in corners for mounting.
 3. Nominal size, **14 by 10 inches** (360 mm by 250 mm) unless **7 by 10 inches** (180 by 250 mm) is the largest size that can be applied where needed.
- D. Metal-Backed, Butyrate Warning Signs:
1. Weather-resistant, nonfading, preprinted, cellulose-acetate butyrate signs with **0.0396-inch** (1-mm) galvanized-steel backing; and with colors, legend, and size required for application.
 2. **1/4-inch** (6.4-mm) grommets in corners for mounting.
- E. Nominal size, **14 by 10 inches** (360 mm by 250 mm) unless **7 by 10 inches** (180 by 250 mm) is the largest size that can be applied where needed.
- F. Warning label and sign shall include, but are not limited to, the following legends:

1. Multiple Power Source Warning: "DANGER - ELECTRICAL SHOCK HAZARD - EQUIPMENT HAS MULTIPLE POWER SOURCES."

First subparagraph below applies to OSHA requirements for building operations and does not reflect the clear working space required by NFPA 70.

2. Workspace Clearance Warning: "WARNING - OSHA REGULATION - AREA IN FRONT OF ELECTRICAL EQUIPMENT MUST BE KEPT CLEAR FOR 36 INCHES (915 MM)."
3. "XXXX VOLTS"
4. "KEEP AWAY"
5. "BURIED CABLE"
6. "DO NOT TOUCH SWITCH"
7. <Insert names and wording of warning signs or labels; e.g., arc-flash, multiple services and voltages, and others>.

G. Plasticized Tags:

1. Manufacturer's standard preprinted or partially preprinted accident-prevention and operational tags, on plasticized card stock with matte finish suitable for writing, approximately 3-1/4-inch x 5-5/8-inch, with brass grommets and wire fasteners, and with appropriate preprinted wording including large-size primary wording, including but not limited to the following legends: "DANGER", "CAUTION", "DO NOT OPERATE".

2.7 INSTRUCTION SIGNS

Coordinate this article with Drawings.

- A. Engraved, laminated acrylic or melamine plastic, minimum 1/16 inch (1.6 mm) thick for signs up to 20 sq. inches (129 sq. cm) and 1/8 inch (3.2 mm) thick for larger sizes.
 1. Engraved legend with [black letters on white face] <Insert colors>.
 2. Punched or drilled for mechanical fasteners.
 3. Framed with mitered acrylic molding and arranged for attachment at applicable equipment.
- B. Adhesive Film Label: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be 3/8 inch (10 mm).
- C. Adhesive Film Label with Clear Protective Overlay: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be 3/8 inch (10 mm). Overlay shall provide a weatherproof and UV-resistant seal for label.

2.8 EQUIPMENT IDENTIFICATION LABELS

- A. Adhesive Film Label: Machine printed, in black letters on white background, by thermal transfer or equivalent process. Minimum letter height shall be 1/4 inch (7 mm).
- B. Adhesive Film Label with Clear Protective Overlay: Machine printed, in black letters on

white background, by thermal transfer or equivalent process. Minimum letter height shall be **1/4 inch (7 mm)**. Overlay shall provide a weatherproof and UV-resistant seal for label.

- C. Self-Adhesive, Engraved, Laminated Acrylic, or Melamine Label: Adhesive backed, with black letters on white background. Minimum letter height shall be **1/4 inch (7 mm)**.
- D. Engraved, Laminated Acrylic or Melamine Label: Punched or drilled for screw mounting. Black letters on a white background. Minimum letter height shall be **1/4 inch (7 mm)**.

Retain paragraph below to specify type of label for identifying outdoor equipment if specified in "Identification Schedule" Article.

- E. Stenciled Legend: In nonfading, waterproof, [**black**] <Insert color> ink or paint. Minimum letter height shall be [**1 inch (25 mm)**] <Insert dimension>.
- F. Emergency Equipment labels shall be white letters on red background..
- G. Provide nameplates with a minimum letter height as indicated below. Examples are given below for the size of letters to use for a given application and this not a list of the equipment to be identified. All equipment is required to be identified.
 - 1. For equipment designation: switchboards and motor control centers: 1/2 inch, panel boards: 1/4 inch. For voltage, bus ampacity, feeder source, and circuit number: 1/8 inch.
 - 2. Individual circuit breakers and or motor starters in motor control centers: For equipment designation and section number: 1/4 inch, for load served and location of load: 1/8 inch. Inside the door, a typed label shall provide complete motor data including nameplate horsepower, full load amperes, code letter, service factor, and voltage/phase rating.
 - 3. Individual breakers in switchgears and switchboards: for breaker number (address number) and equipment designation; 1/4 inch, for breaker frame size and trip setting; 1/8 inch
 - 4. Individual circuit breaker and spaces in panel boards: for numbers (section number) 1/4 inch.
 - 5. Individual circuit breakers in distribution panel boards: 1/4 inch for panel being fed and 1/8 inch for its location.
 - 6. Transformers: 1/4 inch for equipment designation and size; 1/8 inch for primary and secondary voltages, primary source and circuit number, secondary load and its location.
 - 7. Individual remote indicating lights, meters, instruments, and control switches: 1/8 inch, indicate unit, equipment, or fire detector being monitored and condition indicated by illumination.
 - 8. Individual switches and pilots: 1/8 inch, identify mechanical unit being served.
 - 9. Disconnects, relay panels, lighting contactors: 1/4 inch for voltage and source circuit number.

2.9 CABLE TIES

- A. General-Purpose Cable Ties: Fungus inert, self-extinguishing, one piece, self-locking, Type 6/6 nylon.
1. Minimum Width: **1/8 inch (3 mm)**.
 2. Tensile Strength at **73 deg F (23 deg C)**, According to ASTM D 638: **12,000 psi (82.7 MPa)**.
 3. Temperature Range: **Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C)**.
- B. UV-Stabilized Cable Ties: Fungus inert, designed for continuous exposure to exterior sunlight, self-extinguishing, one piece, self-locking, Type 6/6 nylon.
1. Minimum Width: **3/16 inch (5 mm)**.
 2. Tensile Strength at **73 deg F (23 deg C)**, According to ASTM D 638: **12,000 psi (82.7 MPa)**.
 3. Temperature Range: **Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C)**.
- C. Plenum-Rated Cable Ties: Self-extinguishing, UV stabilized, one piece, self-locking.
1. Minimum Width: **3/16 inch (5 mm)**.
 2. Tensile Strength at **73 deg F (23 deg C)**, According to ASTM D 638: **7000 psi (48.2 MPa)**.
 3. UL 94 Flame Rating: 94V-0.
 4. Temperature Range: **Minus 50 to plus 284 deg F (Minus 46 to plus 140 deg C)**.

2.10 MISCELLANEOUS IDENTIFICATION PRODUCTS

- A. Paint: Comply with requirements in Division 09 painting Sections for paint materials and application requirements. Select paint system applicable for surface material and location (exterior or interior).
- B. Fasteners for Labels and Signs: Self-tapping, stainless-steel screws or stainless-steel machine screws with nuts and flat and lock washers.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Verify identity of each item before installing identification products.

Coordinate first paragraph below with Drawings.

- B. Location: Install identification materials and devices at locations for most convenient viewing without interference with operation and maintenance of equipment.
- C. Apply identification devices to surfaces that require finish after completing finish work.

Retain first paragraph below if self-adhesive identification products are specified. See Editing Instruction No. 1 in the Evaluations.

- D. Self-Adhesive Identification Products: Clean surfaces before application, using materials and methods recommended by manufacturer of identification device.

Retain first paragraph below for nonadhesive signs or labels.

- E. Attach signs and plastic labels that are not self-adhesive type with mechanical fasteners appropriate to the location and substrate.

Retain first paragraph below if color-coding bands are specified to identify different systems and distinguish one from another.

- F. System Identification Color-Coding Bands for Raceways and Cables: Each color-coding band shall completely encircle cable or conduit. Place adjacent bands of two-color markings in contact, side by side. Locate bands at changes in direction, at penetrations of walls and floors, at **50-foot (15-m)** maximum intervals in straight runs, and at **25-foot (7.6-m)** maximum intervals in congested areas.
- G. Cable Ties: For attaching tags. Use general-purpose type, except as listed below:
 - 1. Outdoors: UV-stabilized nylon.
 - 2. In Spaces Handling Environmental Air: Plenum rated.
- H. Underground-Line Warning Tape: During backfilling of trenches install continuous underground-line warning tape directly above line at **6 to 8 inches (150 to 200 mm)** below finished grade. Use multiple tapes where width of multiple lines installed in a common trench [**or concrete envelope**] exceeds **16 inches (400 mm)** overall.
- I. Painted Identification: Comply with requirements in Division 09 painting Sections for surface preparation and paint application.

3.2 IDENTIFICATION SCHEDULE

Retain first paragraph below if Project contains concealed wiring more than 600 V that is adjacent to accessible building surfaces; for example, wiring below floors or wiring in vertical shafts behind gypsum board or masonry partitions.

- A. Wire and Cable Marker:
 - 1. For wire/cables smaller than No. 2/0 use manufacturer's standard cable/conductor markers of wrap-around, pre-numbered plastic coated type are to be used and numbered to show circuit identification.
 - 2. For cables No. 4 AWG and larger heat shrink sleeving is to be used for phase color-coding.
- B. Cable/Conductor Identification:
 - 1. The application of cable/conductor identification, with circuit number, on each

wire / cable in each box/enclosure/cabinet is required. The identification shall match the marking system used in panel boards, shop drawings, and contract documents.

C. System Color Coding Schedule:

1. Where electrical emergency power is exposed, conduit shall have "RED" stripes on each section every 5 feet of electrical conduit (visible from the floor or above a suspended ceiling) and within 3 feet of all equipment.) All junction or pull boxes shall have the cover painted red.
2. Paging system conduits shall have "GREEN" bands, 5' on centers for the entire length of conduit run. All junction or pull boxes shall have the cover painted green with the associated zone number written neatly on the box cover with permanent marker.
3. Security system conduits shall have "BLUE" bands, 5' on centers for the entire length. All junction or pull boxes shall have the cover painted blue.
4. Temperature control conduits shall have "BROWN" bands, 5' on centers for the entire length. All junction or pull boxes shall have the cover painted brown.
5. Closed circuit television (CCTV) conduits shall have YELLOW bands, 5' on center for the entire length. All junction or pull boxes shall have the cover painted yellow.
6. Fire Alarm conduit shall be a continuous red factory finish.

D. Concealed Raceways, Duct Banks, More Than 600 V, within Buildings: Tape and stencil 4-inch (100-mm) wide black stripes on 10-inch (250-mm) centers over orange background that extends full length of raceway or duct and is 12 inches (300 mm) wide. Stencil legend "DANGER CONCEALED HIGH VOLTAGE WIRING" with 3-inch (75-mm) high black letters on 20-inch (500-mm) centers. Stop stripes at legends. Apply to the following finished surfaces:

1. Floor surface directly above conduits running beneath and within 12 inches (300 mm) of a floor that is in contact with earth or is framed above unexcavated space.
2. Wall surfaces directly external to raceways concealed within wall.
3. Accessible surfaces of concrete envelope around raceways in vertical shafts, exposed in the building, or concealed above suspended ceilings.

Retain first paragraph below for circuits operating more than 600 V; paragraph contains requirements exceeding those in NFPA 70.

E. Accessible Raceways, More Than 600 V: Self-adhesive vinyl Snap-around labels. Install labels at maximum intervals.

Retain one or both of first two paragraphs below. Delete both for existing systems and replace with the existing identification scheme.

F. Accessible Raceways, 600 V or Less, for Service, Feeder, and Branch Circuits More Than A, and V to ground: Identify with self-adhesive vinyl label self-adhesive vinyl tape applied in bands. Install labels at maximum intervals.

G. Junction and Pull Box ID: Identify the covers of each junction and pull box of the following systems with self-adhesive vinyl labels with the wiring system legend and

system voltage. System legends shall be as follows:

1. Emergency Work: EM.
2. Power.
3. Uninterruptible Power Supply: UPS.
4. Fiber Optics: FO.
5. Closed Circuit Television: CCTV.
6. Paging System: PA.
7. Radio Frequency: RF.
8. Fire Alarm: FA.
9. Temperature Control: TC.

Retain first paragraph below if color-coding of power and lighting conductors for phase or voltage level identification is required to suit authorities having jurisdiction or special Project requirements. If retaining, coordinate with Division 26 Section "Low-Voltage Electrical Power Conductors and Cables" and revise to indicate extent of color-coding required. For existing buildings, indicate whether requirements apply to both old and new wiring or to new wiring only. Below applies only to phase conductors. Color-coding of grounded and grounding conductors is dictated by NFPA 70. Verify that Owner does not require another color-code.

Specify that colors for factory-assembled cable, such as MC and AC, must match colors listed in first paragraph below.

H. Power-Circuit Conductor Identification, 600 V or Less: For conductors in vaults, pull and junction boxes, manholes, and handholes, use color-coding conductor tape to identify the phase.

1. Color-Coding for Phase Identification, 600 V or Less: Use colors listed below for branch-circuit conductors.
 - a. Color shall be factory applied [or field applied for sizes larger than No. 8 AWG, if authorities having jurisdiction permit].
 - b. Colors for 208/120-V Circuits:
 - 1) Phase A: Black.
 - 2) Phase B: Red.
 - 3) Phase C: Blue.
 - 4) Neutral: White
 - 5) Ground: Green
 - 6) Isolated Ground: Green with a yellow tracer
 - c. Colors for 480/277-V Circuits:

Colors specified in first three subparagraphs below are those generally used for phase conductors at this voltage.

- 1) Phase A: Brown.
- 2) Phase B: Orange.
- 3) Phase C: Yellow.
- 4) Neutral: Gray
- 5) Ground: Green

6) Isolated Ground: Green with a yellow tracer

If field-applied color-coding is permitted, retain subparagraph below.

- d. Field-Applied, Color-Coding Conductor Tape: Apply in half-lapped turns for a minimum distance of 6 inches (150 mm) from terminal points and in boxes where splices or taps are made. Apply last two turns of tape with no tension to prevent possible unwinding. Locate bands to avoid obscuring factory cable markings.
- I. Power-Circuit Conductor Identification, More than 600 V: For conductors in vaults, pull and junction boxes, manholes, and handholes, use write-on tags nonmetallic plastic tag holder with adhesive-backed phase tags, and a separate tag with the circuit designation.
- J. Install instructional sign including the color-code for conductors using adhesive-film-type labels.

Retain first paragraph below for future expansion of circuits or if required for circuits for other purposes. Coordinate with Drawings.

- K. Conductors to Be Extended in the Future: Attach write-on tags marker tape to conductors and list source.
- L. Auxiliary Electrical Systems Conductor Identification: Identify field-installed alarm, control, and signal connections.
 - 1. Identify conductors, cables, and terminals in enclosures and at junctions and terminals. Identify by system and circuit designation.
 - 2. Use system of marker tape designations that is uniform and consistent with system used by manufacturer for factory-installed connections.
 - 3. Coordinate identification with Project Drawings, manufacturer's wiring diagrams, and the Operation and Maintenance Manual.
- M. Locations of Underground Lines: Identify with underground-line detectable warning tape for power, lighting, communication, and control wiring and optical fiber cable.
 - 1. Install underground-line detectable line marker for encased duct bank, direct-buried cables, and cables in raceway.
- N. Workspace Indication: Install floor marking tape to show working clearances in the direction of access to live parts. Workspace shall be as required by NFPA 70 and 29 CFR 1926.403 unless otherwise indicated. Do not install at flush-mounted panelboards and similar equipment in finished spaces.
- O. Danger Signs:
 - 1. Critical Switches/Controls: Danger signs shall be provided on switches and similar controls, regardless of whether concealed or locked up, where untimely or inadvertent operation could result in danger to persons, or damage to equipment, or damage to or loss of property.

- P. Warning Labels for Indoor Cabinets, Boxes, and Enclosures for Power and Lighting: Self-adhesive warning labels Baked-enamel warning signs Metal-backed, butyrate warning signs.
1. Comply with 29 CFR 1910.145.
 2. Identify system voltage with black letters on an orange background.
 3. Apply to exterior of door, cover, or other access.
 4. For equipment with multiple power or control sources, apply to door or cover of equipment including, but not limited to, the following:
 - a. Power transfer switches.
 - b. Controls with external control power connections.
 - c. **<Insert items>**.
- Q. Caution Signs:
1. The following red caution sign is to be provided for all circuit breakers and switchboards where turning off a circuit will automatically start an emergency operation:
 - a. "Caution Turning Off this Circuit will Automatically Start Emergency Operation"
 2. The following red caution sign is to be provided for all automatic transfer switches, switches, circuit breakers, equipment, and emergency panels that are energized by the emergency power system:
 - a. "Caution Automatically Energized by Emergency Power Supply System".
- R. Operating Instruction Signs: Install instruction signs to facilitate proper operation and maintenance of electrical systems and items to which they connect. Install instruction signs with approved legend where instructions are needed for system or equipment operation. Where detailed instructions or explanations are needed, provide plasticized tags with clearly written messages adequate for intended purposes.
- S. Emergency Operating Instruction Signs: Install instruction signs with white legend on a red background with minimum **3/8-inch (10-mm)** high letters for emergency instructions at equipment used for **[power transfer] [load shedding] <Insert emergency operations>**.

Coordinate paragraph below with electrical Sections in Divisions 26, 27, and 28. Delete items not in Project.

- T. Equipment Identification Labels: On each unit of equipment, install unique designation label that is consistent with wiring diagrams, schedules, and the Operation and Maintenance Manual. Apply labels to disconnect switches and protection equipment, central or master units, control panels, control stations, terminal cabinets, and racks of each system. Systems include power, lighting, control, communication, signal, monitoring, and alarm systems unless equipment is provided with its own identification.
1. Labeling Instructions:

- a. Indoor Equipment: Mechanically fastened, engraved, laminated acrylic or melamine label. Unless otherwise indicated, provide a single line of text with 1/2-inch (13-mm) high letters on 1-1/2-inch (38-mm) high label; where two lines of text are required, use labels 2 inches (50 mm) high. Use black lettering on white field for normal and white letters on a red field for emergency. Provide text matching terminology and numbering of the contract documents and shop drawings. The sign shall include unit designation, source circuit number, circuit voltage, and other data specifically indicated. Also, the sign shall indicate normal source circuit number ("Fed from . . .") and emergency source circuit number when the equipment is a transfer switch or fed directly from a transfer switch.
- b. Outdoor Equipment: Engraved, laminated acrylic or melamine label
Stenciled legend 4 inches (100 mm) high.
- c. Elevated Components: Increase sizes of labels and letters to those appropriate for viewing from the floor.
- d. Fasten labels with appropriate mechanical fasteners that do not change the NEMA or NRTL rating of the enclosure.

2. Equipment to Be Labeled:

Identification labeling of some items listed below may be required by individual Sections or by NFPA 70.

- a. Panelboards: include main bus ampacity on sign. Typewritten directory of circuits in the location provided by panelboard manufacturer. Panelboard identification shall be **[self-adhesive, engraved] [engraved]**, laminated acrylic or melamine label.
- b. Enclosures and electrical cabinets.
- c. Access doors and panels for concealed electrical items.
- d. Switchgear.
- e. Switchboards.
- f. Disconnect switch.
- g. Transformers: Label that includes tag designation shown on Drawings for the transformer, feeder, and panelboards or equipment supplied by the secondary.
- h. Substations.
- i. Emergency system boxes and enclosures.
- j. Motor-control centers.
- k. Enclosed switches.
- l. Selector switches, indicating lights. (Circuit number and voltage not required on sign).
- m. Enclosed circuit breakers.
- n. Enclosed controllers.
- o. Variable-speed controllers.
- p. Push-button stations.
- q. Power transfer equipment.
- r. Contactors.
- s. Remote-controlled switches, dimmer modules, and control devices.
- t. Battery-inverter units.
- u. Battery racks.
- v. Power-generating units.

- w. Monitoring and control equipment.
 - x. UPS equipment.
 - y. Telephone cabinets and switching equipment. (Circuit number and voltage not required on sign.)
 - z. Fire alarm panels.
 - aa. Security monitoring master station.
 - bb. Relays
 - cc. Lighting contactors
 - dd. Individual distribution circuit breakers
 - ee. **<Insert equipment>**.
3. All panel boards shall have a typed panel schedule indicating the date, contractor, type of equipment served, and its location.

3.3 ELECTRICAL PANEL NAMING CONVENTIONS

A. Naming Electrical Panels for Grounds & Outlying Buildings

- 1. Use DEN utility map for main and secondary grids
- 2. Example: **L-13F4TDEH1-A**
 - a. **L-13** indicates Utility map book page location. Choices: A through FF (West to East) and 1 through 31 (South to North).
 - b. **F4** indicates Location grid on above page. Choices: A through J (West to East) and 1 through 10 (North to South).
 - c. **T** Indicates Airline Tenant, **R** for Retail / Food and Beverage tenant or panel if appropriate, or blank [no space] if DEN.
 - d. **D** Indicates Distribution panel if appropriate, or blank (no space) if Not Distribution.
 - e. **E** Indicates panel feeder function. Choices: E (Emergency), ES (Essential Power) or U (UPS Origin).
 - f. **H** indicates Panel voltage. Choices: H = 600 or 480Y/277 or L = 208Y/120 or 240/120.
 - g. **1** indicates Sequence number of this panel supplied from this source. Choices: 1...N.
 - h. **-A** indicates Sub-fed panel suffix, if appropriate. Choices: -A ...as required.

B. Naming Electrical Panels for Concourse Buildings and Tunnel System

- 1. Example: **B-AW1TDEL1-A**
 - a. **B-** indicates Concourse letter. Choices: A through C (South to North).
 - b. **A** indicates Floor level. Choices: T (Tunnel) or B (Basement) or A (Apron) or C (Concourse) or M Mezzanine) or 4 (Fourth Floor) or 5 (Fifth Floor) or R (Roof).
 - c. **W1** indicates Core area. Choices: CE (Center Core East Side) or CW (Center Core West Side) or E1 ... E3 (Sub-Core Number East of Center Core) or W1 ... W3 (Sub-Core Number West of Center Core).
 - d. **T** Indicates Airline Tenant, **R** for Retail / Food and Beverage tenant or panel

- if appropriate, or blank [no space] if DEN.
- e. **D** indicates distribution panel if appropriate or blank (No Space) if Not Distribution.
 - f. **E** Indicates panel feeder function. Choices: E (Emergency), ES (Essential Power) or U (UPS Origin)
 - g. **L** indicates Panel voltage. Choices: H = 600 or 480Y/277 or L = 208Y/120 or 240/120
 - h. **1** indicates Sequence number of this panel supplied from this source. Choices: 1...N
 - i. **-A** indicates Sub-fed panel suffix, if appropriate. Choices: -A ...as required.

C. Naming Electrical Panels for Terminal, AOB & Parking Structures

1. Example: **6-11CTDEL2-A**

- a. **6-** indicates Floor level. Choices: T (Tunnel) or 1 through 11, depending on building.
- b. **11C** indicates Module designation (see Architectural designation). Choices: 01 through 15 and A through D.
- c. **T** Indicates AIRLINE TENANT, **R** for Retail / Food and Beverage tenant or panel if appropriate, or blank (No Space) if DEN.
- d. **D** Indicates distribution panel if appropriate, or blank (No Space) if Not Distribution.
- e. **E** Indicates panel feeder function. Choices: E (Emergency), ES (Essential Power) or U (UPS Origin).
- f. **L** indicates Panel voltage. Choices: H = 600 or 480Y/277 or L = 208Y/120 or 240/120.
- g. **2** indicates Sequence number of this panel supplied from this source. Choices: 1...N.
- h. **-A** indicates Sub-fed panel suffix, if appropriate. Choices: -A ...as required.

D. Naming Disconnects and Transformers

- 1. Disconnects shall have the same as the equipment they serve.
- 2. Transformers shall have the same name as the low-voltage panel they supply power to with the extension of -X

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260553

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SECTION 260573 - OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes computer-based, fault-current and overcurrent protective device coordination studies. Protective devices shall be set based on results of the protective device coordination study.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For computer software program to be used for studies.
 - 1. Include data substantiating that materials comply with requirements.
- B. Other Action Submittals: The following submittals shall be made after the approval process for system protective devices has been completed. Submittals [**shall**] [**may**] be in digital form.

1. Coordination-study input data, including completed computer program input data sheets.
2. Study and Equipment Evaluation Reports.
3. Coordination-Study Report.

1.4 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements retained in "Quality Assurance" Article.

- A. Qualification Data: For coordination-study specialist.
- B. Product Certificates: For coordination-study and fault-current-study computer software programs, certifying compliance with IEEE 399.

1.5 QUALITY ASSURANCE

- A. Studies shall use computer programs that are distributed nationally and are in wide use. Software algorithms shall comply with requirements of standards and guides specified in this Section. Manual calculations are not acceptable.
- B. Coordination-Study Specialist Qualifications: An entity experienced in the application of computer software used for studies, having performed successful studies of similar magnitude on electrical distribution systems using similar devices.

Retain subparagraph below if electrical engineer responsible for design of this Project will not be responsible for results of study and set points of system protective devices.

1. Professional engineer, licensed in the state where Project is located, shall be responsible for the study. All elements of the study shall be performed under the direct supervision and control of engineer.
- C. Comply with IEEE 242 for short-circuit currents and coordination time intervals.
- D. Comply with IEEE 399 for general study procedures.

PART 2 - PRODUCTS

2.1 COMPUTER SOFTWARE DEVELOPERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming computer software developers and products. Retain paragraph and list of computer software developers in this Article. See Section 016000 "Product Requirements."

- A. Computer Software Developers: Subject to compliance with requirements, provide products by one of the following:
 1. CGI CYME.

2. EDSA Micro Corporation.
3. ESA Inc.
4. Operation Technology, Inc.
5. SKM Systems Analysis, Inc.
6. ETAP Inc.
7. <Insert manufacturer>
8. or approved equal.

2.2 COMPUTER SOFTWARE PROGRAM REQUIREMENTS

- A. Comply with IEEE 399.
- B. Analytical features of fault-current-study computer software program shall include "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.
- C. Computer software program shall be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program shall report device settings and ratings of all overcurrent protective devices and shall demonstrate selective coordination by computer-generated, time-current coordination plots.

See Editing Instruction No. 2 in the Evaluations for discussion of optional features.

1. Optional Features:
 - a. Arcing faults.
 - b. Simultaneous faults.
 - c. Explicit negative sequence.
 - d. Mutual coupling in zero sequence.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine Project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance. Devices to be coordinated are indicated on Drawings.
 1. Proceed with coordination study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to coordination study may not be used in study.

3.2 POWER SYSTEM DATA

Verify that power system data is indicated on Drawings, allowing Contractor to complete the data gathering specified in this Article. Drawing Coordination Checklist may be useful in verification.

- A. Gather and tabulate the following input data to support coordination study:
1. Product Data for overcurrent protective devices specified in other electrical Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
 2. Impedance of utility service entrance.
 3. Electrical Distribution System Diagram: In hard-copy and electronic-copy formats, showing the following:
 - a. Circuit-breaker and fuse-current ratings and types.
 - b. Relays and associated power and current transformer ratings and ratios.
 - c. Transformer kilovolt amperes, primary and secondary voltages, connection type, impedance, and X/R ratios.
 - d. Generator kilovolt amperes, size, voltage, and source impedance.
 - e. Cables: Indicate conduit material, sizes of conductors, conductor material, insulation, and length.
 - f. Busway ampacity and impedance.
 - g. Motor horsepower and code letter designation according to NEMA MG 1.
 4. Data sheets to supplement electrical distribution system diagram, cross-referenced with tag numbers on diagram, showing the following:
 - a. Special load considerations, including starting inrush currents and frequent starting and stopping.
 - b. Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.
 - c. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.
 - d. Generator thermal-damage curve.
 - e. Ratings, types, and settings of utility company's overcurrent protective devices.
 - f. Special overcurrent protective device settings or types stipulated by utility company.
 - g. Time-current-characteristic curves of devices indicated to be coordinated.
 - h. Manufacturer, frame size, interrupting rating in amperes rms symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers.
 - i. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.
 - j. Panelboards, switchboards, motor-control center ampacity, and interrupting rating in amperes rms symmetrical.

3.3 FAULT-CURRENT STUDY

- A. Calculate the maximum available short-circuit current in amperes rms symmetrical at

circuit-breaker positions of the electrical power distribution system. The calculation shall be for a current immediately after initiation and for a three-phase bolted short circuit at each of the following:

1. Switchgear and switchboard bus.
 2. Medium-voltage controller.
 3. Motor-control center.
 4. Distribution panelboard.
 5. Branch circuit panelboard.
 6. **<Insert significant locations in system.>**
- B. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Include studies of system-switching configurations and alternate operations that could result in maximum fault conditions.
- C. Calculate momentary and interrupting duties on the basis of maximum available fault current.

See Editing Instruction No. 4 in the Evaluations for discussion of standards listed in first paragraph below.

- D. Calculations to verify interrupting ratings of overcurrent protective devices shall comply with [IEEE 141] [IEEE 241] and IEEE 242.

See "Referenced Standards" Article in the Evaluations for scope of transformer standards referenced in four subparagraphs and associated subparagraphs below. Delete standards for transformers not used in this Project.

1. Transformers:
 - a. ANSI C57.12.10.
 - b. ANSI C57.12.22.
 - c. ANSI C57.12.40.
 - d. IEEE C57.12.00.
 - e. IEEE C57.96.
 2. Medium-Voltage Circuit Breakers: IEEE C37.010.
 3. Low-Voltage Circuit Breakers: IEEE 1015 and IEEE C37.20.1.
 4. Low-Voltage Fuses: IEEE C37.46.
- E. Study Report:
1. Show calculated X/R ratios and equipment interrupting rating (1/2-cycle) fault currents on electrical distribution system diagram.

Retain subparagraph below only for medium- and high-voltage circuit breakers under certain circumstances described in IEEE 399.

2. Show interrupting (5-cycle) and time-delayed currents (6 cycles and above) on medium- **[and high-]**voltage breakers as needed to set relays and assess the sensitivity of overcurrent relays.

F. Equipment Evaluation Report:

1. For 600-V overcurrent protective devices, ensure that interrupting ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.
2. For devices and equipment rated for asymmetrical fault current, apply multiplication factors listed in the standards to 1/2-cycle symmetrical fault current.
3. Verify adequacy of phase conductors at maximum three-phase bolted fault currents; verify adequacy of equipment grounding conductors and grounding electrode conductors at maximum ground-fault currents. Ensure that short-circuit withstand ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.

3.4 COORDINATION STUDY

A. Perform coordination study using approved computer software program. Prepare a written report using results of fault-current study. Comply with IEEE 399.

1. Calculate the maximum and minimum 1/2-cycle short-circuit currents.

Retain first subparagraph below for medium-voltage equipment.

2. Calculate the maximum and minimum interrupting duty (5 cycles to 2 seconds) short-circuit currents.
3. Calculate the maximum and minimum ground-fault currents.

See Editing Instruction No. 4 in the Evaluations for discussion of standards listed in first paragraph below.

B. Comply with [IEEE 141] [IEEE 241] [IEEE 242] recommendations for fault currents and time intervals.

C. Transformer Primary Overcurrent Protective Devices:

1. Device shall not operate in response to the following:
 - a. Inrush current when first energized.
 - b. Self-cooled, full-load current or forced-air-cooled, full-load current, whichever is specified for that transformer.
 - c. Permissible transformer overloads according to IEEE C57.96 if required by unusual loading or emergency conditions.
2. Device settings shall protect transformers according to IEEE C57.12.00, for fault currents.

D. Motors served by voltages more than 600 V shall be protected according to IEEE 620.

E. Conductor Protection: Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and conductor melting curves in IEEE 242.

Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary relay protection or total clearing time of the fuse. To determine temperatures that damage insulation, use curves from cable

manufacturers or from listed standards indicating conductor size and short-circuit current.

F. Coordination-Study Report: Prepare a written report indicating the following results of coordination study:

1. Tabular Format of Settings Selected for Overcurrent Protective Devices:

- a. Device tag.
- b. Relay-current transformer ratios; and tap, time-dial, and instantaneous-pickup values.
- c. Circuit-breaker sensor rating; and long-time, short-time, and instantaneous settings.
- d. Fuse-current rating and type.
- e. Ground-fault relay-pickup and time-delay settings.

2. Coordination Curves: Prepared to determine settings of overcurrent protective devices to achieve selective coordination. Graphically illustrate that adequate time separation exists between devices installed in series, including power utility company's upstream devices. Prepare separate sets of curves for the switching schemes and for emergency periods where the power source is local generation. Show the following information:

- a. Device tag.
- b. Voltage and current ratio for curves.
- c. Three-phase and single-phase damage points for each transformer.
- d. No damage, melting, and clearing curves for fuses.
- e. Cable damage curves.
- f. Transformer inrush points.
- g. Maximum fault-current cutoff point.

G. Completed data sheets for setting of overcurrent protective devices.

PART 4 - METHOD OF MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260573

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SECTION 260583 - ELECTRICAL CONNECTIONS FOR EQUIPMENT

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Electrical connections to equipment specified under other Sections or furnished by the Owner.
- B. Applications of electrical power, control and monitoring connections specified in this section include the following:
 - 1. From electrical source to motor starters.
 - 2. From motor starters to motors.
 - 3. To lighting fixtures and wiring devices.
 - 4. To converters, rectifiers, transformers, inverters, switchgear, switchboards, panel boards, generators and similar equipment.
 - 5. To grounds including ground electrode connections.
 - 6. Equipment furnished in other Divisions (unless indicated otherwise).
 - 7. Electrical connections for equipment, that are not furnished as integral part of equipment, are specified in [Division 11] [Division 14] [Division 21] [Division 22] [Division 23] [Division 27] [Division 28] and other Division 26 sections, and are criteria of this Section.
 - 8. Refer to [Division 14] [Division 21] [Division 22] [Division 23] [Division 27]

- [Division 28] sections for motor starters and controllers furnished integrally with equipment; not criteria of this Section.
9. Refer to [Division 14] [Division 21] [Division 22] [Division 23] [Division 27] [Division 28] sections for control system wiring, not criteria of this section.
 10. Junction boxes and disconnect switches required for connecting motors and other electrical units of equipment are specified in applicable Division 26 sections, and are criteria of this Section.
- C. Related requirements:
1. Section 260519 "Low-Voltage Electrical Power Conductors and Cables".

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- D. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. The following data shall be submitted in accordance with Sections 013300 "Submittal Procedures" required prior to starting installation:
1. Product Data: Manufacturer's data on electrical connections for equipment products and materials.
 - a. Include data substantiating that materials comply with requirements.
 2. Complete wiring diagrams and/or shop drawings for installation purposes shall be furnished under the Mechanical or other Divisions, as required by DEN Project Manager, prior to installation.

1.4 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.5 QUALITY ASSURANCE

- A. Products, materials, equipment and systems shall comply with the following Codes and Standards:

1. NFPA Compliance: NFPA 70, "National Electrical Code (NEC)" as adopted and amended by the Denver Building Code and as applicable to products used and the installation of electrical power connections (terminals and splices), junction boxes, motor starters and disconnect switches.
2. IEEE Compliance: Std. 241, "IEEE Recommended Practice for Electric Power Systems in Commercial Buildings" pertaining to connections and terminations.
3. ANSI Compliance: Applicable requirements of ANSI/NEMA and ANSI/EIA standards pertaining to products and installation of electrical connections for equipment.
4. UL Compliance: UL Std. 486A, "Wire Connectors and Soldering Lugs for Use with Copper Conductors" including, but not limited to, tightening of electrical connectors to torque values indicated. Electrical connection products and materials are to be UL-listed and labeled.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.6 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MATERIALS AND COMPONENTS

- A. Products shall be as specified in other Sections of this Division.
- B. General: Each electrical connection shall be a complete assembly of materials, including but not necessarily limited to, pressure connectors, terminals (lugs), electrical insulating tape, heat-shrinkable insulating tubing, cable ties, stress cones, splice kits, termination kits, solder less wire nuts, and other items and accessories as needed to complete splices and terminations as required.
 1. Connectors and Terminals: Electrical connectors and terminals shall mate and match, including sizes and ratings, with equipment terminals that are recommended by equipment manufacturer for intended applications.
 2. Electrical Connection Accessories: Electrical insulating tape, heat-shrinkable insulating tubing and boots, stress cones, splice kits, termination kits, wirenuts and cable ties as recommended for use by accessories manufacturers for type of services required.

2.2 MECHANICAL AND ELECTRICAL COORDINATION

Verify if EXHIBIT A will be included in this Section, or delete and reference Section 019990.

- A. Responsibility: It is the contractor's responsibility to complete the EXHIBIT A

SCHEDULE included at the end of this Section. Reference Section 019990 "Standard Forms". The Contractor shall include all costs and work associated with these items in his bid.

- B. Verify location, size, and characteristics of all mechanical equipment before installation of electric service. In all cases of the installation of heating, ventilating, air conditioning, plumbing, and other mechanical equipment, the Contractor is responsible for all revisions, changes, and modifications necessary to properly supply electric services to the equipment.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Verify that equipment is ready for electrical connection, wiring, and energization.

3.2 PREPARATION

- A. Review equipment submittals prior to installation and electrical rough-in. Verify location, size, and type of connections. Coordinate details of equipment connections with supplier and installer.

3.3 INSTALLATION

- A. Use wire and cable with insulation suitable for temperatures encountered in heat-producing equipment.
- B. Make conduit connections to equipment using flexible conduit. Use liquid-tight flexible conduit in damp or wet locations. Length shall be six feet (6') maximum.
- C. Install pre-finished cord set where connection with attachment plug is indicated or specified, use attachment plug with suitable strain-relief clamps.
- D. Provide suitable strain-relief clamps for cord connections to outlet boxes and equipment connection boxes.
- E. Make wiring connections in control panel or in wiring compartment of pre-wired equipment in accordance with manufacturer's instructions. Provide interconnecting wiring as required for a complete operating system.
- F. Install disconnect switches, controllers, control stations, and control devices such as limit switches and temperature switches as required for a complete operating system. Connect with conduit and wiring as required for a complete operating system.

3.4 EQUIPMENT CONNECTION SCHEDULE

- A. Furnish, set in place, and wire, except as may be otherwise indicated, all heating, ventilating, air conditioning, plumbing, fire protection, and other motors and controls in accordance with the electrical/mechanical coordination schedule. The contractor shall carefully coordinate with work performed under the Mechanical and other Divisions if these specifications.
- B. All line and low voltage wiring shall be installed utilizing materials and methods as specified in the Division 26 of the technical specifications.
- C. Provide NEMA-rated motors and equipment suitable for operation on the voltage systems as designated below, with tolerances for the allowable voltage variations above and below the nominal:

1. Rated Motor Voltage:

Service Voltage and Phase:	1/3 HP and smaller 1-Phase:	1/2 HP and Larger 3-Phase:
120/208V, 3-Phase	115V	208V (only when 480V is not available)
277/480V, 3-Phase		460V

3.5 INSTALLATION OF ELECTRICAL CONNECTIONS

- A. Electrical connections shall be installed in accordance with equipment manufacturer's written instructions and with recognized industry practices, and complying with applicable requirements of UL, NEC and NECA's "Standard of Installation" to ensure that products fulfill requirements.
 - 1. As a minimum: Each feeder circuit to panelboards, switchboards, motor control centers, transformers, and 480-volt (and higher) motor circuits shall have an insulated equipment ground conductor.
 - 2. All medium voltage splices and terminations are to be made by a certified cable splicer/terminator.
 - 3. Electrical service and feeders are to be maintained to occupied areas and operational facilities when temporary service is required during interruptions to existing facilities. Momentary outages for replacing existing wiring systems with new wiring systems shall be scheduled. When the "cutting-over" has been successfully accomplished, temporary wiring is to be removed.
 - 4. Splices shall be covered with electrical insulating material equivalent to, or of greater insulation rating, than electrical insulation rating of those conductors being spliced.
 - 5. Cables and wires shall be trimmed as long as practicable and routing shall be arranged to facilitate inspection, testing, and maintenance.
 - 6. Connectors and terminals, including screws and bolts, shall be tightened in accordance with equipment manufacturer's published torque tightening values for equipment connectors. Proper torquing tools, including torque screwdriver, beam-type torque wrench, and ratchet wrench with adjustable torque settings

shall be used to comply with torquing values contained in UL 496A or the manufacturer's literature.

7. Identification markers are to be fastened to each electrical power supply wire/cable conductor in accordance with Section 260553 "Identification for Electrical Systems".
 - a. Markers are to be affixed on each terminal conductor, as close as possible to the point of connection.

3.6 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. The correct direction of rotation of each motor is to be verified.
- B. Provide measured torquing value checklist with witness signature to DEN Project Manager.
- C. Perform infrared scanning of all splices and terminations as required in Section 260519 "Low-Voltage Electric Power Conductors and Cables".

PART 4 - MEASUREMENT

4.1 MEASUREMENT

- A. No separate measurement will be made for the work specified in this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work specified in this Section, but shall be included in the Contract Lump Sum Bid Price for Division 16 - Electrical, which price shall include all necessary and incidental material and work thereto.

END OF SECTION 260583

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SECTION 260913 - ELECTRICAL POWER MONITORING AND CONTROL

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes the following for monitoring[**and control**] of electrical power system:

Retain one or both subparagraphs below. Retain first if work includes only local metering and monitoring, without connections to data transmission network. Retain both if monitoring and control are connected to a LAN.

1. PC-based workstation(s) and software.

In subparagraph below, retain first option for serial connection of hand-held computer and other close-connected I/O-enabled devices; retain second option for daisy-chaining addressable devices including relays, meters, actuators, and power monitors to a network server; or retain third option for network server, workstation, networked PCs, and connection to existing LANs and WAN.

If applying for LEED certification, a power monitoring and control system to measure energy usage of different systems and equipment can be used to satisfy some of the requirements of LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1. A Measurement & Verification (M&V) Plan, developed by the design team, is required to achieve this credit. The M&V period extends for at least one year of postconstruction occupancy. Refer to the International Performance Measurement & Verification Protocol (IPMVP), Volume III: "Concepts and Options for Determining Energy Savings in New Construction," for additional information.

2. Communication network and interface modules for [**RS-232**] [**RS-485, Modbus TCP/IP**] [**IEEE 802.3**] data transmission protocols.

B. Related Sections:

Retain Section in subparagraph below that contains requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 262713 "Electricity Metering" for equipment to meter electricity consumption and demand for incoming service feeders and tenant submetering.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. Ethernet: Local area network based on IEEE 802.3 standards.
- B. Firmware: Software (programs or data) that has been written onto read-only memory (ROM). Firmware is a combination of software and hardware. Storage media with ROMs that have data or programs recorded on them are firmware.
- C. HTML: Hypertext markup language.
- D. I/O: Input/output.
- E. KY Pulse: A term used by the metering industry to describe a method of measuring consumption of electricity that is based on a relay changing status in response to the rotation of the disk in the meter.
- F. LAN: Local area network; sometimes plural as "LANs."
- G. LCD: Liquid crystal display.
- H. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or remote-control, signaling and power-limited circuits.
- I. Modbus TCP/IP: An open protocol for exchange of process data.
- J. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
- K. PC: Personal computer; sometimes plural as "PCs."
- L. rms: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.
- M. RS-232: A TIA standard for asynchronous serial data communications between terminal devices.
- N. RS-485: A TIA standard for multipoint communications using two twisted-pairs.

- O. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.
- P. THD: Total harmonic distortion.
- Q. UPS: Uninterruptible power supply; used both in singular and plural context.
- R. WAN: Wide area network.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Attach copies of approved Product Data submittals for products (such as switchboards and switchgear) that describe power monitoring and control features to illustrate coordination among related equipment and power monitoring and control.
 - 2. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For power monitoring and control equipment. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Outline Drawings: Indicate arrangement of components and clearance and access requirements.
 - 2. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices to be used. Describe characteristics of network and other data communication lines.
 - 3. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 4. Wiring Diagrams: For power, signal, and control wiring. Coordinate nomenclature and presentation with a block diagram.
 - 5. UPS sizing calculations for workstation.
 - 6. Surge Suppressors: Data for each device used and where applied.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified [**Installer**] [**manufacturer**].

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
- C. Other Informational Submittals:
 - 1. Manufacturer's system installation and setup guides, with data forms to plan and record options and setup decisions.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For power monitoring and control units, to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - 1. Operating and applications software documentation.
 - 2. Software licenses.
 - 3. Software service agreement.
 - 4. PC installation and operating documentation, manuals, and software for the PC and all installed peripherals. Software shall include system restore, emergency boot diskettes, and drivers for all installed hardware. Provide separately for each PC.
 - 5. Hard copies of manufacturer's specification sheets, operating specifications, design guides, user's guides for software and hardware, and PDF files on CD-ROM of the hard-copy submittal.
- B. Software and Firmware Operational Documentation:

Retain first subparagraph below for PC-based control system.

- 1. Self-study guide describing the process for setting equipment's network address; setting Owner's options; procedures to ensure data access from any PC on the network, using a standard Web browser; and recommended firewall setup.
 - 2. Software operating and upgrade manuals.
 - 3. Software Backup: On a magnetic media or compact disc, complete with Owner-selected options.
 - 4. Device address list and the set point of each device and operator option, as set in applications software.
 - 5. Graphic file and printout of graphic screens and related icons, with legend.
- C. Software Upgrade Kit: For Owner to use in modifying software to suit future power system revisions or power monitoring and control revisions.

Retain first paragraph below for PC-based control system.

- D. Software licenses and upgrades required by and installed for operating and programming digital and analog devices.

1.7 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Retain applicable subparagraphs below. Quantities indicated are examples only.

1. Addressable Relays: One for every [10] <Insert number> installed. Furnish at least one of each type.
2. Data Line Surge Suppressors: One for every [10] <Insert number> of each type installed. Furnish at least one of each type.
3. <Insert material>.

1.9 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.
- B. Manufacturer Qualifications: A firm experienced in manufacturing power monitoring and control equipment similar to that indicated for this Project and with a record of successful in-service performance.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.10 COORDINATION

- A. Coordinate features of distribution equipment and power monitoring and control components to form an integrated interconnection of compatible components.
 1. Match components and interconnections for optimum performance of specified functions.
- B. Coordinate Work of this Section with those in Sections specifying distribution components that are monitored or controlled by power monitoring and control equipment.

- C. Power monitoring on the Concourses, in the Main Terminal, the Airport Office Building and other buildings as needed: Equipment shall be compatible with POWER-NET, from Cutler Hammer.

1.11 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning with Substantial Completion, provide software support for **[two (2)] <Insert number>** years.
- B. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within **[two (2)] <Insert number>** years from date of Substantial Completion. Upgrading software shall include the operating systems. Upgrade shall include new or revised licenses for use of software.
 - 1. Provide thirty (30) days' notice to Owner to allow scheduling and access to system and to allow Owner to upgrade computer equipment if necessary.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Eaton Corporation; Cutler-Hammer products.
 - 2. General Electric Company; GE Consumer & Industrial.
 - 3. Landis+Gyr Inc.
 - 4. Rockwell Automation, Inc.; Allen-Bradley brand.
 - 5. Schneider Electric USA, Inc.
 - 6. **<Insert manufacturer's name>**.
 - 7. or approved equal.

2.2 FUNCTIONAL DESCRIPTION

Coordinate descriptions in this article with power measuring and monitoring work of this Section and with control devices specified in other Sections. Use sample schedule in the Evaluations and the Specification Coordination Checklist to assist in coordination.

A. Instrumentation and Recording Devices: Monitor and record load profiles and chart energy consumption patterns.

1. Calculate and Record the Following:

- a. Load factor.
- b. Peak demand periods.

The Section Text specifies electricity meters only. Add other meter types with Modbus TCP/IP output.

LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1 require meters that comply with requirements of the International Performance Measurement & Verification Protocol (IPMVP), Volume III, Chapter 4, "M&V Methods for Energy Conservation Measure Isolation" (Option B) or "Whole Building Calibrated Simulation" (Option D). As a minimum, require metering at the main service and at the major feeders and systems. Indicate location of meters on Drawings.

2. Measure and Record Metering Data for the Following:

- a. Electricity.
- b. Domestic water.
- c. Natural gas.
- d. **<Insert utility>**.

B. Software: Calculate allocation of utility costs.

1. Automatically Import Energy Usage Records to Allocate Energy Costs for the Following:

- a. At least [**15**] **<Insert number>** departments.
- b. At least [**30**] **<Insert number>** tenants.
- c. At least [**five**] **<Insert number>** processes.
- d. At least [**five**] **<Insert number>** buildings.
- e. **<Insert entity>**.

C. Power Quality Monitoring: Identify power system anomalies and measure, display, and record trends and alarms of the following power quality parameters:

1. Voltage regulation and unbalance.
2. Continuous three-phase rms voltage.
3. Periodic max./min./avg. voltage samples.
4. Harmonics.
5. Voltage excursions.
6. **<Insert parameter>**.

- D. Emergency Load Shedding. Preserve critical loads or avoid total shutdown due to unforeseen loss of power sources according to the following logic:
1. Determine system topology.
 2. Evaluate remaining loads and sources.
 3. Shed loads in less than 100 ms.
 4. **<Insert activity related to load shedding>**.
- E. Demand Management:
1. Peaking or co-generator control.
 2. Load interlocking.
 3. Load shedding.
 4. Load trimming.
 5. **<Insert management strategy>**.
- F. System: Report equipment status and power system control.

2.3 SYSTEM REQUIREMENTS

- A. Monitoring and Control System: Include PC-based workstation with its operating system and application software, connected to data transmission network.
- B. Surge Protection: For external wiring of each conductor entry connection to components to protect components from voltage surges originating external to equipment housing and entering through power, communication, signal, control, or sensing leads.
1. Minimum Protection for Power Lines 120 V and More: Auxiliary panel suppressors complying with requirements in Section 264313 "Surge Protection for Low-Voltage Electrical Power Circuits."
 2. Minimum Protection for Communication, Signal, Control, and Low-Voltage Power Lines: Comply with requirements as recommended by manufacturer for type of line being protected.
- C. Addressable Devices: All transmitters and receivers shall communicate unique device identification and status reports to monitoring and control clients.

Retain paragraph below for interface with the BAS. Coordinate with Division 23 Section "Instrumentation and Control for HVAC."

- D. BAS Interface: Provide factory-installed hardware and software to enable the BAS to monitor, display, and record data for use in processing reports.

Retain one of two subparagraphs below. Retain first subparagraph if interface with the BAS is through hardwired points and minimal interface is required. Retain second subparagraph if extensive interface with the BAS is required and is beyond what hardwired points can provide. Requirement may exclude some manufacturers.

1. Hardwired Monitoring Points: Electrical power demand (kilowatts), electrical power consumption (kilowatt-hours)[, **power factor**] <Insert monitoring point>.
2. ASHRAE 135 (BACnet) LonTalk Modbus Industry-accepted, open-protocol Insert type of interface communication interface with the BAS shall enable the BAS operator to remotely monitor meter information from a BAS operator workstation. Control features and monitoring points displayed locally at metering panel shall be available through the BAS.

2.4 OPERATING SYSTEM

Retain one of first four paragraphs below. Revise remaining paragraphs to match software capability. Retain first paragraph for a single PC connected to monitor a single power meter, circuit monitor, energy meter, or utility monitor. Monitored device can be one in this Section or can be specified in Sections that are listed in the Specification Coordination Checklist. Graphics and Web connections are not included.

- A. Software: Configured to run on a portable laptop computer, a single PC, or a palm computer, with capability for accessing a single meter at a time. System is not connected to a LAN. Modbus TCP/IP, RS-232, and RS-485 digital communications.

Retain first paragraph below for a single PC connected to monitor multiple devices: power meters, circuit monitors, energy meters, or utility monitors. Remote operation of addressable devices specified in other Sections is enabled. Graphics and Web connections are not included.

- B. Software: Configured to run on a single PC, with capability for accessing multiple devices simultaneously. Modbus TCP/IP, RS-232, and RS-485 digital communications.

Retain first paragraph below for multiple PCs connected to monitor multiple devices: power meters, circuit monitors, energy meters, or utility monitors. Remote operation of addressable devices specified in other Sections is enabled. Graphics and Web connections are not included.

- C. Software: Configured for a server and multiple client PCs, each with capability for accessing multiple devices simultaneously. Ethernet, Modbus TCP/IP, RS-232, and RS-485 digital communications.

Retain first paragraph below for multiple PCs connected to monitor multiple devices: power meters, circuit monitors, energy meters, or utility monitors. Remote operation of addressable devices specified in other Sections is enabled. Graphics, Web access, and fully specified functionality are included.

- D. Software: Configured for a server and multiple client PCs, each with capability for accessing multiple devices simultaneously. Software shall include interactive graphics client and shall be Web enabled. Workstations and portable computers shall not require any software except for an Internet browser to provide connectivity and full functionality. Include a firewall recommended by manufacturer. 100 Base-T Ethernet, Modbus TCP/IP RS-232, and RS-485 digital communications.
- E. Operating System Software: Based on [32] <Insert number>-bit, Microsoft Windows workstation operating system. Software shall have the following features:
 1. Multiuser and multitasking to allow independent activities and monitoring to occur simultaneously at different workstations.
 2. Graphical user interface to show pull-down menus and a menu tree format.

3. Capability for future additions within the indicated system size limits.

Retain paragraph below if a single point failure in workstation and server is unacceptable.

- F. Peer Computer Control Software: Shall detect a failure of workstation[**and associated server,**] and shall cause other workstation[**and associated server**] to assume control of all system functions without interruption of operation. Drivers shall be provided in both central computers to support this mode of operation.

2.5 APPLICATIONS SOFTWARE

A. Basic Requirements:

1. Fully compatible with and based on the approved operating system.
2. Password-protected operator login and access; three levels, minimum.
3. Password-protected setup functions.
4. Context-sensitive online help.
5. Capability of creating, deleting, and copying files; and automatically maintaining a directory of all files, including size and location of each sequential and random-ordered record.
6. Capability for importing custom icons into graphic views to represent alarms and I/O devices.
7. Automatic and encrypted backups for database and history; automatically stored at [**central control PC**] [**selected workstation**] and encrypted with a nine-character alphanumeric password, which must be used to restore or read data contained in backup.
8. Operator audit trail for recording and reporting all changes made to user-defined system options.

B. Workstation Server Functions:

1. Support other client PCs on the LAN[**and WAN**].
2. Maintain recorded data in databases accessible from other PCs on the LAN[**and WAN**].

C. Data Formats:

1. User-programmable export and import of data to and from commonly used [**Microsoft Windows**] <Insert system> spreadsheet, database, billing, and other applications; using dynamic data exchange technology.
2. Option to convert reports and graphics to HTML format.
3. Interactive graphics.
4. Option to send preprogrammed or operator designed e-mail reports.

D. Metered Data: Display metered values in real time.

E. Remote Control:

1. Display circuit-breaker status and allow breaker control.

Retain subparagraph below when the remote computer includes the automatic load shedding and restoration of these loads.

2. User defined with load-shedding automatically initiated and executed schemes responding to programmed time schedules, set points of metered demands, utility contracted load shedding, or combinations of these.
- F. Equipment Documentation: Database for recording of equipment ratings and characteristics; with capability for graphic display on monitors.
- G. Graphics: Interactive color-graphics platform with pull-down menus and mouse-driven generation of power system graphics, in formats widely used for such drafting; to include the following:
1. Site plan.
 2. Floor plans.
 3. Equipment elevations.
 4. Single-line diagrams.
- H. User-Defined Monitoring and Control Events: Display and record with date and time stamps accurate to 0.1 second, and including the following:
1. Operator log on/off.
 2. Attempted operator log on/off.
 3. All alarms.
 4. Equipment operation counters.
 5. Out-of-limit, pickup, trip, and no-response events.
- I. Trending Reports: Display data acquired in real-time from different meters or devices, in historical format over user-defined time; unlimited as to interval, duration, or quantity of trends.
1. Spreadsheet functions of sum, delta, percent, average, mean, standard deviation, and related functions applied to recorded data.
 2. Charting, statistical, and display functions of standard Windows-based spreadsheet.
- J. Alarms: Display and record alarm messages from discrete input and controls outputs, according to user programmable protocol.
1. Functions requiring user acknowledgment shall run in background during computer use for other applications and override other presentations when they occur.

Coordinate requirements in first paragraph below with field-mounted instrument specifications to ensure that measured data are of the quality to produce specified waveform displays.

- K. Waveform Data: Display and record waveforms on demand or automatically on an alarm or programmed event. Include the graphic displays of the following, based on user-specified criteria:
1. Phase voltages, phase currents, and residual current.

2. Overlay of three-phase currents, and overlay each phase voltage and current.
 3. Waveforms ranging in length from [2] **<Insert number>** cycles to [5] **<Insert number>** minutes.
 4. Disturbance and steady-state waveforms up to 512 points per cycle.
 5. Transient waveforms up to 83,333 points per cycle on 60-Hz base.
 6. Calculated waveform, based on recorded data, on a minimum of four cycles of data of the following:
 - a. THD.
 - b. rms magnitudes.
 - c. Peak values.
 - d. Crest factors.
 - e. Magnitude of individual harmonics.
- L. Data Sharing: Allow export of [**recorded displays and**] tabular data to third-party applications software.
1. Tabular data shall be in the comma-separated values.
 2. **<Insert data sharing protocol>**.
- M. Activity Billing Software:
1. Automatically compute and prepare activity demand and energy-use statements based on metering of energy use and peak demand integrated over user-defined interval.
 2. Intervals shall be same as used by electric utilities, including current vendor.
 3. Import metered data from saved records that were generated by metering and monitoring software.
 4. Maintain separate directory for each activity's historical billing information.
 5. Prepare summary reports in user-defined formats and time intervals.
- N. Reporting: User commands initiate the reporting of a list of current alarm, supervisory, and trouble conditions in system or a log of past events.
1. Print a record of user-defined alarm, supervisory, and trouble events on workstation printer.
 2. Sort and report by device name and by function.
 3. Report type of signal (alarm, supervisory, or trouble), description, date, and time of occurrence.
 4. Differentiate alarm signals from other indications.
 5. When system is reset, report reset event with same information concerning device, location, date, and time.

Retain paragraph below for local display if needed in addition to data transmitted to a workstation. The display monitor described can be replaced by a workstation or a permanently connected laptop if installed at the main office of system manager. Otherwise, the display monitor is co-located with the power monitor, but this location is normally unattended and the display monitor provides data display in case network is down. Adjust monitor specifications, considering that limited computing power will exist locally.

- O. Display Monitor:

1. Backlighted LCD to display metered data with [**touch-screen**] [**touch-pad**] **<Insert interface>** selecting device.
2. Touch-screen display shall be a minimum 12-inch diagonal, resolution of 800 by 600 RGB pixels, 256 colors; NEMA 250, Type 1 display enclosure.
3. Display [**four (4)**] **<Insert number>** values on one screen at same time.

2.6 COMMUNICATION COMPONENTS AND NETWORKS

- A. Network Configuration: High-speed, multi-access, open nonproprietary, industry standard communication protocol; LANs complying with EIA 485, 100 Base-T Ethernet, and Modbus TCP/IP.

2.7 POWER MONITORS

See the "Writing Guide" Article in the Evaluations for discussion on whether this article should be retained. Note that the specified device is a monitor and a controller and does not include accessories such as instrument transformers and field-mounted sensors. See the Specification Coordination Checklist for additional details.

UL 1244 applies to electrical and electronic measuring or testing equipment, with voltage not to exceed 480 V between phases for three-phase supply circuits and 250 V for single-phase supply circuits.

- A. Separately mounted, permanently installed instrument for power monitoring and control, complying with UL 1244.
 1. Enclosure: NEMA 250, Type [**1**] [**12**] **<Insert number>**.
- B. Environmental Conditions: System components shall be capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability:
 1. Indoor installation in [**non-air-conditioned**] [**nontemperature-controlled**] spaces that have environmental controls to maintain ambient conditions of [**0 to 122 deg F** (minus 18 to plus 50 deg C)] **<Insert temperature range>** dry bulb and 20 to 90 percent relative humidity, noncondensing.
- C. rms Real-Time Measurements:
 1. Current: Each phase, neutral, average of three phases, percent unbalance.
 2. Voltage: Line-to-line each phase, line-to-line average of three phases, line-to-neutral each phase, line-to-neutral average of three phases, line-to-neutral percent unbalance.
 3. Power: Per phase and three-phase total.
 4. Reactive Power: Per phase and three-phase total.
 5. Apparent Power: Per phase and three-phase total.
 6. Power Factor: Per phase and three-phase total.
 7. Displacement Power Factor: Per phase and three-phase total.
 8. Frequency.
 9. THD: Current and voltage.

10. Accumulated Energy: Real kWh, reactive kVARh, apparent kVAh (signed/absolute).
 11. Incremental Energy: Real kWh, reactive kVARh, apparent kVAh (signed/absolute).
 12. Conditional Energy: Real kWh, reactive kVARh, apparent kVAh (signed/absolute).
- D. Demand Current Calculations, per Phase, Three-Phase Average and Neutral:
1. Present.
 2. Running average.
 3. Last completed interval.
 4. Peak.
- E. Demand Real Power Calculations, Three-Phase Total:
1. Present.
 2. Running average.
 3. Last completed interval.
 4. Predicted.
 5. Peak.
 6. Coincident with peak kVA demand.
 7. Coincident with kVAR demand.
- F. Demand Reactive Power Calculations, Three-Phase Total:
1. Present.
 2. Running average.
 3. Last completed interval.
 4. Predicted.
 5. Peak.
 6. Coincident with peak kVA demand.
 7. Coincident with kVAR demand.
- G. Demand Apparent Power Calculations, Three-Phase Total:
1. Present.
 2. Running average.
 3. Last completed interval.
 4. Predicted.
 5. Peak.
 6. Coincident with peak kVA demand.
 7. Coincident with kVAR demand.
- H. Average Power Factor Calculations, Demand Coincident, Three-Phase Total:
1. Last completed interval.
 2. Coincident with kW peak.
 3. Coincident with kVAR peak.
 4. Coincident with kVA peak.

- I. Power Analysis Values:
1. THD, Voltage and Current: Per phase, three phase, and neutral.
 2. Displacement Power Factor: Per phase, three phase.
 3. Fundamental Voltage, Magnitude and Angle: Per phase.
 4. Fundamental Currents, Magnitude and Angle: Per phase.
 5. Fundamental Real Power: Per phase, three phase.
 6. Fundamental Reactive Power: Per phase.
 7. Harmonic Power: Per phase, three phase.
 8. Phase rotation.
 9. Unbalance: Current and voltage.
 10. Harmonic Magnitudes and Angles for Current and Voltages: Per phase, up to [31st] [63rd] <Insert number> harmonic.
- J. Power Demand Calculations: According to one of the following calculation methods, selectable by the user:
1. Thermal Demand: Sliding window updated every second for the present demand and at end of the interval for the last interval. Adjustable window that can be set in 1-minute intervals, from 1 to 60 minutes.
 2. Block Interval with Optional Subintervals: Adjustable for 1-minute intervals, from 1 to 60 minutes. User-defined parameters for the following block intervals:
 - a. Sliding block that calculates demand every second, with intervals less than 15 minutes, and every 15 seconds with an interval between 15 and 60 minutes.
 - b. Fixed block that calculates demand at end of the interval.
 - c. Rolling block subinterval that calculates demand at end of each subinterval and displays it at end of the interval.
 3. Demand Calculation Initiated by a Synchronization Signal:

Retain one or both of first two subparagraphs below.

 - a. Signal is a pulse from an external source. Demand period begins with every pulse. Calculation shall be configurable as either a block or rolling block calculation.
 - b. Signal is a communication signal. Calculation shall be configurable as either a block or rolling block calculation.
 - c. Demand can be synchronized with clock in the power meter.
- K. Sampling:
1. Current and voltage shall be digitally sampled at a rate high enough to provide accuracy to 63rd harmonic of 60-Hz fundamental.
 2. Power monitor shall provide continuous sampling at a rate of [128] <Insert number> samples per cycle on all voltage and current channels in the meter.

- L. Minimum and Maximum Values: Record monthly minimum and maximum values, including date and time of record. For three-phase measurements, identify phase of recorded value. Record the following parameters:
1. Line-to-line voltage.
 2. Line-to-neutral voltage.
 3. Current per phase.
 4. Line-to-line voltage unbalance.
 5. Line-to-neutral voltage unbalance.
 6. Power factor.
 7. Displacement power factor.
 8. Total power.
 9. Total reactive power.
 10. Total apparent power.
 11. THD voltage L-L.
 12. THD voltage L-N.
 13. THD current.
 14. Frequency.
- M. Harmonic Calculation: Display and record the following:
1. Harmonic magnitudes and angles for each phase voltage and current through **[31st] [63rd] <Insert number>** harmonic. Calculate for all three phases, current and voltage, and residual current. Current and voltage information for all phases shall be obtained simultaneously from same cycle.
 2. Harmonic magnitude reported as a percentage of the fundamental or as a percentage of rms values, as selected by user.
- N. Current and Voltage Ratings:
1. Designed for use with current inputs from standard instrument current transformers with 5-A secondary and shall have a metering range of 0-10 A.
 2. Withstand ratings shall not be less than 15 A, continuous; 50 A, lasting over 10 seconds, no more frequently than once per hour; 500 A, lasting 1 second, no more frequently than once per hour.
 3. Designed for use with voltage inputs from standard instrument potential transformers with a 120-V secondary.
- O. Accuracy:
- Retain first subparagraph below when revenue meter accuracy is required. See Evaluations for discussion of the listed standards.
1. Comply with ANSI C12.20, Class 0.5; and IEC 60687, Class 0.5 for revenue meters. Accuracy from Light to Full Rating shall meet the following criteria:
 - a. Power: Accurate to 0.25 percent of reading, plus 0.025 percent of full scale.
 - b. Voltage and Current: Accurate to 0.075 percent of reading, plus 0.025 percent of full scale.
 - c. Power Factor: Plus or minus 0.002, from 0.5 leading to 0.5 lagging.
 - d. Frequency: Plus or minus 0.01 Hz at 45 to 67 Hz.

Retain subparagraph below for equipment monitoring accuracy when the metering is a factory-installed breaker accessory. Generally, accuracy standards are not applicable. The values listed below are typical and need to be verified.

2. For meters that are circuit-breaker accessories, metering accuracy at full-scale shall not be less than the following:
 - a. Current: Plus or minus 2.5 percent.
 - b. Voltage: Plus or minus 1.5 percent.
 - c. Energy, Demand, and Power: Plus or minus 4.0 percent.
 - d. Frequency: Plus or minus 1 Hz.

P. Waveform Capture:

1. Capture and store steady-state waveforms of voltage and current channels; initiated manually. Each capture shall be for **[3] <Insert number>** cycles, **[128] <Insert number>** data points for each cycle, allowing resolution of harmonics to **[31st] <Insert number>** harmonic of basic 60 Hz.
2. Store captured waveforms in internal nonvolatile memory; available for PC display, archiving, and analysis.

Q. Input: **[One] <Insert number>** digital input signal(s).

1. Normal mode for on/off signal.
2. Demand interval synchronization pulse, accepting a demand synchronization pulse from a utility demand meter.
3. Conditional energy signal to control conditional energy accumulation.

R. Outputs:

1. Operated either by user command sent via communication link, or set to operate in response to user-defined alarm or event.
2. Closed in either a momentary or latched mode as defined by user.
3. Each output relay used in a momentary contact mode shall have an independent timer that can be set by user.
4. One digital KY pulse to a user-definable increment of energy measurement. Output ratings shall be up to 120-V ac, 300-V dc, 50 mA, and provide 3500-V rms isolation.
5. **[One (1)] <Insert number>** relay output module(s), providing a load voltage range from 20- to 240-V ac or from 20- to 30-V dc, supporting a load current of 2 A.
6. Output Relay Control:
 - a. Relay outputs shall operate either by user command sent via communication link or in response to user-defined alarm or event.
 - b. Normally open and normally closed contacts, field configured to operate as follows:
 - 1) Normal contact closure where contacts change state for as long as signal exists.

- 2) Latched mode when contacts change state on receipts of a pickup signal; changed state is held until a dropout signal is received.
- 3) Timed mode when contacts change state on receipt of a pickup signal; changed state is held for a preprogrammed duration.
- 4) End of power demand interval when relay operates as synchronization pulse for other devices.
- 5) Energy Pulse Output: Relay pulses quantities used for absolute kWh, absolute kVARh, kVAh, kWh In, kVARh In, kWh Out, and kVARh Out.
- 6) Output controlled by multiple alarms using Boolean-type logic.

S. Onboard Data Logging:

1. Store logged data, alarms, events, and waveforms in [80] [800] <Insert number> KB of onboard nonvolatile memory.
2. Stored Data:

Retain first subparagraph below when metered data is used for internal cost allocation. For customer billing use equipment specified in Section 262713 "Electricity Metering."

- a. Billing Log: User configurable; data shall be recorded every 15 minutes, identified by month, day, and 15-minute interval. Accumulate 24 months of monthly data, 32 days of daily data, and between 2 and 52 days of 15-minute interval data, depending on number of quantities selected.
 - b. Custom Data Logs: [**One (1)**] [**Three (3)**] user-defined log(s) holding up to 96 parameters. Date and time stamp each entry to the second and include the following user definitions:
 - 1) Schedule interval.
 - 2) Event definition.
 - 3) Configured as "fill-and-hold" or "circular, first-in first-out."
 - c. Alarm Log: Include time, date, event information, and coincident information for each defined alarm or event.
 - d. Waveform Log: Store captured waveforms configured as "fill-and-hold" or "circular, first-in first-out."
3. Default values for all logs shall be initially set at factory, with logging to begin on device power up.

T. Alarms.

1. User Options:
 - a. Define pickup, dropout, and delay.
 - b. Assign one of [**four (4)**] <Insert number> severity levels to make it easier for user to respond to the most important events first.
 - c. Allow for combining up to [**four (4)**] <Insert value> alarms using Boolean-type logic statements for outputting a single alarm.
2. Alarm Events:

- a. Over/undercurrent.
- b. Over/undervoltage.
- c. Current imbalance.
- d. Phase loss, current.
- e. Phase loss, voltage.
- f. Voltage imbalance.
- g. Over kW demand.
- h. Phase reversal.
- i. Digital input off/on.
- j. End of incremental energy interval.
- k. End of demand interval.

U. Control Power: 90- to 457-V ac or 100- to 300-V dc.

V. Communications:

Retain one of two options in first subparagraph below to coordinate with "Operating System" Article.

1. Power monitor shall be permanently connected to communicate via [**Modbus TCP via a 100 Base-T Ethernet**] [**RS-485 Modbus TCP/IP**].
2. Local plug-in connections shall be for RS-232 and 100 Base-T Ethernet.

The display monitor described in paragraph below can be replaced by a workstation or a permanently connected laptop if installed at the main office of system manager. Otherwise, the display monitor would be co-located with the power monitor, but this location is normally unattended and the display monitor will provide data display in case network is down.

W. Display Monitor:

1. Backlighted LCD to display metered data with [**touch-screen**] [**touch-pad**] **<Insert interface>** selecting device.
2. Touch-screen display shall be a minimum 12-inch diagonal, resolution of 800 by 600 RGB pixels, 256 colors; NEMA 250, Type 1 display enclosure.
3. Display [**four (4)**] **<Insert number>** values on one screen at same time.

Coordinate list below with meter capabilities specified in subparagraphs above.

- a. Current, per phase rms, three-phase average[**and neutral**].
- b. Voltage, phase to phase, phase to neutral, and three-phase averages of phase to phase and phase to neutral.
- c. Real power, per phase and three-phase total.
- d. Reactive power, per phase and three-phase total.
- e. Apparent power, per phase and three-phase total.
- f. Power factor, per phase and three-phase total.
- g. Frequency.
- h. Demand current, per phase and three-phase average.
- i. Demand real power, three-phase total.
- j. Demand apparent power, three-phase total.
- k. Accumulated energy (MWh and MVARh).
- l. THD, current and voltage, per phase.

4. Reset: Allow reset of the following parameters at the display:
 - a. Peak demand current.
 - b. Peak demand power (kW) and peak demand apparent power (kVA).
 - c. Energy (MWh) and reactive energy (MVARh).

2.8 STANDALONE, WEB-ENABLED MONITORING AND CONTROL INSTRUMENT

See the "Writing Guide" Article in the Evaluations for discussion on whether this article should be retained. Note that the specified device is a monitor and a controller and does not include accessories such as instrument transformers and field-mounted sensors. See the Specification Coordination Checklist for additional details.

- A. Separately mounted, permanently installed instrument for power monitoring and control.
 1. Enclosure: NEMA 250, Type [1] [12] <Insert number>.
- B. Environmental Conditions: System components shall be capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability.
 1. Indoor installation in [**non-air-conditioned**] [**nontemperature-controlled**] spaces that have environmental controls to maintain ambient conditions of [0 to 122 deg F (minus 18 to plus 50 deg C)] <Insert temperature range> dry bulb and 20 to 90 percent relative humidity, noncondensing.
- C. Power-Distribution Equipment Monitor: Web enabled, with integral network port and embedded Web server with factory-configured firmware and HTML-formatted Web pages for viewing of power monitoring and equipment status information from connected devices equipped with digital communication ports.

Default LAN in this Section is 100 Base-T.

- D. LAN Connectivity: Multipoint, RS-485 Modbus serial communication network, interconnecting all breaker trip units, protective relays, drives, and metering devices equipped with communications. Serial communication network connected to Ethernet server that functions as a gateway and server, providing data access via [**10 Base-T**] [**100 Base-T**] [**100 Base-FX**] LAN.
- E. Communication Devices within the Equipment: Addressed at factory and tested to verify reliable communication with network server.
- F. Server Configuration:
 1. Initial network parameters set using a standard Web browser. Connect via a local operator interface, or an RJ-45 port accessible from front of equipment.
 2. Network server shall be factory programmed with embedded HTML-formatted Web pages that are user configurable and that provide detailed communication diagnostic information for serial and Ethernet ports as status of RS-485 network;

- with internal memory management information pages for viewing using a standard Web browser.
3. Login: Password protected; password administration accessible from the LAN using a standard Web browser.
 4. Operating Software: Suitable for local access; firewall protected.
- G. Data Access:
1. Network server shall include embedded HTML pages providing real-time information from devices connected to RS-485 network ports via a standard Web browser.
- H. Equipment Monitoring Options: Login shall be followed by a main menu for selecting summary Web pages that follow.
- I. Summary Web pages shall be factory configured to display the following information for each communicating device within the power equipment lineup:

Revise subparagraphs below to match monitoring devices specified in schedules. Optional text adds features that may be desirable add-ons to the basic.

1. **[User-Configured Custom Home Page: Provide for the lineup, showing status-at-a-glance of key operating values].**
2. Circuit Summary Page: Circuit name, three-phase average rms current, power (kW), power factor, and breaker status.
3. Load Current Summary Page: Circuit name, Phase A, B, and C rms current values.
4. Demand Current Summary Page: Circuit name, Phase A, B, and C average demand current values.
5. Power Summary Page: Circuit name, present demand power (kW), peak demand power (kW), and recorded time and date.
6. Energy Summary Page: Circuit name, energy (kWh), reactive energy (kVARh), and time/date of last reset.

Retain first subparagraph below if monitoring includes dry-type transformers in unit substations.

7. Transformer Status Page: Transformer tag, coil temperatures, and cooling fan status.

Retain first subparagraph below if monitoring includes motor-control center. Adjust status descriptions as appropriate for device type.

8. Motor-Control Center Status Page: Circuit name, three-phase average rms current, thermal capacity (percentage), and drive output frequency (Hz) contactor status.
9. Specific Device Pages: Each individual communicating device shall display detailed, real-time information, as appropriate for device type.
 - a. Display historical energy data that shall be logged automatically for each device, as appropriate for device type.
 - b. Display historical data logged from each device in graphical time-trend plots. Value to be displayed on time-trend plot shall be user selectable. Time interval to be displayed on scale shall be for previous day or week.

10. Export historical energy data to a PC or workstation through network using FTP (File Transfer Protocol). Format exported data in a CSV (Comma Separated Variable) file format for importing into spreadsheet applications.

J. Communications:

Retain first subparagraph below if this standalone power monitoring instrument is connected to the World Wide Web. Activation requires a service provider.

1. Power monitor: Permanently connected to communicate via **[RS-485 Modbus TCP/IP] [Modbus TCP via a 100 Base-T Ethernet]**.
2. Local Plug-in Connections: RS-232 and 100 Base-T Ethernet.
3. Monitor Display: Backlighted LCD to display metered data with **[touch-screen] [touch-pad] <Insert interface>** selecting device.

2.9 WORKSTATION HARDWARE

A. Environmental Conditions: System components shall be capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability:

1. Indoor installation in spaces that have environmental controls to maintain ambient conditions of **[36 to 122 deg F (2 to 50 deg C)] <Insert temperature range>** dry bulb and 20 to 90 percent relative humidity, noncondensing.

B. Computer: Standard unmodified PC of modular design, designed for the latest version of Windows operating system.

1. Memory: **<Insert capacity>** of usable installed memory.
2. Real-Time Clock. Automatic time correction once every 24 hours by synchronizing clock with **[the Time Service Department of the U.S. Naval Observatory] <Insert service>**.
3. Ports: Two RS-232-F serial ports for general use; one parallel port; four USB ports
4. Replaceable graphics board.
5. LAN Adapter Card.
6. Sound Card: For playback and recording of digital WAV sound files associated with audible warning and alarm functions.
7. Color Monitor: WXGA TFT, not less than **[18 inches (455 mm)] <Insert measurement>**, LCD type.
8. Keyboard: US English.
9. Mouse: Standard.
10. Minimum Disk Storage: **<Insert capacity>**, 7200 rpm hard drive.
11. CD-RW/DVD-ROM Drive.
12. Report Printer: Minimum resolution **[600] <Insert number>** dpi laser printer.
 - a. Connected to central station and designated workstations.
 - b. RAM: **[2] <Insert number>** MB, minimum.
 - c. Printing Speed: Minimum **[12] <Insert number>** pages per minute.

- d. Paper Handling: Automatic sheet feeder with [250] <Insert number>-sheet paper cassette and with automatic feed.

Redundant computers and associated hardware and software should be used if a single point failure would be unacceptable.

- C. Redundant Central Computer: Connected in a hot standby, peer configuration; automatically maintains copies of system software, application software, and data files. System transactions and other activities that alter system data files shall be updated to system files of redundant computer in near real-time. If central computer fails, redundant computer shall assume control immediately and automatically.
- D. UPS: Self-contained; complying with requirements in Section 263353 "Static Uninterruptible Power Supply."
 1. Size: Provide a minimum of [6] <Insert number> hours of operation of workstation station equipment[, **including 2 hours of alarm printer operation**].

Retain remainder of this article if Section 263353 "Static Uninterruptible Power Supply" is used for other UPS units. Coordinate UPS requirements with that Section.

2. Batteries: Sealed, valve regulated, recombinant, lead calcium.
3. Accessories:
 - a. Transient voltage suppression.
 - b. Input-harmonics reduction.
 - c. Rectifier/charger.
 - d. Battery disconnect device.
 - e. Static bypass transfer switch.

Subparagraphs below are optional accessories.

- f. Internal maintenance bypass/isolation switch.
- g. External maintenance bypass/isolation switch.
- h. Output isolation transformer.
- i. Remote UPS monitoring.
- j. Battery monitoring.
- k. Remote battery monitoring.
- l. <Insert accessories>.

2.10 RS-232 ASCII INTERFACE

Retain this article if selected monitoring or control devices require field-installed remotely located RS-232 ports, or if required for digital paging, local event recording, and similar systems. RS-232 communication connections are not recommended for distances of more than 50 feet (15 m), although transmission over distances of 300 feet (90 m) is possible with specialized equipment.

- A. ASCII interface shall allow RS-232 connections to be made between a meter or circuit monitor operating as the host PC and any equipment that will accept RS-232 ASCII command strings, such as [**local display panels**] [**dial-up modems**][**and alarm transmitters**] <Insert device>.

- B. Pager System Interface: Alarms shall be able to activate a pager system with customized message for each input alarm.
1. RS-232 output shall be capable of connection to a pager interface that can be used to call a paging system or service and send a signal to a portable pager. System shall allow an individual alphanumeric message per alarm input to be sent to paging system. This interface shall support both numeric and alphanumeric pagers.
- C. Alarm System Interface:
1. RS-232 output shall be capable of transmitting alarms from other monitoring and alarm systems to workstation software.
- D. Cables:
1. PVC-Jacketed, RS-232 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, polypropylene insulation, and individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage; PVC jacket. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.
 - a. NFPA 70, Type CM.
 - b. Flame Resistance: UL 1581, Vertical Tray.
 2. Plenum-Type, RS-232 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, plastic insulation, and individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage; plastic jacket. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.
 - a. NFPA 70, Type CMP.
 - b. Flame Resistance: NFPA 262, Flame Test.

2.11 LAN CABLES

- A. Comply with Section 271500 "Communications Horizontal Cabling."

Retain one or both paragraphs below only if Project includes field-wired, RS-485 communication links. RS-485 communications require 2 twisted pairs with a distance limitation of 4000 feet (1220 m).

- B. RS-485 Cable:
1. PVC-Jacketed, RS-485 Cable: Paired, 2 pairs, twisted, No. 22 AWG, stranded (7x30) tinned copper conductors, PVC insulation, unshielded, PVC jacket, and NFPA 70, Type CMG.
 2. Plenum-Type, RS-485 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, fluorinated-ethylene-propylene insulation, unshielded, and fluorinated-ethylene-propylene jacket, and NFPA 70, Type CMP.

Category 5e and Category 6 are listed in current standards; however, lesser-category cabling is generally available and is suitable for 10 Base-T transmission. See the "Product Characteristics" Article in the Evaluations in Section 271500 "Communications Horizontal Cabling" for discussion of options in paragraph below.

- C. Unshielded Twisted Pair Cables: Category [5e] [6] as specified for horizontal cable for data service in Section 271500 "Communications Horizontal Cabling."

2.12 LOW-VOLTAGE WIRING

- A. Comply with Section 260523 "Control-Voltage Electrical Power Cables."
- B. Low-Voltage Control Cable: Multiple conductor, color-coded, No. 20 AWG copper, minimum.
 - 1. Sheath: PVC; except in plenum-type spaces, use sheath listed for plenums.
 - 2. Ordinary Switching Circuits: Three conductors unless otherwise indicated.
 - 3. Switching Circuits with Pilot Lights or Locator Feature: Five conductors unless otherwise indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine pathway elements intended for cables. Check raceways, cable trays, and other elements for compliance with space allocations, installation tolerances, hazards to cable installation, and other conditions affecting installation.
 - 1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CABLING

- A. Comply with NECA 1.
- B. Install cables and wiring according to requirements in Section 271500 "Communications Horizontal Cabling."

Retain one of first two paragraphs below.

- C. Wiring Method: Install wiring in raceway and cable tray except within consoles, cabinets, desks, and counters. Conceal raceway and wiring except in unfinished spaces.
- D. Wiring Method: Install wiring in raceway and cable tray except within consoles, cabinets, desks, and counters and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Use NRTL-listed

plenum cable in environmental air spaces, including plenum ceilings. Conceal raceway and cables except in unfinished spaces.

- E. Install LAN cables using techniques, practices, and methods that are consistent with specified category rating of components and that ensure specified category performance of completed and linked signal paths, end to end.
- F. Install cables without damaging conductors, shield, or jacket.

3.3 IDENTIFICATION

- A. Identify components and power and control wiring according to Section 260553 "Identification for Electrical Systems."
- B. Label each power monitoring and control module with a unique designation.

3.4 GROUNDING

- A. Comply with IEEE 1100, "Recommended Practice for Powering and Grounding Electronic Equipment."

3.5 FIELD QUALITY CONTROL

Retain paragraph below, to identify who shall perform tests and inspections. Retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- B. Tests and Inspections:

1. Electrical Tests: Use caution when testing devices containing solid-state components.
2. Continuity tests of circuits.
3. Operational Tests: Set and operate controls at workstation and at monitored and controlled devices to demonstrate their functions and capabilities. Use a methodical sequence that cues and reproduces actual operating functions as

recommended by manufacturer. Submit sequences for approval. Note response to each test command and operation. Note time intervals between initiation of alarm conditions and registration of alarms at central-processing workstation.

- a. Coordinate testing required by this Section with that required by Sections specifying equipment being monitored and controlled.
- b. Test LANs according to requirements in Section 271500 "Communications Horizontal Cabling."
- c. System components with battery backup shall be operated on battery power for a period of not less than 10 percent of calculated battery operating time.
- d. Verify accuracy of graphic screens and icons.
- e. Metering Test: Load feeders, measure loads on feeder conductor with an rms reading clamp-on ammeter, and simultaneously read indicated current on the same phase at central-processing workstation. Record and compare values measured at the two locations. Resolve discrepancies greater than 5 percent and record resolution method and results.
- f. Record metered values, control settings, operations, cues, time intervals, and functional observations and submit test reports printed by workstation printer.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Power monitoring and control equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. Correct deficiencies, make necessary adjustments, and retest. Verify that specified requirements are met.
- F. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
- G. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.
- H. Remove and replace malfunctioning devices and circuits and retest as specified above.

3.6 DEMONSTRATION

Services specified in this article are optional; retain if Project warrants.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain systems. See Section 017900 "Demonstration and Training."

Revise hours in first subparagraph below to suit Project. Three or more sessions, four hours each, on different days may be required for complex installations. Coordinate with requirements in Section 017900 "Demonstration and Training."

1. Train Owner's management and maintenance personnel in interpreting and using monitoring displays and in configuring and using software and reports. Include troubleshooting, servicing, adjusting, and maintaining equipment. Provide a minimum of **[twelve (12)] <Insert number>** hours' training.
2. Training Aid: Use approved final versions of software and maintenance manuals as training aids.

3.7 ON-SITE ASSISTANCE

- A. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[three (3)] <Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **260913**

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SECTION 260923 - LIGHTING CONTROL DEVICES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1. ASHRAE/IESNA 90.1, Section 9, "Lighting," sets minimum interior and exterior lighting power densities and minimum requirements for lighting controls.

Local switches, occupancy sensors, and daylight-harvesting controls can be used to comply with the requirements of LEED-NC, LEED-CI, and LEED for Schools Credit EQ 6.1. However, use of task lighting may also be required, depending on the type of lighting system used on Project.

Occupancy sensors and daylight-harvesting controls can be combined with other energy-conserving measures to comply with the requirements of LEED-NC, LEED-CS, and LEED for Schools Credit EA 1 or with LEED-CI Credit EA 1.2.

Time switches and occupancy sensors can be combined to comply with the requirements of LEED-NC, LEED-CS, and LEED for Schools Credit SS 8 or with LEED-CI Credit SS 1, Option 1F.

ALL ENGINEER NOTES TO BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Time switches.
 - 2. Photoelectric switches.
 - 3. Standalone daylight-harvesting switching controls.
 - 4. Indoor occupancy sensors.
 - 5. Outdoor motion sensors.

6. Lighting contactors.
7. Emergency shunt relays.

B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 262726 "Wiring Devices" for wall-box dimmers, wall-switch occupancy sensors, and manual light switches.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include data substantiating that materials comply with requirements.

B. Shop Drawings: Show installation details for occupancy and light-level sensors.

Retain first subparagraph below unless control connections are indicated on Drawings.

1. Interconnection diagrams showing field-installed wiring.
2. Include diagrams for power, signal, and control wiring.

Coordinate requirements for coordination drawings with DEN Project Manager.

- C. Coordination Drawings: Include drawings to show lighting control equipment layouts and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

1.4 INFORMATIONAL SUBMITTALS

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

A. Field quality-control reports.

B. Qualification Data: For firms and persons specified in "Quality Assurance" Article.

- C. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of lighting control device to include in emergency, operation, and maintenance manuals.
- B. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Testing Agency Qualifications: Testing agency as defined by OSHA 29 CFR 1910.7, or a member company of the International Electrical Testing Association that is acceptable to authorities having jurisdiction.
- B. Source Limitations: Obtain lighting control equipment components through one source from a single manufacturer.
- C. Firms responding to this specification shall provide proof that they have been regularly engaged in the design, manufacturing and testing of lighting control equipment for not less than five (5) years.

1.7 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

- A. Manufacturer shall provide a product warranty for a period of not less than two (2) years from date of installation. Warranty shall cover unlimited replacement of lighting control equipment modules during the warranty period.

1.8 SEQUENCING AND SCHEDULING

- A. The lighting control equipment installation is to be sequenced and scheduled with other work to reduce possibility of damage to equipment during the remainder of construction period.

- B. Power Outages: Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

1.9 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects.

Coordinate extra stock requirements with DEN Project Manager.

- A. Furnish extra materials including ten (10) percent of installed units, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents. Deliver materials as directed by DEN Project Manager.

1.10 ENVIRONMENTAL CONDITIONS

- A. The lighting control equipment unit shall be capable of continuous operation under the following temperature conditions:
1. Relative humidity: 95% non-condensing.
 2. Altitude: 5500 feet (1667 meters) without any de-rating.
 3. Functioning: -30°F (-34°C) (Outdoor) to 120°F (49°C) (Indoor & Outdoor).
 4. The neutral shall not be combined for lighting circuits with electronic or dimming ballasts, and should be bonded according to local codes and National Electrical Code (NEC).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 TIME SWITCHES

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**

1. [Cooper Industries, Inc.](#)
2. [Intermatic, Inc.](#)
3. [Invensys Controls.](#)
4. [Leviton Manufacturing Co., Inc.](#)
5. [NSi Industries LLC; TORK Products.](#)
6. [Tyco Electronics; ALR Brand.](#)
7. **<Insert manufacturer's name>.**
8. or approved equal.

Retain "Electronic Time Switches" or "Electromechanical-Dial Time Switches" Paragraph below.

B. **Electronic Time Switches: Solid state, programmable, with alphanumeric display; complying with UL 917.**

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain "Contact Configuration" Subparagraph below if configuration is not indicated on Drawings.

2. Contact Configuration: [SPST] [DPST] [DPDT] **<Insert configuration>.**
3. Contact Rating: [30-A inductive or resistive, 240-V ac] [20-A ballast load, 120-/240-V ac] **<Insert rating>.**

Retain one of eight "Programs" subparagraphs below.

4. Programs: Eight on-off set points on a 24-hour schedule[**and an annual holiday schedule that overrides the weekly operation on holidays**].
5. Programs: Two on-off set points on a 24-hour schedule, allowing different set points for each day of the week[**and an annual holiday schedule that overrides the weekly operation on holidays**].
6. Programs: **<Insert number>** channels; each channel is individually programmable with eight on-off set points on a 24-hour schedule.
7. Programs: **<Insert number>** channels; each channel is individually programmable with two on-off set points on a 24-hour schedule with a skip-a-day weekly schedule.
8. Programs: **<Insert number>** channels; each channel is individually programmable with two on-off set points on a 24-hour schedule, allowing different set points for each day of the week.
9. Programs: **<Insert number>** channels; each channel is individually programmable with 40 on-off operations per week and an annual holiday schedule that overrides the weekly operation on holidays.
10. Programs: **<Insert number>** channels; each channel is individually programmable with 40 on-off operations per week, plus four seasonal schedules that modify the basic program, and an annual holiday schedule that overrides the weekly operation on holidays.
11. Programs: **<Insert configuration>**[**and an annual holiday schedule that overrides the weekly operation on holidays**].
12. Circuitry: Allow connection of a photoelectric relay as substitute for on-off function of a program[**on selected channels**].

13. Astronomic Time: **[All] [Selected]** channels.

If retaining first subparagraph below, the timer will change the time at 2:00 a.m. on the second Sunday in March and on the first Sunday in November.

14. Automatic daylight savings time changeover.
15. Battery Backup: Not less than seven days reserve, to maintain schedules and time clock.

- C. Electromechanical-Dial Time Switches: Comply with UL 917.

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain "Contact Configuration" Subparagraph below if configuration is indicated on Drawings.

2. Contact Configuration: **[SPST] [DPST] [SPDT] [DPDT] <Insert configuration>**.
3. Contact Rating: **[30-A inductive or resistive, 240-V ac] [20-A ballast load, 120-/240-V ac] <Insert rating>**.

Five subparagraphs below describe optional features.

4. Circuitry: Allows connection of a photoelectric relay as a substitute for the on-off function of a program.

Retain first subparagraph below to make time switches self-adjust for seasonal changes and automatically adjust on-off times as days grow shorter or longer.

5. Astronomic time dial.
6. Eight-Day Program: Uniquely programmable for each weekday and holidays.
7. Skip-a-day mode.
8. Wound-spring reserve carryover mechanism to keep time during power failures, minimum of **[16] <Insert number>** hours.

2.2 OUTDOOR PHOTOELECTRIC SWITCHES

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Industries, Inc.
2. Intermatic, Inc.
3. NSi Industries LLC; TORK Products.
4. Tyco Electronics; ALR Brand.
5. **<Insert manufacturer's name>**.
6. or approved equal.

Retain one of two "Description" paragraphs below. Light-level range is typical for dusk-to-dawn lighting applications. An inductive rating for a switch means it is UL tested at a 50 percent power factor.

First "Description" Paragraph describes a device with built-in, metal-oxide-varistor surge protection, a selection of contact ratings, and a range of adjustments to orient the photocell. These features allow flexibility in making the device suitable for a range of mounting and control situations.

Second "Description" Paragraph describes a device with less-effective surge protection, having a fixed load-breaking contact capacity. Its main application is control of a single lighting fixture. It is designed for mounting on a fixture.

- B. Description: Solid state, with [SPST] [DPST] <Insert configuration> dry contacts rated for [1800-VA tungsten or 1000-VA inductive] <Insert value>, to operate connected relay, contactor coils, or microprocessor input; complying with UL 773A.
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Light-Level Monitoring Range: 1.5 to 10 fc (16.14 to 108 lux), with an adjustment for turn-on and turn-off levels within that range[, and a directional lens in front of the photocell to prevent fixed light sources from causing turn-off].
 3. Time Delay: Fifteen second minimum, to prevent false operation.
 4. Surge Protection: Metal-oxide varistor.
 5. Mounting: Twist lock complies with NEMA C136.10, with base-and-stem mounting or stem-and-swivel mounting accessories as required to direct sensor to the north sky exposure.
- C. Description: Solid state, with [SPST] [DPST] dry contacts rated for 1800 VA, to operate connected load, complying with UL 773.
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Light-Level Monitoring Range: 1.5 to 10 fc (16.14 to 108 lux), with an adjustment for turn-on and turn-off levels within that range.
 3. Time Delay: Thirty-second minimum, to prevent false operation.
 4. Lightning Arrester: Air-gap type.
 5. Mounting: Twist lock complying with NEMA C136.10, with base.

2.3 PHOTOELECTRIC CONTROL

- A. Description: Completely self-contained, adjustable type, in NEMA 1 enclosure with adjustable 0 to 15 minute minimum time delay to provide a dead band zone for temporary changes in daylighting.
- B. Automatic Operation:
1. Daylight Only Lighting Level 50 Footcandles or More: No fixtures on.
 2. Daylight Only Lighting Level less than 50 Footcandles: Photocell No. 1 (PC 1) activates SW 1 lamps in Daylighting fixtures.
 3. Daylight Only Lighting Level Less than 25 Footcandles: Photocell No. 2 (PC 2) activates SW 2 lamps in Daylighting fixtures with SW 1 lamps previously activated. All fixture lamps activated.
- C. Footcandle Lighting Level Readings: Measured at the "Workplane" at 3 feet above finish floor.

2.4 DAYLIGHT-HARVESTING SWITCHING CONTROLS

Daylight-harvesting switching controls are suitable for standalone, general indoor daylight-harvesting applications. Photoelectric switching controls in this article are for turning lighting on and off, depending on the amount of daylight reaching the coverage area. Daylight-harvesting switching controls are for interior space lighting. Switching range should correspond to typical interior lighting levels for the space in which lighting is mounted. The power pack in this article contains circuit-switching relay(s) and powers the sensor.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Cooper Industries, Inc.](#)
 2. [Eaton Corporation.](#)
 3. [Hubbell Building Automation, Inc.](#)
 4. [Leviton Manufacturing Co., Inc.](#)
 5. [Lithonia Lighting; Acuity Brands Lighting, Inc.](#)
 6. [NSi Industries LLC; TORK Products.](#)
 7. [Sensor Switch, Inc.](#)
 8. [Tyco Electronics; ALR Brand.](#)
 9. [Watt Stopper.](#)
 10. **<Insert manufacturer's name>.**
 11. or approved equal.
- B. Ceiling-Mounted Switching Controls: Solid-state, light-level sensor unit, with separate power pack[**mounted on luminaire**], to detect changes in indoor lighting levels that are perceived by the eye.
- C. Electrical Components, Devices, and Accessories:
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Operating Ambient Conditions: Dry interior conditions, 32 to 120 deg F (0 to 49 deg C).
 3. Sensor Output: Contacts rated to operate the associated power pack, complying with UL 773A. Sensor is powered by the power pack.

Retain "Power Pack" Subparagraph below if unit is suitable for controlling a single lighting circuit, provided the circuit load does not exceed the listed aggregate load. Multi-circuit power packs are also available.

4. Power Pack: Dry contacts rated for [20] **<Insert value>**-A ballast load at 120- and 277-V ac, for [13] **<Insert value>**-A tungsten at 120-V ac, and for [1] **<Insert value>** hp at 120-V ac. Sensor has 24-V dc, 150-mA, Class 2 power source, as defined by NFPA 70.
5. General Space Sensors Light-Level Monitoring Range: 10 to 200 fc (108 to 2152 lux), with an adjustment for turn-on and turn-off levels within that range.
6. Atrium Space Sensors Light-Level Monitoring Range: 100 to 1000 fc (1080 to 10800 lux), with an adjustment for turn-on and turn-off levels within that range.

7. Skylight Sensors Light-Level Monitoring Range: 1000 to 10,000 fc (10 800 to 108 000 lux), with an adjustment for turn-on and turn-off levels within that range.
8. Time Delay: Adjustable from 5 to 300 seconds to prevent cycling.
9. Set-Point Adjustment: Equip with deadband adjustment of 25, 50, and 75 percent above the "on" set point, or provide with separate adjustable "on" and "off" set points.
10. Test Mode: User selectable, overriding programmed time delay to allow settings check.
11. Control Load Status: User selectable to confirm that load wiring is correct.
12. Indicator: Two digital displays to indicate the beginning of on-off cycles.

2.5 DAYLIGHT-HARVESTING DIMMING CONTROLS

Daylight-harvesting dimming controls are suitable for standalone, general indoor daylight-harvesting applications. Photoelectric switching controls in this article are for dimming electrical lighting as the amount of daylight reaching the coverage area increases. Daylight-harvesting dimming controls are for lighting in a single interior space. Switching range corresponds to typical interior lighting levels for the space in which lighting is mounted. Controller unit is suitable for several standard 0- to 10-V dc electronic dimming ballasts. The limit for the basis-of-design product is 50 ballasts. The power pack in this article contains circuit-switching relay(s) and powers the sensor.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Cooper Industries, Inc.](#)
 2. [Hubbell Building Automation, Inc.](#)
 3. [Leviton Mfg. Company Inc.](#)
 4. [Lithonia Lighting; Acuity Lighting Group, Inc.](#)
 5. [Watt Stopper.](#)
 6. **<Insert manufacturer's name>.**
 7. or approved equal.
- B. System Description: Sensing daylight and electrical lighting levels, the system adjusts the indoor electrical lighting levels. As daylight increases, the lights are dimmed.
 1. Lighting control set point is based on two lighting conditions:
 - a. When no daylight is present (target level).
 - b. When significant daylight is present.
 2. System programming is done with two hand-held, remote-control tools.
 - a. Initial setup tool.
 - b. Tool for occupants to adjust the target levels by increasing the set point up to 25 percent, or by minimizing the electric lighting level.

- C. Ceiling-Mounted Dimming Controls: Solid-state, light-level sensor unit, with separate controller unit, to detect changes in lighting levels that are perceived by the eye.
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Sensor Output: 0- to 10-V dc to operate electronic dimming ballasts. Sensor is powered by controller unit.
 3. Power Pack: Sensor has 24-V dc, Class 2 power source, as defined by NFPA 70.
 4. Light-Level Sensor Set-Point Adjustment Range: 20 to 60 fc (120 to 640 lux).

2.6 INDOOR OCCUPANCY SENSORS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Bryant Electric](#).
 2. [Cooper Industries, Inc.](#)
 3. [Hubbell Building Automation, Inc.](#)
 4. [Leviton Manufacturing Co., Inc.](#)
 5. [Lightolier Controls](#).
 6. [Lithonia Lighting; Acuity Brands Lighting, Inc.](#)
 7. [Lutron Electronics Co., Inc.](#)
 8. [NSi Industries LLC; TORK Products](#).
 9. [RAB Lighting](#).
 10. [Sensor Switch, Inc.](#)
 11. [Square D](#).
 12. [Watt Stopper](#).
 13. <Insert manufacturer's name>.
 14. or approved equal.
- B. General Requirements for Sensors: Wall- or ceiling-mounted, solid-state indoor occupancy sensors with a separate power pack.

Retain subparagraphs below to specify various types of units required for Project.

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Operation: Unless otherwise indicated, turn lights on when coverage area is occupied, and turn them off when unoccupied; with a time delay for turning lights off, adjustable over a minimum range of 1 to 15 minutes.
3. Sensor Output: Contacts rated to operate the connected relay, complying with UL 773A. Sensor is powered from the power pack.
4. Power Pack: Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Sensor has 24-V dc, 150-mA, Class 2 power source, as defined by NFPA 70.
5. Mounting:

- a. Sensor: Suitable for mounting in any position on a standard outlet box.
 - b. Relay: Externally mounted through a 1/2-inch (13-mm) knockout in a standard electrical enclosure.
 - c. Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
6. Indicator: Digital display, to show when motion is detected during testing and normal operation of sensor.
 7. Bypass Switch: Override the "on" function in case of sensor failure.
 8. Automatic Light-Level Sensor: Adjustable from 2 to 200 fc (21.5 to 2152 lux); turn lights off when selected lighting level is present.

Retain one or more of "PIR Type," "Ultrasonic Type," and "Dual-Technology Type" paragraphs below. Revise coverage area of detectors and add detectors with different coverage patterns and features to suit Project.

- C. PIR Type: Ceiling mounted; detect occupants in coverage area by their heat and movement.
 1. Detector Sensitivity: Detect occurrences of 6-inch- (150-mm-) minimum movement of any portion of a human body that presents a target of not less than 36 sq. in. (232 sq. cm).
 2. Detection Coverage (Room): Detect occupancy anywhere in a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 3. Detection Coverage (Corridor): Detect occupancy within 90 feet (27.4 m) when mounted on a 10-foot- (3-m-) high ceiling.
- D. Ultrasonic Type: Ceiling mounted; detect occupants in coverage area through pattern changes of reflected ultrasonic energy.
 1. Detector Sensitivity: Detect a person of average size and weight moving not less than 12 inches (305 mm) in either a horizontal or a vertical manner at an approximate speed of 12 inches/s (305 mm/s).

Areas listed in detection coverage subparagraphs below are typical.

2. Detection Coverage (Small Room): Detect occupancy anywhere within a circular area of 600 sq. ft. (56 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 4. Detection Coverage (Large Room): Detect occupancy anywhere within a circular area of 2000 sq. ft. (186 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
 5. Detection Coverage (Corridor): Detect occupancy anywhere within 90 feet (27.4 m) when mounted on a 10-foot- (3-m-) high ceiling in a corridor not wider than 14 feet (4.3 m).
- E. Dual-Technology Type: Ceiling mounted; detect occupants in coverage area using PIR and ultrasonic detection methods. The particular technology or combination of technologies that control on-off functions is selectable in the field by operating controls on unit.

1. Sensitivity Adjustment: Separate for each sensing technology.
2. Detector Sensitivity: Detect occurrences of **6-inch-** (150-mm-) minimum movement of any portion of a human body that presents a target of not less than **36 sq. in.** (232 sq. cm), and detect a person of average size and weight moving not less than **12 inches** (305 mm) in either a horizontal or a vertical manner at an approximate speed of **12 inches/s** (305 mm/s).
3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of **1000 sq. ft.** (93 sq. m) when mounted on a **96-inch-** (2440-mm-) high ceiling.

2.7 SWITCHBOX-MOUNTED OCCUPANCY SENSORS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Bryant Electric.](#)
 2. [Cooper Industries, Inc.](#)
 3. [Hubbell Building Automation, Inc.](#)
 4. [Leviton Manufacturing Co., Inc.](#)
 5. [Lightolier Controls.](#)
 6. [Lithonia Lighting; Acuity Brands Lighting, Inc.](#)
 7. [Lutron Electronics Co., Inc.](#)
 8. [NSi Industries LLC; TORK Products.](#)
 9. [RAB Lighting.](#)
 10. [Sensor Switch, Inc.](#)
 11. [Square D.](#)
 12. [Watt Stopper.](#)
 13. **<Insert manufacturer's name>.**
 14. or approved equal.

Each manufacturer's switch rating is different; however, rated design values are generally not less than those stated in "General Requirements for Sensors" Paragraph below.

- B. General Requirements for Sensors: Automatic-wall-switch occupancy sensor, suitable for mounting in a single gang switchbox.
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Operating Ambient Conditions: Dry interior conditions, **32 to 120 deg F** (0 to 49 deg C).
 3. Switch Rating: Not less than 800-VA fluorescent at 120 V, 1200-VA fluorescent at 277 V, and 800-W incandescent.

"WS1" and "WS2" in "Wall-Switch Sensor Tag WS1" and "Wall-Switch Sensor Tag WS2" paragraphs below are a suggested marking system on Drawings when detectors with different sensor characteristics are required.

C. Wall-Switch Sensor Tag WS1:

1. Standard Range: 180-degree field of view, field adjustable from 180 to 40 degrees; with a minimum coverage area of [900 sq. ft. (84 sq. m)] [2100 sq. ft (196 sq. m)].
2. Sensing Technology: [PIR] [Dual technology - PIR and ultrasonic].
3. Switch Type: [SP.] [SP, dual circuit.] [SP, manual "on," automatic "off."] [SP, field selectable automatic "on," or manual "on" automatic "off."]
4. Voltage: [Match the circuit voltage] [120 V] [277 V] [Dual voltage, 120 and 277 V]; [passive-infrared] [dual-technology] type.
5. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc (108 to 1600 lux). The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.

Retain one of two "off" time-delay subparagraphs below.

6. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
7. Concealed "off" time-delay selector at 30 seconds, and 5, 10, and 20 minutes.
8. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and helps eliminate false "off" switching.

"Wall-Switch Sensor Tag WS2" Paragraph below is typical for square and near-square rectangular rooms.

D. Wall-Switch Sensor Tag WS2:

1. Standard Range: 210-degree field of view, with a minimum coverage area of 900 sq. ft. (84 sq. m).
2. Sensing Technology: PIR.
3. Switch Type: [SP.] [SP, dual circuit.] [SP, manual "on," automatic "off."] [SP, field selectable automatic "on," or manual "on" automatic "off."]
4. Voltage: [Match the circuit voltage] [120 V] [277 V] [Dual voltage, 120 and 277 V]; [passive-infrared] [dual-technology] type.
5. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc (108 to 1600 lux). The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.

Retain one of two "off" time-delay subparagraphs below.

6. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
7. Concealed "off" time-delay selector at 30 seconds, and 5, 10, and 20 minutes.
8. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and helps eliminate false "off" switching.

2.8 HIGH-BAY OCCUPANCY SENSORS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Hubbell Building Automation, Inc.](#)

2. <Insert manufacturer's name>.
3. or approved equal.

High-bay occupancy sensors are for lighting control of high-bay interior spaces illuminated with high-intensity-discharge lamped luminaires. Lamp and ballast combinations are available for metal halide and high-pressure sodium lamps with CVA and pulse-start ballasts.

B. General Description: Solid-state unit. The unit is designed to operate with the lamp and ballasts indicated.

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain subparagraphs below to specify various types of units required for Project.

2. Operation: Turn lights on when coverage area is occupied, and to half-power when unoccupied; with a time delay for turning lights to half-power that is adjustable over a minimum range of 1 to 16 minutes.
3. Continuous Lamp Monitoring: When lamps are dimmed continuously for 24 hours, automatically turn lamps on to full power for 15 minutes for every 24 hours of continuous dimming.

Certain lamp and ballast combinations have a 131 deg F (55 deg C) maximum ambient rating. If used, reduce the high value of the range to 131 deg F (55 deg C).

4. Operating Ambient Conditions: 32 to 149 deg F (0 to 65 deg C).
5. Mounting: Threaded pipe.
6. Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
7. Detector Technology: PIR.

MyzerPORT in subparagraph below is available from most fixture manufacturers.

8. Power and dimming control from the lighting fixture ballast that has been modified to include the dimming capacitor and MyzerPORT option.

Hubbell provides the following selection of lens coverage in mounting height to horizontal coverage distance ratios: 1.5 x 0.23 for mounting heights from 12 to 28 feet (3.7 to 8.5 m); 1.0 x 0.23 for mounting heights from 22 to 36 feet (6.7 to 11 m); 0.7 x 0.16 for mounting heights from 44 to 50 feet (13.4 to 15.2 m); and 0.80 x 0.60 for mounting heights from 12 to 36 feet (93.7 to 11 m).

- C. Detector Coverage: User selectable by interchangeable PIR lenses, suitable for mounting heights from 12 to 50 feet (3.7 to 15.2 m).
- D. Accessories: Obtain manufacturer's installation and maintenance kit with laser alignment tool for sensor positioning and power port connectors.

2.9 EXTREME-TEMPERATURE OCCUPANCY SENSORS

Extreme-temperature occupancy sensors are used to turn electrical lighting on or off when the coverage area is occupied or unoccupied. These sensors are for lighting control of open structures, cold storage, freezers, and similar applications.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
1. [Cooper Industries, Inc.](#)
 2. [Sensor Switch, Inc.](#)
 3. **<Insert manufacturer's name>**.
 4. or approved equal.
- B. **Description:** Ceiling-mounted, solid-state, extreme-temperature occupancy sensors with a separate power pack.
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended application in damp locations.

Retain subparagraphs below to specify various types of units required for Project.

2. **Operation:** Turn lights on when coverage area is occupied, and turn them off when unoccupied; with a time delay for turning lights off, adjustable over a minimum range of 1 to 30 minutes.
 3. **Operating Ambient Conditions:** From **minus 40 to plus 125 deg F** (minus 40 to plus 52 deg C).
 4. **Sensor Output:** Contacts rated to operate the connected relay, complying with UL 773A. Sensor is powered from the power pack.
 5. **Power Pack:** Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Sensor has 24-V dc, 150-mA, Class 2 power source, as defined by NFPA 70.
 6. **Mounting:**
 - a. **Sensor:** Suitable for mounting in any position on a standard outlet box.
 - b. **Relay:** Externally mounted through a **1/2-inch (13-mm)** knockout in a standard electrical enclosure.
 - c. **Time-Delay and Sensitivity Adjustments:** Recessed and concealed behind cover.
 7. **Bypass Switch:** Override the "on" function in case of sensor failure.
 8. **Automatic Light-Level Sensor:** Adjustable from **2 to 10 fc** (21.5 to 108 lux); keep lighting off when selected lighting level is present.
- C. **Detector Technology:** PIR. Ceiling mounted; detect occupants in coverage area by their heat and movement.
1. **Detector Sensitivity:** Detect occurrences of **6-inch- (150-mm-)** minimum movement of any portion of a human body that presents a target of not less than **36 sq. in. (232 sq. cm)**.
 2. **Detection Coverage (Room):** Detect occupancy anywhere in a circular area of **1500 sq. ft. (139 sq. m)** when mounted on a **96-inch- (2440-mm-)** high ceiling.
 3. **Detection Coverage (High Bay):** Detect occupancy within **25 feet (7.6 m)** when mounted on a **25-foot- (7.6-m-)** high ceiling.

2.10 OUTDOOR MOTION SENSORS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Bryant Electric.](#)
 2. [Cooper Industries, Inc.](#)
 3. [Hubbell Building Automation, Inc.](#)
 4. [Leviton Manufacturing Co., Inc.](#)
 5. [Lithonia Lighting; Acuity Brands Lighting, Inc.](#)
 6. [NSi Industries LLC; TORK Products.](#)
 7. [RAB Lighting.](#)
 8. [Sensor Switch, Inc.](#)
 9. [Watt Stopper.](#)
 10. **<Insert manufacturer's name>.**
 11. or approved equal.
- B. General Requirements for Sensors: Solid-state outdoor motion sensors.

Retain features in subparagraphs below applicable to motion sensors for Project.

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. **[PIR] [Dual-technology (PIR and infrared)]** type, weatherproof. Detect occurrences of **6-inch-** (150-mm-) minimum movement of any portion of a human body that presents a target of not less than **36 sq. in.** (232 sq. cm). Comply with UL 773A.
3. Switch Rating:
 - a. Lighting-Fixture-Mounted Sensor: **[1000-W incandescent, 500-VA fluorescent] <Insert rating>.**
 - b. Separately Mounted Sensor: Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Sensor has 24-V dc, 150-mA, Class 2 power source, as defined by NFPA 70.
4. Switch Type: **[SP.] [SP, dual circuit.] [SP, manual "on," automatic "off. "] [SP, field selectable automatic "on," or manual "on" automatic "off. "] [With bypass switch to override the "on" function in case of sensor failure.]**
5. Voltage: **[Match the circuit voltage] [120-V] [277-V] [Dual voltage, 120- and 277-V]** type.
6. Detector Coverage:
 - a. Standard Range: 210-degree field of view, with a minimum coverage area of **900 sq. ft.** (84 sq. m).
 - b. Long Range: 180-degree field of view and **110-foot** (34-m) detection range.
 - c. **<Insert coverage area>.**

7. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc (108 to 1600 lux). The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.

Retain one of two "off" time-delay subparagraphs below.

8. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
9. Concealed "off" time-delay selector at 30 seconds, and 5, 10, and 20 minutes.
10. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and help eliminate false "off" switching.
11. Operating Ambient Conditions: Suitable for operation in ambient temperatures ranging from minus 40 to plus 130 deg F (minus 40 to plus 54 deg C), rated as "raintight" according to UL 773A.

2.11 LIGHTING CONTACTORS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Allen-Bradley/Rockwell Automation.
 2. ASCO Power Technologies, LP.
 3. Eaton Corporation.
 4. General Electric Company; GE Consumer & Industrial - Electrical Distribution; Total Lighting Control.
 5. Square D.
 6. **<Insert manufacturer's name>.**
 7. or approved equal.
- B. Description: Electrically operated and [**mechanically**] [**electrically**] held, combination-type lighting contactors with [**fusible switch**] [**nonfused disconnect**], complying with NEMA ICS 2 and UL 508.

Revise subparagraphs below, if required, for specific ratings; or indicate on Drawings. Coordinate control voltage with lighting control system if used. See Evaluations for suggested options to be indicated on Drawings.

1. Current Rating for Switching: Listing or rating consistent with type of load served, including tungsten filament, inductive, and high-inrush ballast (ballast with 15 percent or less total harmonic distortion of normal load current).
2. Fault Current Withstand Rating: Equal to or exceeding the available fault current at the point of installation.
3. Enclosure: Comply with NEMA 250.
4. Provide with control and pilot devices as [**indicated on Drawings**] [**scheduled**], matching the NEMA type specified for the enclosure.

Retain "Interface with DDC System for HVAC" Paragraph below for interface with the DDC system for HVAC. Coordinate with Section 230923 "Direct Digital Control (DDC) System for HVAC."

- C. Interface with DDC System for HVAC: Provide hardware interface to enable the DDC system for HVAC to monitor and control lighting contactors.
1. Monitoring: On-off status, **<Insert monitoring point>**.
 2. Control: On-off operation, **<Insert control point>**.

2.12 EMERGENCY SHUNT RELAY

Retain this article for emergency lighting switched on and off by manual, photoelectric, or other automatic switching devices. An emergency shunt relay will bypass or shunt the manual switch or other control device and turn connected lights on during a power outage.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Lighting Control and Design](#).
 2. [Watt Stopper](#).
 3. **<Insert manufacturer's name>**.
 4. or approved equal.
- B. Description: Normally closed, electrically held relay, arranged for wiring in parallel with manual **[or automatic]** switching contacts; complying with UL 924.
1. Coil Rating: **[120] [277]** V.

2.13 CONDUCTORS AND CABLES

- A. Power Wiring to Supply Side of Remote-Control Power Sources: Not smaller than No. 12 AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Classes 2 and 3 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than **[No. 18] [No. 22] [No. 24]** AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Class 1 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than **[No. 14] [No. 16] [No. 18]** AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

PART 3 - EXECUTION

3.1 SENSOR INSTALLATION

- A. Coordinate layout and installation of ceiling-mounted devices with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, smoke detectors, fire-suppression systems, and partition assemblies.
- B. Install and aim sensors in locations to achieve not less than 90 percent coverage of areas indicated. Do not exceed coverage limits specified in manufacturer's written instructions.

3.2 CONTACTOR INSTALLATION

Retain this article when specifying electrically held units in Part 2.

- A. Mount electrically held lighting contactors with elastomeric isolator pads to eliminate structure-borne vibration, unless contactors are installed in an enclosure with factory-installed vibration isolators.

3.3 WIRING INSTALLATION

Coordinate this article with Drawings.

- A. Wiring Method: Comply with Section 260519 "Low-Voltage Electrical Power Conductors and Cables." Minimum conduit size is 1/2 inch (13 mm).
- B. Wiring within Enclosures: Comply with NECA 1. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.
- C. Size conductors according to lighting control device manufacturer's written instructions unless otherwise indicated.
- D. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.
- E. Tighten lighting control equipment assembly joints with torque wrench or similar tool recommended by bus assembly manufacturer. Tighten joints again after lighting systems have been energized for 30 days.
- F. Connect lighting control equipment assemblies and components to wiring system and to ground as indicated and instructed by manufacturer.
- G. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.

- H. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

3.4 IDENTIFICATION

- A. Identify components and power and control wiring according to Section 260553 "Identification for Electrical Systems."
 - 1. Identify controlled circuits in lighting contactors.
 - 2. Identify circuits or luminaires controlled by photoelectric and occupancy sensors at each sensor.
- B. Label time switches and contactors with a unique designation.

3.5 FIELD QUALITY CONTROL

Retain "Testing Agency," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to evaluate lighting control devices and perform tests and inspections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Operational Test: After installing time switches and sensors, and after electrical circuitry has been energized, start units to confirm proper unit operation.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 3. Manufacturer's representative shall visit site, verify installation, start up and test, and submit to DEN Project Manager, a letter stating equipment and installation meets intent of Contract Documents and manufacturer's warranties and guarantees are in effect

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Lighting control devices will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting sensors to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.
1. For occupancy and motion sensors, verify operation at outer limits of detector range. Set time delay to suit Owner's operations.
 2. For daylighting controls, adjust set points and deadband controls to suit Owner's operations.
 3. Align high-bay occupancy sensors using manufacturer's laser aiming tool.

3.7 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.8 PROTECTION

- A. Provide final protection to ensure that moisture does not enter lighting control equipment assembly.

3.9 DEMONSTRATION

This article covers optional services; retain if Project warrants. Coordinate with requirements in Section 017900 "Demonstration and Training." If Project includes programmable lighting controls, coordinate with system testing.

- A. Coordinate demonstration of products specified in this Section with demonstration requirements for low-voltage, programmable lighting control systems specified in Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls."
- B. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain lighting control devices.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260923

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SECTION 260926 - LIGHTING CONTROL PANELBOARDS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED-NC Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1-2004. ASHRAE/IESNA 90.1-2004, Section 9, "Lighting," sets minimum interior and exterior lighting power densities and minimum requirements for lighting controls.

Additional lighting controls can be used to meet the requirements of LEED-NC Credit IEQ 6.1 if individual lighting controls are provided for a minimum of 90 percent of the building occupants and lighting system controls are provided for all shared multi-occupant spaces to enable adjustment to meet group needs. Indicate locations of lighting controls on Drawings.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes: Lighting controls using electrically operated circuit breakers.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 260923 "Lighting Control Devices" for field-mounted photoelectric switches, occupancy sensors, and motion sensors.
2. Section 260933 "Central Dimming Controls" for daylight harvesting control components.

3. Section 260936.19 "Standalone Multipreset Modular Dimming Controls" for daylight harvesting control components.
4. Section 262416 "Panelboards".

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. DDC: Direct digital control.
- B. IP: Internet protocol.
- C. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- D. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
- E. PC: Personal computer; sometimes plural as "PCs."
- F. RS-485: A serial network protocol, similar to RS-232, complying with TIA-485-A.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for control modules, power distribution components, manual switches and plates, and conductors and cables.
 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each lighting control panelboard and related equipment.
 1. Include dimensioned plans, elevations, sections, and details. Show tabulations of installed devices, equipment features, and ratings.
 2. Detail enclosure types and details for types other than NEMA 250, Type 1.
 3. Detail bus configuration, current, and voltage ratings.

4. Short-circuit current rating of panelboards and overcurrent protective devices.
5. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.

Retain first subparagraph below if final system short-circuit and coordination studies is performed by designer or assigned to independent consultant. These curves are also beneficial to Owner for future additions or reevaluations of overcurrent protective device settings.

6. Include time-current coordination curves for each type and rating of overcurrent protective device included in panelboards. Submit on translucent log-log graph paper; include selectable ranges for each type of overcurrent protective device.
7. Include diagrams for power, signal, and control wiring.

Retain "Block Diagram" Subparagraph below when control is digital, PC based, or IP based.

8. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices to be used. Describe characteristics of network and other data communication lines.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below if lighting controls are connected to devices or systems specified in other Sections.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Submit evidence that lighting controls are compatible with connected monitoring and control devices and systems specified in other Sections.
 1. Show interconnecting signal and control wiring and interfacing devices that prove compatibility of inputs and outputs.
 2. For networked controls, list network protocols and provide statements from manufacturers that input and output devices comply with interoperability requirements of the network protocol.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- B. Qualification Data: For testing agency.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548.16 "Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Seismic Qualification Certificates: For panelboards, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- D. Field quality-control reports.

Retain first paragraph below for PC- and IP-based control systems.

- E. Software licenses and upgrades required by and installed for operation and programming of digital and analog devices.
- F. Sample Warranty: For manufacturer's special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For lighting controls to include in emergency, operation, and maintenance manuals.

Retain "Software and Firmware Operational Documentation" Paragraph below for PC- and IP-based control systems.

- B. Software and Firmware Operational Documentation:
 1. Software operating and upgrade manuals.
 2. Program Software Backup: On magnetic media or compact disk, complete with data files.
 3. Printout of software application and graphic screens.
 4. Device address list.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Electrically Operated, Molded-Case Circuit Breakers: Equal to **<Insert number>** percent of amount installed[**for each size indicated**], but no fewer than **<Insert number>**.

1.8 QUALITY ASSURANCE

Retain "Testing Agency Qualifications" Paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also defines "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Handle and prepare panelboards for installation according to [NECA 407] [NEMA PB 1.1].

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

- 1. Warranty Period: Minimum [five (5)] <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Products" Paragraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

A. Products: Subject to compliance with requirements, provide one of the following:

1. Acuity Brands, Inc., Lighting Control & Design, Inc.; SmartBreaker Panels.
2. Eaton Corporation; Cutler-Hammer Business Unit; Pow-R-Command Lighting Control Panelboards.
3. General Electric Company; GE Energy Management - Electrical Distribution; A-Series Lighting Control Panels.
4. Siemens Energy; i-3 Lighting Controls.
5. Square D; by Schneider Electric; PowerLink G3 Lighting Control Panelboards.
6. **<Insert manufacturer's name; product name or designation>**.
7. or approved equal.

B. Source Limitations: Obtain lighting controls and power distribution components from single manufacturer.

2.2 SYSTEM DESCRIPTION

A. Input signal from field-mounted or on-board signal source shall open or close one or more electrically operated circuit breakers in the lighting control panelboards. Any combination of inputs shall be programmable to any combination outputs.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with 47 CFR, Subpart A and Subpart B, for Class A digital devices.

2.3 PERFORMANCE REQUIREMENTS

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete below if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

A. Seismic Performance: Panelboards shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] **<Insert requirement>**.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [1.5] [1.0].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. **<Insert requirements for Component Amplification Factor and Component Response Modification Factor>.**

- B. Expansion Requirements: Capacity for future expansion of number of control functions by 25 percent of current capacity; to include equipment ratings, housing capacities, spare spaces for circuit breakers, terminals, number of conductors in control cables, and control software.

Retain "Interface with DDC System for HVAC" Paragraph below for interface with the DDC system for HVAC. Coordinate with Section 230923 "Direct Digital Control (DDC) System for HVAC."

- C. Interface with DDC System for HVAC: Provide hardware and software to enable the DDC system for HVAC to monitor, control, display, and record data for use in processing reports.

Retain "Hardwired Points" or "Communication Interface" Subparagraphs below. Retain first if interface with the DDC system for HVAC is through hardwired points and minimal interface is required. Retain second if extensive interface with the DDC system for HVAC is required and is beyond what hardwired points can provide. Requirement may exclude some manufacturers.

1. Hardwired Points:
 - a. Monitoring: On-off status, **<Insert monitoring point>.**
 - b. Control: On-off operation, **<Insert control point>.**
2. Communication Interface: Comply with **[ASHRAE 135] <Insert type of interface>**. The communication interface shall enable the DDC system for HVAC operator to remotely control and monitor lighting from a DDC system for HVAC operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through the DDC system for HVAC.

2.4 PANELBOARDS

- A. Refer to Section 262416 "Panelboards" for general requirements.
- B. The lighting panelboards may contain remotely operated circuit breakers and standard branch circuit breakers specified in Section 262416 "Panelboards."
- C. Assemblies: Comply with UL 67 and NEMA PB 1.

Retain one of two "Surge Protective Device" paragraphs below.

- D. Surge Protective Device: Field mounted, complying with Section 264313 "Surge Protection for Low-Voltage Electrical Power Circuits."
- E. Surge Protective Device: Integrally mounted, complying with UL 1449 Type 1.
 - 1. Comply with IEEE C62.41, Category C, 200-kA short-circuit current rating.
 - 2. Non-modular type with the following features and accessories:
 - a. Digital-display indicator lights for power and protection status.
 - b. **<Insert features and accessories>**.
- F. Enclosures: Comply with UL 50 and NEMA 250.

Retain "Future Devices" Paragraph below if future provisions are required.

- G. Future Devices: Mounting brackets, bus connections, filler plates, and necessary appurtenances required for future installation of devices.

Retain one or both "Panelboard Short-Circuit Current Rating" paragraphs below for series-rated system or system that has panelboards and circuit breakers rated for full value of short-circuit current available at location of equipment. Typical short-circuit current rating of electrically operated circuit breakers is 10 kA. If higher values and series ratings are required, verify availability with manufacturers.

- H. Panelboard Short-Circuit Current Rating: Rated for series-connected system with integral or remote upstream overcurrent protective devices and labeled by an NRTL. Include size and type of allowable upstream and branch devices, listed and labeled for series-connected, short-circuit rating by an NRTL.
- I. Panelboard Short-Circuit Current Rating: Fully rated to interrupt [**10-kA**] symmetrical short-circuit current available at terminals.
- J. Panelboards shall have a UL-listed interrupting rating[**of 10 kA**], sufficient for the application, or a UL-listed, series-connected rating for the maximum available fault current at that point in the system.

2.5 CIRCUIT BREAKERS

- A. Remotely operated branch circuit breakers used for lighting control shall provide branch-circuit overcurrent protection.

In "Labeled with SWD and HID Ratings" Paragraph below, SWD rating is only available for 15- and 20-A, single-pole circuit breakers. Retain option if specifying other breaker sizes.

See Editing Instruction No. 2 in the Evaluations for discussion on short-circuit current ratings for equipment complying with UL 489.

- B. Labeled with SWD and HID Ratings: Comply with UL 489 for 15- and 20-A, single-pole branch devices.[**15- and 20-A circuit breakers, if scheduled, shall be a product of the same manufacturer and be of the same class as the rated circuit breakers.**]

Retain "Switching Endurance Rating" Paragraph below if endurance in excess of UL 489 SWD test is required. Verify test method and available ratings with manufacturers.

- C. Switching Endurance Rating: Not less than [50,000] [200,000] <Insert number> full-load open/close/open remote operations.
- D. Remotely Operated Circuit Breakers: Manual override switch or handle position shall enable or disable the remote operation of the device and allow breaker handle to manually control the breaker's on-off status.

Retain "Main" option in article title below if retaining "Slave Panel Controllers" Article.

2.6 [MAIN]CONTROLLERS

- A. Description: Controllers shall contain the power supply and electronic control for operating and monitoring remotely operated branch circuit breakers.

See Editing Instruction No. 2 in the Evaluations for discussion on short-circuit current ratings for equipment complying with UL 916.

1. Comply with UL 916; with a microprocessor-based, solid-state, 365-day timing and control unit.
2. Power Supply: Powered from the panelboard, sized to provide control power for the operation of the remotely operated circuit breakers, controller, bus system, low-voltage inputs, field-installed occupancy sensors, and low-voltage photo sensors.
3. Integral keypad and digital-display front panel for local setup, including the following:
 - a. Blink notice, time adjustable from software.
 - b. Ability to log and display remotely operated breaker on-time.
 - c. Capability for accepting downloadable firmware so that the latest production features may be added in the future without replacing the module.
4. Nonvolatile memory shall retain all setup configurations. After a power failure, the controller shall automatically reboot and return to normal system operation.

Retain "Ethernet Communications" Paragraph below if networking lighting control panelboards. Coordinate with "Control Network" Article.

5. Ethernet Communications: Comply with [ASHRAE 135] <Insert network protocol> protocols.
 - a. Each input connected to the controller shall control any remotely operated breaker in any other networked lighting control panel.
 - b. A schedule programmed at one controller shall be able to control any remotely operated breaker in any other networked lighting control panel.

In "Time Synchronization" Subparagraph below, the typical value ranges from one hour to 24 hours.

6. Time Synchronization: The timing unit shall be updated not less than every **<Insert number>** hour(s) with the network time server.
 7. Web Server: Display information listed below over a standard Web-enabled server for displaying information over a standard Web browser.
 - a. A secure, password-protected login screen for modifying operational parameters, accessible to authorized users via Web page interface.
 - b. Separate Web page, showing status of each main and slave lighting control panel with the arrangement of breakers on the page matching the physical appearance of the panel. Status shall include breaker nametags, pole configuration, location in panel, actual contact state (on-off/tripped/manual), and breaker on-time and blink information in real time.
 - c. Panel summary showing the master and slave panels connected to the controller.
 - d. Controller diagnostic information.
 - e. Show front panel mimic screens for setting up controller parameters, input types, zones, and operating schedules. These mimic screens shall also allow direct breaker control and zone overrides.
 8. Alarm and E-mail Notification: Automatically initiate alarms based on preconfigured conditions listed below and routing alarm alerts as set at the control panel.
 - a. General Alarms: Power loss, non-responding breakers, loss and restoration of sub-net communications, loss and restoration of serial port communications, loss and restoration of DDC system for HVAC commands.
 - b. Specific Alarms: Input status, zone status, breaker status on-time (0 to 99999 hours).
 - c. E-mail Notification: Automatically route e-mail messages to five individual e-mail addresses. Within the body text of the e-mail, include a link that automatically redirects the user to the associated panels' status Web page.
- B. Timing Unit:
1. **[365-day calendar]** **[seven day calendar]**, astronomical clock, and automatic adjustments for daylight savings and leap year.
 2. Clock configurable for 12-hour (A.M./P.M.) or 24-hour format.
 3. **[16]** **<Insert number>** independent schedules, each having **[24]** **<Insert number>** time periods.
 4. Schedule periods settable to the minute.
 5. Day-of-week, day-of-month, day-of-year with one-time or repeating capability.
 6. **[32]** **<Insert number>** special date periods.
- C. With **[8]** **[16]** **<Insert number>** inputs, each configurable to the following parameters:
1. Normally open, normally closed, two-wire maintained toggle, two-wire momentary toggle, two-wire momentary on, two-wire momentary off, or three-wire momentary operation.

2. On and off-delay timers for local override operation, adjustable from five minutes to 12 hours. Local override shall be by field-installed, two-wire momentary toggle switch.

2.7 SLAVE PANEL CONTROLLERS

Retain this article if more than one lighting control panelboard is under unified control of the main controller.

- A. Slave panels shall contain the necessary busses and network hardware to allow connection of the sub-net wiring between panels, with programming at the main panel controller. Programmable timing unit, Web server, alarm and e-mail notification, and Ethernet connection to the control network is not required provided all of these functions are available for the slave panel from the main lighting panel controller.
- B. Sub-net wiring connections shall allow connection of wiring to a terminal that can be removed from the panel without interrupting communications to other panels.
- C. Slave panels shall contain a nameplate label attached to the deadfront trim indicating the panel designation, panel network address, and panel designation of the associated master panel.

2.8 CONTROL NETWORK

Retain first option in "Panel Controllers" Paragraph below if networking more than one main controller. Retain second option if the network connects controllers associated with relay-based lighting control system controllers or addressable fixture lighting control system controllers.

- A. Panel Controllers: Networked with other [**lighting control panel controllers**] [**lighting control system controllers**] in a peer-to-peer configuration using Ethernet [**10Base-T**] [**100Base-T**] network.

Retain "Compliance with ASHRAE 135" Paragraph below for DDC system for HVAC control network. Revise as required for other network protocols.

See "Communication Networks for Lighting Controls" Article in the Evaluations for discussion of communication network options.

- B. Compliance with ASHRAE 135: Controllers shall support serial MS/TP and Ethernet IP communications, and shall be able to communicate directly via DDC system for HVAC RS-485 serial networks and Ethernet 10Base-T networks as a native device.

2.9 MANUAL SWITCHES AND PLATES

Coordinate use of manual switches in this article with override functions, with switch and wall-plate finish specified in Section 262726 "Wiring Devices," and with dimmer control wall-plate finish specified in Section 260933 "Central Dimming Controls" or Section 260936.19 "Standalone Multipreset Modular Dimming Controls."

- A. Keypads: Programmable, designed to control lighting applications and functions associated with the equipment of this Section. The units shall be able to control any system output device, including remotely operated circuit breakers, relays, dimmers, and analog outputs.
- B. Push-Button Switches: Modular, momentary-contact, low-voltage type.
 - 1. Match color specified in Section 262726 "Wiring Devices."

Two subparagraphs below are optional features.

- 2. Integral green **[LED]** pilot light to indicate when circuit is on.
 - 3. Internal white **[LED]** locator light to illuminate when circuit is off.
- C. Manual, Maintained Contact, Full- or Low-Voltage Switch: Comply with Section 262726 "Wiring Devices."
- D. Wall Plates: Single and multigang plates as specified in Section 262726 "Wiring Devices."
- E. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

2.10 CONDUCTORS AND CABLES

- A. Power Wiring to Supply Side of Class 2 Power Source: Not smaller than No. 12 AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Class 2 and Class 3 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 18] [No. 22] [No. 24]** AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Class 1 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 14] [No. 16] [No. 18]** AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Digital and Multiplexed Signal Cables: Unshielded, twisted-pair cable with copper conductors, complying with TIA/EIA-568-B.2, **[Category 5e] [Category 6]** for horizontal copper cable. Comply with requirements in Section 271500 "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.1 EXAMINATION

NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- A. Receive, inspect, handle, and store panelboards according to **[NECA 407] [NEMA PB 1.1]**.
- B. Examine panelboards before installation. Reject panelboards that are damaged or rusted or have been subjected to water saturation.
- C. Examine elements and surfaces to receive panelboards for compliance with installation tolerances and other conditions affecting performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 WIRING INSTALLATION

- A. Comply with NECA 1.

Retain one of two "Wiring Method" paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings.

- B. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters. Conceal raceway and cables except in unfinished spaces.
 - 1. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
 - 2. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- C. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- D. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

3.3 PANELBOARD INSTALLATION

- A. Comply with NECA 1.

NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- B. Install panelboards and accessories according to **[NECA 407] [NEMA PB 1.1]**.

Retain first paragraph below if seismic controls are required for Project. Coordinate with Drawings.

- C. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

In "Mounting Height" Paragraph below, verify that operating handle of top-most switch or circuit breaker,

in on position, is not higher than 79 inches (2000 mm) above finished floor or grade.

- D. Mounting Height: [90 inches (2286 mm)] <Insert dimension> to top of trim above finished floor unless otherwise indicated.
- E. Mount panelboard cabinet plumb and rigid without distortion of box. Mount recessed panelboards with fronts uniformly flush with wall finish and mating with back box.
- F. Install filler plates in unused spaces.

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with Section 260553 "Identification for Electrical Systems."
- C. Create a directory to indicate loads served by each circuit; incorporate Owner's final room designations. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are unacceptable.
- D. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

Retain "Testing Agency" and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate testing requirements with Section 262416 "Panelboards."

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
 - 3. Perform the following infrared scan tests and inspections and prepare reports:

- a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each panelboard. Remove front panels so joints and connections are accessible to portable scanner.
- b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each panelboard 11 months after date of Substantial Completion.
- c. Instruments and Equipment:
 - 1) Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

C. Acceptance Testing Preparation:

1. Test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. Panelboard will be considered defective if it does not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- E. Prepare test and inspection reports, including a certified report that identifies panelboards included and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Confirm correct communication wiring, initiate communications between panels, and program the lighting control system according to approved zone configuration schedules, time-of-day schedules, and input override assignments.
 3. **<Insert startup steps if any>**.

3.7 ADJUSTING

- A. Occupancy Adjustments: When requested within [**twelve (12)**] **<Insert number>** months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.8 SOFTWARE SERVICE AGREEMENT

Services in this article may not be allowed for publicly funded projects.

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for **[two] <Insert number>** years.
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within **[two (2)] <Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: At least **[thirty (30)] <Insert number>** days to allow Owner to schedule and access the system and to upgrade computer equipment if necessary.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain control modules.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260926

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SECTION 260933 - CENTRAL DIMMING CONTROLS

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes microprocessor-based central dimming controls with the following components:
 - 1. Control network.
 - 2. Master-control stations.
 - 3. Partitioned-space master-control stations.
 - 4. Wall stations.
 - 5. Dimmer cabinets.
 - 6. Manual switches and plates for controlling dimmers.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviation and terms that remain after this Section has been edited.

- A. Fade Override: The ability to temporarily set fade times to zero for all lighting scenes.
- B. Fade Rate: The time it takes each zone to arrive at the next scene, dependent on the degree of change in lighting level.

- C. Fade Time: The time it takes all zones to fade from one lighting scene to another, with all zones arriving at the next scene at the same time.
- D. Low Voltage: As defined in NFPA 70, term for circuits and equipment operating at less than 50 V or for remote-control, signaling, and power-limited circuits.
- E. Scene: The lighting effect created by adjusting several zones of lighting to the desired intensity.
- F. SCR: Silicon-controlled rectifier.
- G. Zone: A fixture or group of fixtures controlled simultaneously as a single entity. Also known as a "channel."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. For central dimming controls; include elevation, features, characteristics, and labels.
 - 2. For dimmer panels; include dimensions, features, dimmer characteristics, ratings, and directories.
 - 3. Device plates, plate color, and material.
 - 4. Ballasts and lamp combinations compatible with dimmer controls.
 - 5. Sound data including results of operational tests of central dimming controls.
 - 6. Operational documentation for software and firmware.
 - 7. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail assemblies of standard components, custom assembled for specific application on Project. Indicate dimensions, weights, arrangement of components, and clearance and access requirements.
 - 1. Include elevation views of front panels of control and indicating devices and control stations.
 - 2. Wiring Diagrams: Power, signal, and control wiring.

Retain paragraph below if products have critical features needing hands-on appraisal.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager.

Coordinate sample requirements with DEN Project Manager.

- C. Samples for Initial Selection: For master-control stations, partitioned-space master-control stations, wall stations, dimmer cabinets, and faceplates with factory-applied color finishes and technical features.

Delete paragraph above if colors and other characteristics are preselected or scheduled. Retain first paragraph below with or without above.

- D. Samples for Verification: For master-control stations, partitioned-space master-control stations, wall stations, dimmer cabinets, and faceplates with factory-applied color finishes and technical features.

1.5 INFORMATIONAL SUBMITTALS

- A. Warranty: Special warranty specified in this Section.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For central dimming controls with remote-mounting dimmers to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 1. Software manuals.
 2. Adjustments of scene preset controls, adjustable fade rates, and fade overrides.
 3. Operation of adjustable zone controls.
 4. Testing and adjusting of panic and emergency power features.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MATERIALS MAINTENANCE SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

- A. Furnish extra materials described below, before installation begins, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Dimmers: Full-size units equal to <Insert number> percent of amount installed for each size indicated, but no fewer than <Insert number> units.
 2. Fuses: Equal to <Insert number> percent of amount installed for each size installed, but no fewer than [three (3)] <Insert number>.

1.8 QUALITY ASSURANCE

Retain first paragraph below if devices specified in this Section are to function with low-voltage lighting controls.

- A. Source Limitations: Obtain central dimming controls from a single source with total responsibility for compatibility of lighting control system components specified in this Section and in Section 260923 "Lighting Control Devices."
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Comply with 47 CFR 15, Subparts A and B, for Class A digital devices.
- D. Comply with NFPA 70.
- E. Those firms responding to this specification shall provide proof that they have been regularly engaged in the design, manufacturing and testing of lighting control equipment for not less than five (5) years.

1.9 COORDINATION

Retain this Article if devices specified in this Section are to be interconnected with systems specified in other Sections. Revise to reference relevant Sections.

- A. Coordinate features of devices specified in this Section with systems and components specified in other Sections to form an integrated system of compatible components. Match components and interconnections for optimum performance of specified functions. Include coordination with the following:
 - 1. Section 260923 "Lighting Control Devices."

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this Article are not less than remedies available to Owner under prevailing local laws. Coordinate with Division 01 Section "Product Requirements."

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of central dimming controls that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Damage from transient voltage surges.
 - b. <Insert type of failure>.

Verify available warranties for units and components and insert numbers in subparagraphs below.

2. Warranty Period: Cost to repair or replace any parts for **[two (2)] <Insert number>** years from date of Substantial Completion.
3. Extended Warranty Period: Cost of replacement parts (materials only, f.o.b. the nearest shipping point to Project site), for **[eight (8)] <Insert number>** years, that failed in service due to transient voltage surges.

1.11 SOFTWARE SERVICE AGREEMENT

Services in this Article may not be allowed for publicly funded projects.

- A. Technical Support: Beginning with Substantial Completion, provide software support for **[two (2)] <Insert number>** years.
- B. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within **[two (2)] <Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
 1. Provide **[30] <Insert number>** days' notice to Owner to allow scheduling and access to system and to allow Owner to upgrade computer equipment if necessary.

1.12 ENVIRONMENTAL CONDITIONS

- A. The lighting control equipment unit shall be capable of continuous operation under the following temperature conditions:
 1. Relative humidity: 95% non-condensing.
 2. Altitude: 5500 feet (1667 meters) without any de-rating.
 3. Functioning: -30°F (-34°C) (Outdoor) to 120°F (49°C) (Indoor & Outdoor).
 4. The neutral shall not be combined for lighting circuits with electronic or dimming ballasts, and should be bonded according to local codes and National Electrical Code (NEC).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers in this Article. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Douglas Lighting Controls.
 2. Electrol Engineering.
 3. Electronic Theatre Controls.
 4. Leviton Mfg. Company Inc.
 5. Leviton NSI Division.
 6. Lightolier; a Genlyte Group.
 7. Lithonia Lighting; Acuity Lighting Group, Inc.
 8. Lutron Electronics, Inc.
 9. Strand Lighting, Inc.
 10. **<Insert manufacturer's name>**.
 11. or approved equal.

For remaining articles in Part 2, see Editing Instruction No. 2 in the Evaluations for discussion of compatibility.

2.2 GENERAL SYSTEM REQUIREMENTS

- A. Compatibility:
1. Dimming control components shall be compatible with other elements of lighting fixtures, ballasts, transformers, and lighting controls.

Retain subparagraph below if devices specified in this Section are required to function with low-voltage lighting controls.

2. Dimming control devices shall be compatible with lighting control system components specified in Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls," and in Section 260923 "Lighting Control Devices."

Factory-installed surge protection is not available from all manufacturers. See Evaluations for more information about surge protection.

- B. Line-Voltage Surge Suppression: Factory installed as an integral part of 120- and 277-V ac, solid-state dimmers and control panels.

Retain subparagraph below to allow Contractor the option of providing field-mounted surge protection.

1. Alternative Line-Voltage Surge Suppression: Comply with requirements in Section 264313 "Surge Protection for Low-Voltage Electrical Power Circuits" for

Category [A] [B] locations.

- C. Dimmers and Dimmer Modules: Comply with UL 508.
1. Audible Noise and Radio-Frequency Interference Suppression: Solid-state dimmers shall operate smoothly over their operating ranges without audible lamp or dimmer noise or radio-frequency interference. Modules shall include integral or external filters to suppress audible noise and radio-frequency interference.

Indicate ratings for dimmers and dimmer modules on Drawings.

2. Dimmer or Dimmer-Module Rating: Not less than 125 percent of connected load unless otherwise indicated.

2.3 SYSTEM DESCRIPTION

- A. Description: Microprocessor-based, solid-state controls consisting of control stations and a separately mounted dimmer cabinet.
1. Operation: Change variable dimmer settings of indicated number of zones simultaneously from one preset scene to another when a [rocker switch] [pushbutton] [slider] is operated.
 2. System control shall include master station(s), wall stations, and dimmer panels.

Retain first subparagraph and appropriate associated subparagraphs below if dimming is other than 120-V ac incandescent lighting. Dimmers for fluorescent lamps with magnetic ballasts may not be available from all manufacturers. Add special lighting equipment after verifying that dimmers are available for this equipment.

3. Each zone shall be configurable to control the following light sources:
 - a. Fluorescent lamps with electronic ballasts.
 - b. Line-voltage incandescent lamps.
 - c. Low-voltage incandescent lamps.
 - d. Cold cathode lamps.
 - e. Non-dimmed loads.
 - f. LED lamps.
 - g. <Insert special lighting equipment>.
4. Control of each zone shall interface with controls for the following accessory functions:

Retain three subparagraphs below for lecture rooms. Indicate location of wall station convenient to speaker's podium on Drawings or include a wall station operated by hand-held remote control.

- a. Curtains and drapes.
- b. Blackout curtains.
- c. Projector screens.

Retain first two subparagraphs below for partitioned-space wall stations.

- d. Motorized partitions.
- e. Manually positioned partitions.

5. Memory: Retain preset scenes and fade settings through power failures for at least **[90] <Insert duration>** days by retaining physical settings of controls or by an on-board, automatically recharged battery.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with 47 CFR 15, Subparts A and B, for Class A digital devices.
- D. Comply with NFPA 70.

2.4 CONTROL NETWORK

- A. Dimmers shall receive signals from control stations that are linked to dimmer cabinet with a common network data cable.
- B. Functions of network control stations shall be set up at master station that include the number and arrangement of scene presets, zones, and fade times at wall stations.

Retain one of two subparagraphs below. See Editing Instruction No. 4 in the Evaluations for discussion of control protocols.

1. Control Voltage: 24- or 10-V dc.

First option in subparagraph below is for analog multiplex; second option is for digital.

2. Comply with USITT AMX 192 USITT DMX 512 for data transmission.

2.5 MASTER-CONTROL STATIONS

- A. Functions and Features:
 1. Control adjustment of the lighting level for each scene of each zone, and adjustment of fade-time setting for each scene change from one preset scene to another. Controls shall use **[analog manual sliders] [digital rocker switches with LCD graphic display of light level] <Insert control option>**.
 2. Master channel shall raise and lower lighting level of all zones.
 3. Fade rate for each scene shall be adjustable from zero to **[60] <Insert number>** seconds.
 4. Fade override control for each scene.
 5. Recall each preset scene and allow adjustment of zone controls associated with that scene.
 6. Lockout switch to prevent changes when set.
 7. On and off scene controls for non-dim channel contactors.
 8. Emergency-control pushbutton to bypass all controls, turning all dimmers to full bright and turning on non-dim channel contactors.
 9. Master on and off switch; off position enables housekeeping controls.
 10. Housekeeping controls to turn on selected lighting fixtures for housekeeping functions.

Retain first subparagraph below only when needed at master station. Otherwise, locate control of accessory functions at wall stations.

11. Pushbuttons for accessory functions.
12. Enable and disable wall stations.
13. Communications link to other master stations.

Retain first subparagraph below if retaining "Portable Computer" Article.

14. Provide for connecting a portable computer to program the master station.
 15. Rear-illuminate all scene-select buttons.
 16. Show lighting-level setting and fade-rate setting graphically using LEDs or backlighted bar-graph indicator.
- B. Custom Graphics. Include a graphical display of room configurations and the names for each. Indicate the current spaces configuration with LCD graphic or LED-illuminated indicators, and show which wall stations are active. Inactive wall stations shall be automatically deactivated.
- C. Mounting: Single, flush wall box with manufacturer's standard faceplate[**with hinged transparent locking cover**].

2.6 PARTITIONED-SPACE MASTER-CONTROL STATION

Specialized control station in this Article is specified as a standalone master station with wall stations located in each partitioned space. This Article may be revised to make this station a specialized wall station.

- A. Functions and Features:
1. Automatically combine and separate lighting and accessory function controls as spaces are configured with movable partitions; with controls for adjustment of the lighting level for each scene of each dimmer, and adjustment of fade-rate setting for each scene change from one preset scene to another.

Typical manufacturer's package is for dividing the space covered by master station into partitioned spaces, ranging in number from one to six, allowing to preset up to six scenes for each space so configured.

2. Master controls shall accommodate partitioning the space into [**six (6)**] <Insert number> adjacent rooms.
3. Manual controls to set up [**six (6)**] <Insert number> scenes for each room. Include wall stations in each room to control scenes.
4. Master channel to raise and lower the lighting level of all zones.
5. Adjustable fade rate for each scene from zero to [**60**] <Insert number> seconds.
6. Fade override control for each scene.
7. On and off scene controls for non-dim channel contactors.
8. Emergency-control pushbutton to bypass all controls, turning all dimmers to full bright and turning on non-dim channel contactors.
9. Master on and off switch; off position enables housekeeping controls.
10. Housekeeping controls to turn on selected lighting fixtures for housekeeping functions.

Retain subparagraph below only when needed at master station. Otherwise, locate control of accessory functions at wall stations.

11. Pushbuttons for accessory functions.

Retain first subparagraph below if retaining "Portable Computer" Article.

12. Provide for connecting a portable computer to program the master station.
13. Rear-illuminate all scene-select buttons.
14. Show lighting-level setting and fade-rate setting graphically using LEDs or backlighted bar-graph indicator.

- B. Custom Graphics. Include a graphical display of room configurations and the names for each. Indicate the current spaces configuration with LCD graphic or LED-illuminated indicators, and show which wall stations are active. Inactive wall stations shall be automatically deactivated.

- C. Mounting: Single, flush wall box with manufacturer's standard faceplate[**with hinged transparent locking cover**].

2.7 WALL STATIONS

- A. Functions and Features:

1. Wall stations shall function as a submaster to a master station, containing limited control of selected scenes of the master station.

Retain five subparagraphs below if wall stations are all alike. Otherwise, delete subparagraphs and indicate this information on Drawings. Pushbutton numbering scheme should be set up at associated master station.

2. Controls **<Insert scene description>** to adjust the lighting level of each dimmer for each scene, and the fade time setting for each scene change from one preset scene to another.
3. Numbered pushbuttons to select scenes.
4. Off switch to turn master station off.[**Operating the off switch at any remote station shall automatically turn on selected housekeeping lighting.**]
5. On switch turns all scenes of master station to full bright.

Retain subparagraph below for accessory functions not included in scene controls.

6. Pushbutton controls for accessory functions.

- B. Mounting: Flush, wall box with manufacturer's [**standard faceplate**] **<Insert special material and color for faceplate>**.

- C. Hand-held Cordless Control: Scene-select and accessory function pushbuttons using [**infrared**] [**or radio-frequency**] transmission.

2.8 DIMMER CABINETS

- A. Factory wired[, **convection cooled without fans**] [, **with barriers to accommodate 120- and 277-V feeders**] and suitable to control designated lighting equipment or

accessory functions.

B. Ambient Conditions:

Revise temperature and relative humidity in first two subparagraphs below to design conditions of air-conditioning system. Coordinate with HVAC engineer.

1. Temperature: [60 to 95 deg F (15 to 35 deg C)] <Insert temperature range>.
2. Relative Humidity: [10 to 90] <Insert values> percent, noncondensing.
3. Filtered air supply.

C. Dimmer Cabinet Assembly: NRTL listed and labeled.

D. Cabinet Type: Plug in, modular, and accepting dimmers of each specified type in any plug-in position.

Industry standard for interrupting rating is 10 kA at 120 V. Consult manufacturer or NRTL listing for higher ratings.

1. Integrated Fault-Current Rating: [10,000] <Insert amperes>-A RMS symmetrical.

See Editing Instruction No. 3 in the Evaluations for discussion of solid-state SCR dimmers and alternative technologies.

E. Lighting Dimmers: Solid-state SCR dimmers.

1. Primary Protection: Magnetic or thermal-magnetic circuit breaker, also serving as the disconnecting means.
2. Dimmer response to control signal shall follow the "Square Law Dimming Curve" specified in IESNA's "IESNA Lighting Handbook."
3. Dimming Range: 0 to 100 percent, full output voltage not less than [98] <Insert number> percent of line voltage.
4. Dimmed circuits shall be filtered to provide a minimum 350-mic.sec. current-rise time at a 90-degree conduction angle and 50 percent of rated dimmer capacity. Rate of current rise shall not exceed 30 mA/mic.sec., measured from 10 to 90 percent of load-current waveform.
5. Protect controls of each dimmer with a fuse[and transient voltage surge suppression].

F. Non-dim modules shall include relays with contacts rated to switch 20-A tungsten-filament load at 120-V ac and 20-A electronic ballast load at 277-V ac.

G. Accessory function control modules shall be compatible with requirement of the accessory being controlled.

Paragraph and subparagraphs below are examples of digitally controlled dimming. Revise if control choice for Project is analog (dc voltage) or multiplex (converting multiplex to analog at each dimmer).

H. Digital Control Network:

1. Dimmers shall receive digital signals from digital network control stations that are

- linked to the dimmer cabinet with a common network data cable.
2. Functions of digital network control stations shall be set up at the dimmer cabinet's electronic controls that include indicated number and arrangement of scene presets, channels, and fade times.

Dimmer-controlled lighting circuits that are part of emergency lighting must be transferred by an automatic-transfer switch that complies with UL 1008.

- I. Emergency Power Transfer Switch: Comply with UL 1008; factory prewired and pretested to automatically transfer load circuits from normal to emergency power supply when normal supply fails.
 1. Transfer from normal to emergency supply when normal-supply voltage drops to 55 percent or less.
 2. Retransfer immediately to normal on failure of emergency supply and after an adjustable time-delay of 10 to 90 seconds on restoration of normal supply while emergency supply is available.
 3. Integrated Fault-Current Rating: Same value as listed for the panel.
 4. Test Switch: Simulate failure of normal supply to test controls associated with transfer scheme.

Retain subparagraph below for projects in seismic areas.

5. Fabricate and test dimmer boards to withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems."

2.9 PORTABLE COMPUTER

- A. Description: As recommended by master-control station manufacturer, to program master station and associated wall stations[, **and all interconnected master stations**]. Portable computer shall be laptop style with a battery runtime of at least two hours. Display shall be an 11-inch (280-mm) interactive-matrix LCD and shall have required hardware, firmware, and software to program specified control functions of master-control stations.
- B. Software shall be configured and customized by master-station manufacturer.

2.10 MANUAL SWITCHES AND PLATES

Coordinate use of manual switches in this Article with required control and override functions, occupancy sensor applications where used, switch and wall-plate finish Specifications in Division 26 Section "Wiring Devices," and dimmer-control wall-plate finish Specifications in Division 26 Section "Modular Dimming Controls."

- A. Switches: Modular, momentary pushbutton, low-voltage type.
 1. Color: Gray unless otherwise indicated.

Delete first two subparagraphs below if not applicable.

2. Integral Pilot Light: Indicate when circuit is on. Use where indicated.

3. Locator Light: Internal illumination.
4. Wall Plates: Comply with requirements in Section 262726 "Wiring Devices" for materials, finish, and color. Use multigang plates if more than one switch is indicated at a location.
5. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

2.11 CONDUCTORS AND CABLES

- A. Wiring to Supply Side of Remote-Control Power Sources: Not smaller than No. 12 AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Classes 2 and 3 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. [18] [22] [24] AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Class 1 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. [14] [16] [18] AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Unshielded, Twisted-Pair Data Cable: Category [5e] [6]. Comply with requirements in Section 271500 "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.1 WIRING INSTALLATION

- A. Comply with NECA 1.

Indicate wiring method on Drawings. Delete first paragraph and subparagraphs below if wiring method for lighting control devices is specified in Section 260533 "Raceways and Boxes for Electrical Systems."

- B. Wiring Method:
 1. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
 2. Install unshielded, twisted-pair cable for control and signal transmission conductors, complying with Section 271500 "Communications Horizontal Cabling."
 3. Minimum conduit size shall be 1/2 inch (13 mm).
- C. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.
- D. Size conductors according to lighting control device manufacturer's written instructions unless otherwise indicated.

- E. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.
- F. Install dimmer cabinets for each zone.

3.2 IDENTIFICATION

- A. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identifying components and power and control wiring.
- B. Label each dimmer module with a unique designation.
- C. Label each scene control button with approved scene description.

3.3 ADJUSTING

- A. Set field-adjustments to match loads.

3.4 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.5 PROTECTION

- A. Provide final protection to ensure that moisture does not enter lighting control equipment assembly.

3.6 FIELD QUALITY CONTROL

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections and prepare test reports.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:

1. Continuity tests of circuits.
 2. Operational Test: Set and operate controls to demonstrate their functions and capabilities in a methodical sequence that cues and reproduces actual operating functions.
 - a. Include testing of dimming control equipment under conditions that simulate actual operational conditions. Record control settings, operations, cues, and functional observations.
 3. Emergency Power Transfer: Test listed functions.
- C. Remove and replace malfunctioning dimming control components and retest as specified above.
- D. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
- E. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.

3.7 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning with Substantial Completion, service agreement shall include software support for **[two (2)] <Insert number>** years.
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within **[two (2)] <Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
1. Upgrade Notice: At least **[30] <Insert number>** days to allow Owner to schedule and access the system and to upgrade computer equipment if necessary.

3.8 DEMONSTRATION

This Article specifies optional services; retain if Project warrants. Coordinate with Division 01 training requirements. If Project includes programmable lighting controls, coordinate with testing of that system.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain central dimming controls. Laptop portable computer shall be used in training.
- B. Coordinate demonstration of products specified in this Section with demonstration requirements for low-voltage, programmable lighting control system specified in Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls."
- C. Schedule training with Owner, through DEN Project Manager, with at least seven (7)

days' advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260933

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SECTION 260936.19 - STANDALONE MULTIPRESET MODULAR DIMMING CONTROLS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1. ASHRAE/IESNA 90.1, Section 9, "Lighting," sets minimum interior and exterior lighting power densities and minimum requirements for lighting controls.

Occupancy sensors and daylight-harvesting controls can be combined with dimming controls and other energy-conserving measures to comply with the requirements in LEED-NC, LEED-CS, and LEED for Schools Credit EA 1 or with LEED-CI Credit EA 1.2.

Time switches and occupancy sensors can be combined with dimming controls to comply with the requirements in LEED-NC, LEED-CS, and LEED for Schools Credit SS 8 or with LEED-CI Credit SS 1, Option 1F.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Wall-box multiscene dimming controls.
 - 2. Multipreset modular dimming controls.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. Fade Rate: The time it takes each zone to arrive at the next scene, dependent on the degree of change in lighting level.
- B. Low Voltage: As defined in NFPA 70, the term for circuits and equipment operating at less than 50 V or for remote-control, signaling, and power-limited circuits.
- C. Scene: The lighting effect created by adjusting several zones of lighting to the desired intensity.
- D. SCR: Silicon-controlled rectifier.
- E. Zone: A fixture or group of fixtures controlled simultaneously as a single entity. Also known as a "channel."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. For modular dimming controls; include elevation, dimensions, features, characteristics, ratings, and labels.
 - 2. Device plates and plate color and material.
 - 3. Ballasts and lamp combinations compatible with dimmers.
 - 4. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Include diagrams for power, signal, and control wiring.

Retain "Samples for Initial Selection" Paragraph below if products have critical features needing hands-on appraisal.

Delete sample requirement in paragraphs below if project is of very limited scope, and deletion is approved by DEN Project Manager.

Coordinate sample requirements with DEN Project Manager.

- C. Samples for Initial Selection: For master- and remote-control stations, and faceplates with factory-applied color finishes and technical features.

Delete "Samples for Initial Selection" Paragraph above if colors and other characteristics are preselected and specified or scheduled. Retain "Samples for Verification" Paragraph below with or without above.

- D. Samples for Verification: For master- and remote-control stations, and faceplates with factory-applied color finishes and technical features.

1.5 INFORMATIONAL SUBMITTALS

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- A. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Those firms responding to this specification shall provide proof that they have been regularly engaged in the design, manufacturing and testing of lighting control equipment for not less than five (5) years.

1.8 ENVIRONMENTAL CONDITIONS

- A. The lighting control equipment unit shall be capable of continuous operation under the following temperature conditions:
 1. Relative humidity: 95% non-condensing.
 2. Altitude: 5500 feet (1667 meters) without any de-rating.
 3. Functioning: -30°F (-34°C) (Outdoor) to 120°F (49°C) (Indoor & Outdoor).
 4. The neutral shall not be combined for lighting circuits with electronic or dimming ballasts, and should be bonded according to local codes and National Electrical Code (NEC).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Douglas Lighting Controls](#).
 2. [Leviton Mfg. Company Inc.](#)
 3. [Lightolier Controls](#); a Philips Group brand.
 4. [Lutron Electronics Co., Inc.](#)
 5. <Insert manufacturer's name>.
 6. or approved equal.

2.2 GENERAL DIMMING DEVICE REQUIREMENTS

See Editing Instruction No. 2 in the Evaluations for discussion of compatibility.

- A. Compatibility:
1. Dimming control components shall be compatible with lighting fixtures, ballasts, and transformers.

Retain subparagraph below if devices specified in this Section are required to function with low-voltage lighting controls.

2. Dimming control devices shall be compatible with lighting control system components specified in Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls," and in Section 260923 "Lighting Control Devices."
- B. Dimmers and Dimmer Modules: Comply with UL 508.
1. Audible Noise and Radio-Frequency Interference Suppression: Solid-state dimmers shall operate smoothly over their operating ranges without audible lamp or dimmer noise or radio-frequency interference. Modules shall include integral or external filters to suppress audible noise and radio-frequency interference.

Indicate ratings for dimmers and dimmer modules on Drawings.

2. Dimmer or Dimmer-Module Rating: Not less than 125 percent of connected load unless otherwise indicated.
- C. Surge Protection: Withstand supply power surges without impairment to performance.

1. Panels: 6000 V, 3000 A, complying with IEEE C62.41.1 and IEEE C62.41.2.
2. Other System Devices: 6000 V, 3000 A, complying with IEEE C62.41.1 and IEEE C62.41.2.

- D. Off Control Position: User-selected off position of any control point shall disconnect the load from line supply.

"System Description" Article below describes a wall-box-mounted control station with dimmers, generally applicable to control a small number of circuits.

2.3 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Comply with NFPA 70.

2.4 WALL-BOX MULTISCENE DIMMING CONTROLS

Number of available scenes and zones varies with manufacturer. Typically, four scenes and six zones are available for one master controller. Indicate number of scenes and zones on Drawings. The number of zones and scenes can be increased with optional expansion modules.

- A. Description: Factory-fabricated equipment providing manual dimming consisting of a wall-box-mounted master controller[**and indicated number of wall-box zone stations**]. Controls and dimmers shall be integrated for mounting in multigang wall box under a single wall plate. Each zone shall be adjustable to indicated number of scenes, which shall reside in the memory of zone controller.

Retain first paragraph below if dimming is other than 120-V ac incandescent lighting. Dimmers for fluorescent lamps with magnetic ballasts may not be available from all manufacturers. Insert special lighting equipment after verifying that dimmers are available for this equipment.

- B. Each zone shall be configurable to control the following loads:
1. Fluorescent lamps with electronic ballasts.
 2. Incandescent lamps.
 3. Low-voltage incandescent lamps, derived with electronic transformers.
 4. Non-dim, on-off switching only.
 5. **<Insert special lighting equipment>**.
- C. Dimmers: Regulate voltages to maintain a constant light level, with no visible flicker, when the source voltage varies plus or minus 2 percent rms.
- D. Memory:
1. Retain preset scenes and fade rates through momentary (up to 3-second) power interruptions.

2. Retain preset scenes through power failures for at least [**seven (7)**] <Insert number> days.
- E. Device Plates: Style, material, and color [**shall comply with Section 262726 "Wiring Devices."**] <Insert description.> Master-control cover plate shall be one piece.
- F. Master controller shall include the following:
 1. Cover-mounted switches, including master off, all bright, and selectors for each scene.
 2. Cover-mounted LED indicator lights, one associated with each scene switch, and one for the master off switch.
 3. Concealed switches and indicators for specified function.
 4. A raise/lower switch for each zone for temporary adjustments of the zone, without altering scene values stored in memory.
 5. Fade time indicated by digital display for current scene while fading.
 6. Cover-mounted infrared receiver.
- G. Infrared Transmitters: Wireless remote control for recalling [**each**] [**four (4)**] <Insert number> of the presets. Operate up to **50 feet (15 m)** within line of sight of the master controller.

2.5 MULTIPRESET MODULAR DIMMING CONTROLS

This article is for a four-preset system, which is typical with listed manufacturers.

Number of available scenes and zones varies with manufacturer. Typically, four scenes and 24 zones are available for one master controller. Indicate number of scenes and zones on Drawings. The number of zones and scenes can be increased with optional expansion modules.

- A. Description: Factory-fabricated equipment providing manual dimming consisting of. the following:
 1. Master controller.
 2. Dimmer panels[, and indicated number of zone stations].
 3. Controls and dimmers shall be integrated for mounting in a multigang wall box under a single wall plate.
 4. Each zone shall be adjustable to indicated number of scenes, which shall reside in the memory of zone controller.

Retain first paragraph below if dimming is other than 120-V ac incandescent lighting. Dimmers for fluorescent lamps with magnetic ballasts may not be available from all manufacturers. Insert special lighting equipment after verifying that dimmers are available for this equipment.

- B. Each zone shall be configurable to control the following loads:
 1. Fluorescent lamps with electronic ballasts.
 2. Incandescent lamps.
 3. Low-voltage incandescent lamps, derived with electronic transformers.

4. Non-dim, on-off switching only.
 5. Neon and cold-cathode lighting.
 6. **<Insert special lighting equipment>**.
- C. Dimmers: Regulate voltages to maintain a constant light level, with no visible flicker, when the source voltage varies plus or minus 2 percent rms.
- D. Memory: Retain preset scenes and fade settings through power failures by retaining physical settings of controls.
- E. Device Plates: Style, material, and color [**shall comply with Section 262726 "Wiring Devices."**] **<Insert description.>** Master-control cover plate shall be one piece.
- F. Master controller shall include the following:
1. Wall-box style, single coverplate supplied by manufacturer.

Indicate number of control and dimmer modules for each master station on Drawings.

2. Cover-mounted switches, including master off, all bright, and selectors for each scene.
 3. Cover-mounted LED indicator lights, one associated with each scene switch, and one for the master off switch.
 4. Concealed switches and indicators for specified function.
 5. A raise/lower switch for each zone for temporary adjustments of the zone, without altering scene values stored in memory.
 6. Fade time indicated by digital display for current scene while fading.
 7. Cover-mounted infrared receiver.
- G. Remote-Control Stations:
1. Numbered push buttons to select scenes.
 2. Off switch to turn master station off. [**Operating the off switch at any remote station shall automatically turn on selected housekeeping lighting.**]
 3. On switch turns all scenes of master station to full bright.
 4. Control Wiring: NFPA 70, Class 2.
 5. Mounting: Single flush wall box with manufacturer's [**standard faceplate**] **<Insert special material and color for faceplate>**.
- H. Infrared Remote-Control Station: Same functions as for standard remote-control station except that functions are input by a hand-held infrared transmitter. Operate up to **50 feet (15 m)** within line of sight of the master controller.
- I. Dimmer Panels: Modular, plug-in type, complying with UL 508.

Industry-standard interrupting rating is 10 kA at 120 V. Consult factory for higher ratings.

1. Integrated Short-Circuit Rating: [**10 kA for 120 V**][, **14 kA for 277 V**].

See Editing Instruction No. 3 in the Evaluations for discussion about use of SCR dimmers and alternative technologies.

2. Dimmers:

- a. Dimming Circuit: Two SCR dimmers, in inverse parallel configuration.
- b. Dimming Curve: Modified "square law" as specified in IESNA's "IESNA Lighting Handbook"; control voltage is 0- to 10-V dc.
- c. Dimming Range: 0 to 100 percent, full output voltage not less than 98 percent of line voltage.
- d. Voltage Regulation: Dimmer shall maintain a constant light level, with no visible flicker, when the source voltage varies plus or minus 2 percent in rms voltage.

J. Circuit Breakers: Complying with UL 489 and classified as switch duty (SWD).

2.6 CONDUCTORS AND CABLES

- A. Wiring to Supply Side of Remote-Control Power Sources: Not smaller than No. 12 AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Class 2 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than **[No. 18] [No. 22] [No. 24]** AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

PART 3 - EXECUTION

3.1 WIRING INSTALLATION

- A. Comply with NECA 1.

Indicate wiring method on Drawings. Delete "Wiring Method" Paragraph below if wiring method for lighting control devices is specified in Section 260533 "Raceways and Boxes for Electrical Systems."

- B. Wiring Method: Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables." Minimum conduit size shall be **1/2 inch (13 mm)**.
- C. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.
- D. Size conductors according to lighting control device manufacturer's written instructions unless otherwise indicated.
- E. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.

3.2 IDENTIFICATION

- A. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identifying components and power and control wiring.
- B. Label each dimmer module with a unique designation.
- C. Label each scene control button with approved scene description.

3.3 ADJUSTING

- A. Set field-adjustments to match loads.

3.4 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.5 PROTECTION

- A. Provide final protection to ensure that moisture does not enter lighting control equipment assembly.

3.6 FIELD QUALITY CONTROL

Retain "Testing Agency" and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Continuity tests of circuits.
 - 2. Operational Test: Set and operate controls to demonstrate their functions and capabilities in a methodical sequence that cues and reproduces actual operating functions.

- a. Include testing of modular dimming control equipment under conditions that simulate actual operational conditions. Record control settings, operations, cues, and functional observations.
- C. Remove and replace malfunctioning modular dimming control components and retest as specified above.
- D. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
- E. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.

3.7 DEMONSTRATION

This article specifies optional services; retain if Project warrants. Coordinate with Section 017900 "Demonstration and Training" requirements. If Project includes programmable lighting controls, coordinate with testing of that system.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain modular dimming controls. **[Laptop portable computer shall be used in training.]**
- B. Coordinate demonstration of products specified in this Section with demonstration requirements for low-voltage, programmable lighting control system specified in Section 260943.13 "Addressable-Fixture Lighting Controls" and Section 260943.23 "Relay-Based Lighting Controls."
- C. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days' advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260936.19

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SECTION 260943.16 - ADDRESSABLE-FIXTURE LIGHTING CONTROLS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED-NC Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1. ASHRAE/IESNA 90.1, Section 9, "Lighting," sets minimum interior and exterior lighting power densities and minimum requirements for lighting controls.

Additional lighting controls can be used to comply with the requirements of LEED-NC Credit IEQ 6.1 if individual lighting controls are provided for a minimum of 90 percent of the building occupants and if lighting system controls are provided for all shared multi-occupant spaces to enable adjustment to meet group needs. Indicate locations of lighting controls on Drawings.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes addressable-fixture lighting controls based on DALI digital controls.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. BAS: Building automation system.
- B. BIM: Building information modeling.
- C. DALI: Digital addressable lighting interface; complies with IEC 60929, Annexes E and G.
- D. Data Bus: Two wires used to communicate with bus connected devices.
- E. DDC: Direct digital control.
- F. Device: A collective term for DALI-compliant bus connected devices, including fluorescent ballasts, incandescent fixtures, manual switches, switching relays, and similar. Sometimes also known as "slave unit."
- G. Group: A set of devices that respond at the same time to messages on the data bus.
- H. HID: High-intensity discharge.
- I. HPS: High-pressure sodium.
- J. IP: Internet protocol.
- K. IR: Infrared.
- L. LAN: Local area network.
- M. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
- N. PC: Personal computer.
- O. Scene: Digital light level associated with a preset; stored in the lighting fixture ballast.
- P. TCP/IP: Transmission control protocol/Internet protocol.
- Q. VPN: Virtual private network.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for control modules, power distribution components, relays, manual switches and plates, and conductors and cables.

2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
3. Include data substantiating that materials comply with requirements.

B. Shop Drawings:

1. Floor Plans: Location, orientation, and coverage area of each sensor; group designations; and other specific design symbols and designations as required to define the installation, location, and configuration of all control devices.
2. Address Drawing: Reflected ceiling plan and floor plans, showing data-bus-connected devices, address for each device, and device groups. The plans shall be based on construction plans, using the same legend, symbols, and schedules.
3. Point List and Data Bus Load: Summary list of all control devices, sensors, ballasts, and other loads connected to each data bus and total connected load for each data bus. Include percentage of rated connected load and device addresses.
4. Wire Termination Diagrams and Schedules: Coordinate nomenclature and presentation with Drawings and block diagram. Differentiate between manufacturer-installed and field-installed wiring.

Retain "Block Diagram" Subparagraph below if this Section includes PC-based local area data bus or link to BIM.

5. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices used. Describe characteristics of network and other data communication lines.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below if lighting controls are connected to devices or systems specified in other Sections.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Submit evidence that lighting controls are compatible with connected monitoring and control devices and systems specified in other Sections.
 1. Show interconnecting signal and control wiring, and interface devices that prove compatibility of inputs and outputs.
 2. For control interfaces and adapters, list network protocols and provide statements from manufacturers that input and output devices comply with interoperability requirements of the LAN or DALI protocol.
- B. Field quality-control reports.
- C. Sample Warranty: For manufacturer's special warranty.

Retain paragraph below for PC- and IP-based control systems.

- D. Software licenses and upgrades required by and installed for operation and programming of digital and analog devices.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For lighting controls to include in emergency, operation, and maintenance manuals.

Retain "Software and Firmware Operational Documentation" Paragraph below for PC- and IP-based control systems.

- B. Software and Firmware Operational Documentation:
 1. Software operating and upgrade manuals.
 2. Program Software Backup: On magnetic media or compact disk, complete with data files.
 3. Device address list.
 4. Printout of software application and graphic screens.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Bus Power Supplies: Equal to **[two (2)] <Insert number>** percent of amount installed, but no fewer than **[two (2)] <Insert number>**.
 2. Controller/Gateways: Equal to **[two (2)] <Insert number>** percent of amount installed, but no fewer than **[two (2)] <Insert number>**.
 3. Incandescent Switching and Dimming Modules: Equal to **[two (2)] <Insert number>** percent of amount installed, but no fewer than **[two (2)] <Insert number>**.
 4. Fluorescent Ballasts: Equal to **[two (2)] <Insert number>** percent of amount installed, but no fewer than **[two (2)] <Insert number>**.
 5. Lighting Control Relays: Equal to **[two (2)] <Insert number>** percent of amount installed, but no fewer than **[two (2)] <Insert number>**.

1.8 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

A. Manufacturer's Warranty: Manufacturer agrees to repair or replace components of lighting controls that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

- a. Software: Failure of input and output to execute switching or dimming commands.
- b. Failure of modular relays to operate under manual or software commands.
- c. Ballast failure.
- d. Damage of electronic components due to transient voltage surges.

Verify available warranties and warranty periods for units and components.

2. Warranty Periods:

- a. For DALI Ballasts: Minimum [**three (3)**] <Insert number> years from date of Substantial Completion.
- b. For Control Components That Are Not Part of Ballasts: Minimum [**three (3)**] <Insert number> years from date of Substantial Completion.

1.9 QUALITY ASSURANCE

A. Those firms responding to this specification shall provide proof that they have been regularly engaged in the design, manufacturing and testing of lighting control equipment for not less than five (5) years.

1.10 ENVIRONMENTAL CONDITIONS

A. The lighting control equipment unit shall be capable of continuous operation under the following temperature conditions:

1. Relative humidity: 95% non-condensing.
2. Altitude: 5500 feet (1667 meters) without any de-rating.
3. Functioning: -30°F (-34°C) (Outdoor) to 120°F (49°C) (Indoor & Outdoor).
4. The neutral shall not be combined for lighting circuits with electronic or dimming ballasts, and should be bonded according to local codes and National Electrical Code (NEC).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 SYSTEM DESCRIPTION

- A. Operation: Input signal from digital signal sources switches or dims DALI devices associated with ballasts or lighting fixtures, or switches field-deployed, DALI-compliant, control relays.
1. Each device and relay is connected to a digital data bus.
 2. Each DALI device and relay has a digital address and can be operated by a digital signal.
 3. Each device or relay can be assigned to any or all of 16 available groups connected to a single data bus.
 4. Each dimming ballast may have as many as 16 preset lighting levels or scenes. Scenes can be programmed to ballasts and may be applied to groups.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with 47 CFR, Subparts A and B, for Class A digital devices.
- D. Comply with protocol described in IEC 60929, Annexes E and G, for DALI lighting control devices, wiring, and computer hardware and software.
- E. Comply with UL 916.

2.2 PERFORMANCE REQUIREMENTS

- A. Surge Suppression: Factory installed as an integral part of control components or field-mounted surge suppressors complying with UL 1449, SPD Type 2.
- B. DALI Requirements:
1. Components: Individually addressable devices (such as ballasts, relays, dimmers, and switches) that are operated from digital signals received through a DALI-compliant bus, from data-entry and -retrieval devices (such as PCs, personal digital assistants, hand-held infrared programming devices, wired

- Ethernet hubs, wireless IEEE 802.11 hubs[, and] **<Insert digital communications device>**). Devices also report status to data-entry and -retrieval devices through the bus.
2. Digital Control: Use peer-to-peer communication and distributed logic, where the failure of any single component shall be automatically isolated and not affect global system functions.

Retain "Ethernet LAN" Paragraph below if the controller/gateways are not connected to DDC system for HVAC.

- C. Ethernet LAN:
 1. Provide an Ethernet LAN to connect controller/gateways to a PC running a Microsoft Windows operating system. Comply with requirements in Section 271500 "Communications Horizontal Cabling."
 2. Ethernet Protocols: Comply with and be compatible with 10/100 BaseT TCP/IP routers and networks.
 3. TCP/IP Modem: Capable of maintaining a secure Internet connection using VPN or equivalent protocol.
- D. BAS Interface: Hardware and software shall interface with BAS to monitor, control, display, and record data for use in processing reports.

Retain "Hardwired Points" or "Communication Interface" Subparagraph below. Retain first subparagraph if interface with BAS is through hardwired points and minimal interface is required. Retain second if extensive interface with BAS is required and is beyond what hardwired points can provide. Requirement may exclude some manufacturers.

1. Hardwired Points:
 - a. Monitoring: On-off status, **<Insert monitoring point>**.
 - b. Control: On-off operation, **<Insert control point>**.
2. Communication Interface: Comply with **[ASHRAE 135]** **<Insert type of interface>**. Communication shall interface with BAS to remotely control and monitor lighting from BAS operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through BAS.

2.3 BUS POWER SUPPLY

The power supply powers the Class 2 low-voltage communications bus to which DALI devices are connected. The controller supports the DALI commands, device settings, and device monitoring.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Leviton Manufacturing Co. Inc.

2. [Lightolier Controls; a Philips Group brand.](#)
3. [Starfield Controls, Inc.](#)
4. [Tridonic.](#)
5. **<Insert manufacturer's name>.**
6. or approved equal.

B. Description: Supply power to data bus for 64 addressable devices, suitable for use with NFPA 70, Class 2 control circuit.

1. Primary Power: Field selectable, 120 and 277 V.
2. Power Supply: Regulated to maintain the operating voltage above 15-V dc under full load, and rated for full charging load of 250 mA and a minimum maintained connected load of 190 mA.
3. Pilot Lights: Indicate data bus ground fault and data bus traffic.

2.4 CONTROLLER/GATEWAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. [Leviton Manufacturing Co. Inc.](#)
2. [Lightolier Controls; a Philips Group brand.](#)
3. [Starfield Controls, Inc.](#)
4. [Tridonic.](#)
5. **<Insert manufacturer's name>.**
6. or approved equal.

B. Description: The DALI controller/gateways link the distributed data buses with an Ethernet network to provide computer configuration, control, analysis, and maintenance. The controller/gateways operate independently and continue to process local inputs and schedules when disconnected from the LAN. The controller/gateways shall provide local intelligence and features including the following:

1. Integrated real-time clock with automatic daylight savings adjustment and leap-year correction.
2. Integrated sunrise/sunset support based on the site location (latitude and longitude).
3. Automatic time schedules, to control groups for scheduled occupancy with support for holiday exceptions.
4. Two digital outputs for additional control and interlocking with external equipment such as fans, valves, and security panels.
5. Support **[one]** **[two]** data bus(es).
6. Computer Monitoring and Configuration: The controller/gateway shall allow configuration, monitoring, and analysis from PCs on the Ethernet LAN.

C. Each data bus shall have the capacity to control 64 addressable devices, using NFPA 70, Class 2 control circuit.

1. Each data bus shall have the capacity to control up to 16 groups and scenes.
2. 10 BaseT Ethernet port for BAS connection.
3. LED indicator lights for Ethernet status (link, send, and receive), power-on, and LAN failure.
4. Linking of switch and sensor inputs to relay and ballast outputs.
5. Viewing relay and ballast output status.
6. Controlling relay and ballast outputs.
7. Setting device addresses.
8. Assigning switch and sensor inputs and relay and ballast output modes.

Retain applicable DALI-compliant addressable devices in first paragraph below. Verify that listed devices are available from manufacturers listed in subsequent articles.

- D. Allow connection of the following DALI-compliant addressable devices:
1. Fluorescent fixture switching and dimming, for linear and compact lamps.
 2. Incandescent fixture switching and dimming.
 3. HID and HPS fixture switching and dimming.
 4. LED fixture switching and dimming.
 5. Occupancy and photoelectric sensors.
 6. Emergency lighting interface complying with UL 924.
- E. Stores system programming in nonvolatile memory.
1. Switch to enable or disable software programming.

If the controller/gateways are not connected to DDC system for HVAC, retain "User Interface" and "Lighting Control System Management Software" articles below as alternatives. Delete both articles if Owner will program controller/gateways with a laptop PC running Microsoft Windows.

2.5 USER INTERFACE

- A. Workstation:
1. A laptop PC, with Microsoft Windows operating system and lighting control system management software installed. With two hard drives and automatic backup software to periodically copy the primary disk image to the second disk.
 2. Include licenses, documentation, and storage media and licensing for a minimum of five concurrent users.
- B. Personal Digital Assistant: Handheld, with custom graphical user-interface software, supplied by the controller/gateway supplier. The software shall provide for all DALI-protocol programming commands to be applied to the controller/gateway via a tethered connection.
- C. Infrared Programming Assistant: Handheld, with custom graphical user-interface software, supplied by the controller/gateway supplier to program the manual switches.

2.6 LIGHTING CONTROL SYSTEM MANAGEMENT SOFTWARE

- A. The software shall provide for programming, configuring, and monitoring all devices connected to all data buses of the lighting control system, using application-specific software with Microsoft Windows-based, user-friendly software with graphical user-interface designed screens.
1. The software shall be object oriented with pop-up menus and built-in help screens. All specified features of the data-bus-connected devices and those associated with controller/gateways shall be included in the software.

2.7 INCANDESCENT FIXTURE SWITCHING AND DIMMING MODULES.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Leviton Manufacturing Co. Inc.](#)
 2. [Lightolier Controls; a Philips Group brand.](#)
 3. [Starfield Controls, Inc.](#)
 4. **<Insert manufacturer's name>.**
 5. or approved equal.
- B. Description: Comply with DALI exponential dimming curve calibrated for the connected lamp type, group, and scene settings, and with DALI light-level and configuration commands. Dimmer rise time shall be not less than 15 mic.sec.

2.8 FLUORESCENT FIXTURE SWITCHING AND DIMMING

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [Lutron Electronics Co., Inc.](#)
 2. [Osram Sylvania.](#)
 3. [Philips Lighting Electronics.](#)
 4. [Tridonic.](#)
 5. **<Insert manufacturer's name>.**
 6. or approved equal.
- B. Each ballast or group shall be addressable and shall include on-off, fade, dimming, scene settings, and other standard DALI control functions and as required to meet the sequence of operation.

- C. Ballasts: Comply with requirements in Section 265100 "Interior Lighting" for ballasts for linear fluorescent lamps, electronic programmed-start, and the following:
1. Starting Method: Programmed rapid start with antiflash (turns on at previously set light level).

Dimming ranges down to 1 and 3 percent of rated lumens are available for some fluorescent lamps.

2. Dimming Range: 100 to 10 percent of rated lumens unless otherwise indicated.
3. Ballast Factor: 1.0 at full output; 0.01 at full dim.
4. Input Voltage Range: 108 to 305 V.

2.9 SENSORS

- A. Comply with requirements in Section 260923 "Lighting Control Devices." All sensors shall be DALI-protocol compliant.
- B. Daylight Harvesting Switching and Dimming Controls:
1. Adjustments and Set Points: All adjustments with exception of sensor range shall be made via the communication network.
 2. Remote Monitoring and Reporting: Sensor value shall be displayed when queried by lighting management software or shall automatically report based on a change of value or change of time period setting.
- C. Indoor Occupancy Sensors: Sensors may be powered directly from the lighting control network or with a standalone power supply. Units powered with a standalone power supply shall interface with the lighting control system through an electrically isolated digital input.

Retain "Relays" Article below to require addressable switches for loads where DALI compliance is not built-in.

2.10 RELAYS

- A. Relays: Electrically operated, mechanically held single-pole switch, rated at 20 A at 277 V. Short-circuit current rating shall be not less than 5 kA. With pilot light indicating when relay is closed and latched. Control shall be by DALI digital data bus. Relay status shall be displayed when queried by lighting management software.
- B. Relay Panel: A single enclosure with incoming lighting branch circuits, relays, and connection to the DALI digital control network.
1. Enclosure: NEMA 250, Type 1, unless otherwise indicated.
 2. Barriers to separate low-voltage and line-voltage components.
 3. Directory: Cover mounted, identifying each relay with its device address and naming the load controlled.
- C. Individually Mounted Relays:

1. Enclosure: Standard outlet box or NEMA 250, Type 1, unless otherwise indicated.
2. Directory: Cover mounted, identifying each relay with its device address.

2.11 MANUAL SWITCHES AND PLATES

Coordinate use of manual switches in this article with required control and override functions, with sensor applications where used, and with switch and wall-plate finish specified in Section 262726 "Wiring Devices."

"Connection Type" Paragraph below is NFPA 70, Class 2, connected to the DALI data bus. Other cabling methods are available, depending on manufacturer.

- A. Connection Type: RS-485 protocol, [**Category 5**] [**Category 5e**] UTP cable, using RJ-45 connectors. Power shall be from the control unit.
- B. Push-Button Switches: Modular, operating over the DALI digital data bus.
 1. Each switch shall control the following functions, in coordination with programmed sequence of operation and related sensors:
 - a. On.
 - b. Off.
 - c. Dimming, increase light level.
 - d. Dimming, decrease light level.
 - e. Return to preset light level.
 2. LED Pilot Lights: On to indicate that the control is active, or when the manual control is operated.
 3. Match color and style specified in Section 262726 "Wiring Devices."
 4. Integral IR receiver for programming.
- C. Wall Plates: Single and multigang plates as specified in Section 262726 "Wiring Devices."
- D. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

2.12 CONDUCTORS AND CABLES

- A. Power Wiring to Supply Side of Class 2 Power Source: Not smaller than No. 12 AWG, complying with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

For Class 2 conductors in "Class 2 Control Cables" Paragraph below, retain wire size based on voltage drop, or use No. 18 AWG.

- B. Class 2 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 18] [No. 22] [No. 24]** AWG, complying with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Class 1 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 14] [No. 16] [No. 18]** AWG, complying with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Digital and Multiplexed Signal Cables: Unshielded, twisted-pair cable with copper conductors, complying with TIA/EIA-568-B.2, **[Category 5e] [Category 6]** for horizontal copper cable and with Section 271500 "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.1 WIRING INSTALLATION

- A. Comply with NECA 1.

Retain one of two "Wiring Method" paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings.

- B. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters **[and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used]**. Conceal raceway and cables except in unfinished spaces.

Retain first subparagraph below if retaining option in "Wiring Method" Paragraph above.

- 1. Install plenum cable in environmental air spaces, including plenum ceilings.
- 2. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
- 3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- C. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- D. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

3.2 IDENTIFICATION

- A. Identify system components, wiring, cabling, boxes, cabinets, and terminals. Comply with identification requirements specified in Section 260553 "Identification for Electrical Systems."

- B. Identify field-installed conductors, interconnecting wiring, and components; install warning signs complying with Section 260553 "Identification for Electrical Systems."
- C. Identify all ceiling-mounted controls with data bus number and device address.
- D. Label each device cable within 6 inches (152 mm) of connection to bus power supply or termination block.

3.3 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Acceptance Testing Preparation:
 - 1. Test continuity of each circuit.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Test each bus controller using a portable PC.
 - 2. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 3. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
- C. Field Test Reports:
 - 1. Printed list of all points created from actual queries of all addressed control points to include ballasts, manual controls, and sensors.
 - 2. Event log verifying the performance of all devices generating event messages to include occupancy sensors, control buttons, alarm messages, and any other change of value messages.
 - 3. Trend data for all daylight zones covering a period of not less than one week and demonstrating performance consistent with the submitted computer models for those spaces.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- D. Lighting controls will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports, including a certified report that identifies bus controllers included and describes query results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Activate light fixtures and verify that all lamps are operating at 100 percent.
 3. Burn-in fluorescent lamps at 100 percent for 100 hours.
 4. Confirm correct communications wiring, initiate communications between DALI devices and controller/gateways, and program the lighting control system according to approved configuration schedules, time-of-day schedules, and input override assignments.
 5. **<Insert startup steps if any>**.

3.5 ADJUSTING

- A. Occupancy Adjustments: When requested within [**twelve (12)**] **<Insert number>** months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.6 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.7 PROTECTION

- A. Provide final protection to ensure that moisture does not enter lighting control equipment assembly.

3.8 SOFTWARE SERVICE AGREEMENT

Services in this article may not be allowed for publicly funded projects.

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for [**two (2)**] **<Insert number>** years.
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within [**two (2)**] **<Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
1. Upgrade Notice: At least [**thirty (30)**] **<Insert number>** days to allow Owner to schedule and access the system and to upgrade computer equipment if necessary.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain the control unit and operator interface.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260943.16

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SECTION 260943.23 - RELAY-BASED LIGHTING CONTROLS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED-NC Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1. ASHRAE/IESNA 90.1, Section 9, "Lighting," sets minimum interior and exterior lighting power densities and minimum requirements for lighting controls.

Additional lighting controls can be used to meet the requirements of LEED-NC Credit EQ 6.1 if individual lighting controls are provided for a minimum of 90 percent of the building occupants and lighting system controls are provided for all shared multi-occupant spaces to enable adjustment to meet group needs. Indicate locations of lighting controls on Drawings.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Retain one of two "Section Includes" paragraphs below.

Edit to suit Project.

- A. Section Includes: Lighting control panels using mechanically held relays for switching.
- B. Section Includes: Networked lighting control panels using control-voltage relays for switching and that are interoperable with BAS.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. BAS: Building automation system.
- B. IP: Internet protocol.
- C. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
- D. PC: Personal computer; sometimes plural as "PCs."
- E. RS-485: A serial network protocol, similar to RS-232, complying with TIA-485-A.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for control modules, power distribution components, relays, manual switches and plates, and conductors and cables.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each relay panel and related equipment.
 - 1. Include dimensioned plans, elevations, sections, and details. Show tabulations of installed devices, equipment features, and ratings.
 - 2. Detail enclosure types and details for types other than NEMA 250, Type 1.
 - 3. Detail wiring partition configuration, current, and voltage ratings.
 - 4. Short-circuit current rating of relays.
 - 5. Include diagrams for power, signal, and control wiring.

Retain "Block Diagram" Subparagraph below when control is digital, PC or IP based.

- 6. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices to be used. Describe characteristics of network and other data communication lines.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below if lighting controls are connected to devices or systems specified in other Sections.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Submit evidence that lighting controls are compatible with connected monitoring and control devices and systems specified in other Sections.
 - 1. Show interconnecting signal and control wiring, and interface devices that prove compatibility of inputs and outputs.
 - 2. For networked controls, list network protocols and provide statements from manufacturers that input and output devices comply with interoperability requirements of the network protocol.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- B. Qualification Data: For testing agency.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

Retain first paragraph below for PC- and IP-based control systems.

- D. Software licenses and upgrades required by and installed for operation and programming of digital and analog devices.
- E. Sample Warranty: For manufacturer's special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For lighting controls to include in emergency, operation, and maintenance manuals.

Retain "Software and Firmware Operational Documentation" Paragraph below for PC- and IP-based control systems.

- B. Software and Firmware Operational Documentation:
 - 1. Software operating and upgrade manuals.
 - 2. Program Software Backup: On magnetic media or compact disk, complete with data files.
 - 3. Device address list.
 - 4. Printout of software application and graphic screens.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Lighting Control Relays: Equal to **<Insert number>** percent of amount installed[**for each size indicated**], but no fewer than **<Insert number>**.

1.8 QUALITY ASSURANCE

Retain "Testing Agency Qualifications" Paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also defines "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

1.9 ENVIRONMENTAL CONDITIONS

- A. The lighting control equipment unit shall be capable of continuous operation under the following temperature conditions:
1. Relative humidity: 95% non-condensing.
 2. Altitude: 5500 feet (1667 meters) without any de-rating.
 3. Functioning: -30°F (-34°C) (Outdoor) to 120°F (49°C) (Indoor & Outdoor).
 4. The neutral shall not be combined for lighting circuits with electronic or dimming ballasts, and should be bonded according to local codes and National Electrical Code (NEC).

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Handle and prepare panels for installation according to NECA 407.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 SYSTEM DESCRIPTION

- A. Input signal from field-mounted manual switches, or digital signal sources, shall open or close one or more lighting control relays in the lighting control panels. Any combination of inputs shall be programmable to any number of control relays.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with 47 CFR, Subparts A and B, for Class A digital devices.
- D. Comply with UL 916.

2.2 PERFORMANCE REQUIREMENTS

Delete "Seismic Performance" Paragraph below if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

- A. Seismic Performance: Lighting control panels shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified [**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: **[1.5] [1.0]**.

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. **<Insert requirements for Component Amplification Factor and Component Response Modification Factor>**.

Retain "Interface with DDC System for HVAC" Paragraph below for interface with the DDC system for HVAC. Coordinate with Section 230923 "Direct Digital Control (DDC) System for HVAC."

- B. BAS Interface: Provide hardware and software to enable the BAS to monitor, control, display, and record data for use in processing reports.

Retain "Hardwired Points" or "Communication Interface" Subparagraph below. Retain first subparagraph if interface with the DDC system for HVAC is through hardwired points and minimal interface is required. Retain second if extensive interface with the DDC system for HVAC is required and is beyond what hardwired points can provide. Requirement may exclude some manufacturers.

1. Hardwired Points:
 - a. Monitoring: On-off status, **<Insert monitoring point>**.
 - b. Control: On-off operation, **<Insert control point>**.
2. Communication Interface: Comply with **[ASHRAE 135] <Insert type of interface>**. The communication interface shall enable the BAS operator to remotely control and monitor lighting from a BAS operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through the BAS.

Retain one of first two articles below. "Lighting Control Relay Panels" Article is for a single lighting control relay panel, typically not more than 42 relays. Retain "Networked Lighting Control Panels" Article for multiple panels networked under unified control and with an optional connection to the BAS.

2.3 LIGHTING CONTROL RELAY PANELS

Retain "Products" Paragraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

- A. **Products: Subject to compliance with requirements, provide one of the following:**

1. Acuity Brands, Inc., Lighting Control & Design, Inc.; GR2400.
2. General Electric Company, GE Consumer & Industrial - Electrical Distribution; LVRC.
3. Leviton Mfg. Company Inc.; Z-Max Plus.
4. Lightolier Controls, a Philips Group brand; Lyteswitch.
5. Siemens Energy & Automation, Inc.; LCP3000EZ.
6. Touch-Plate Technologies; Zone Z.
7. WattStopper, a Legrand Group brand; Lighting Integrator.
8. **<Insert manufacturer's name; product name or designation>**.
9. or approved equal.

- B. Description: Standalone lighting control panel using mechanically latched relays to control lighting and appliances.
- C. Lighting Control Panel:
1. A single enclosure with incoming lighting branch circuits, control circuits, switching relays, and on-board timing and control unit.
 2. A vertical barrier separating branch circuits from control wiring.
- D. Control Unit: Contain the power supply and electronic control for operating and monitoring individual relays.
1. Timing Unit:
 - a. 365-day calendar, astronomical clock, and automatic adjustments for daylight savings and leap year.
 - b. Clock configurable for 12-hour (A.M./P.M.) or 24-hour format.
 - c. **[Four] <Insert number>** independent schedules, each having **[24] <Insert number>** time periods.
 - d. Schedule periods settable to the minute.
 - e. Day-of-week, day-of-month, day-of-year with one-time or repeating capability.
 - f. **[10] <Insert number>** special date periods.

In "Sequencing Control with Override" Subparagraph below, two control units are available from some manufacturers.

2. Sequencing Control with Override:
 - a. Automatic sequenced on and off switching of selected relays at times set at the timing unit, allowing timed overrides from external switches.
 - b. Sequencing control shall operate relays one at a time, completing the operation of all connected relays in not more than 10 seconds.
 - c. Override control shall allow any relay connected to it to be switched on or off by a field-deployed manual switch or by an automatic switch, such as an occupancy sensor.
 - d. Override control "blink warning" shall warn occupants approximately **[five minutes] <Insert time>** before actuating the off sequence.
3. Nonvolatile memory shall retain all setup configurations. After a power failure, the controller shall automatically reboot and return to normal system operation, including accurate time of day and date.

Retain one of two "Relays" paragraphs below. Not all listed manufacturers can comply with requirements when retaining second paragraph. Two-pole relays are available from some manufacturers.

- E. Relays: Electrically operated, mechanically held single-pole switch, rated at 20 A at 277 V. Short-circuit current rating shall be not less than 5 kA. Control shall be three-wire, 24-V ac.

- F. Relays: Electrically operated, mechanically held single-pole switch, rated at 20 A at 120-V tungsten, 30 A at 277-V ballast, 1.5 hp at 120 V, and 3 hp at 277 V. Short-circuit current rating shall be not less than 14 kA. Control shall be three-wire, 24-V ac.
- G. Power Supply: NFPA 70, Class 2, sized for connected equipment, plus 20 percent spare capacity. Powered from a dedicated branch circuit of the panelboard that supplies power to the line side of the relays, sized to provide control power for the local panel-mounted relays, bus system, low-voltage inputs, field-installed occupancy sensors, and photo sensors.

Alternatives to "Operator Interface" Paragraph below are available from some manufacturers. Alternatives include hand-held portable PCs, personal digital assistants, and mobile telephones.

H. Operator Interface:

- 1. Integral alphanumeric keypad and digital display, and intuitive drop-down menus to assist in programming.
- 2. Log and display relay on-time.
- 3. Connect relays to one or more time and sequencing schemes.

2.4 NETWORKED LIGHTING CONTROL PANELS

Revise this article for selected electric control protocol based on the need for flexibility, interoperability, and the most appropriate user interface.

Retain "Products" Paragraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

A. Products: Subject to compliance with requirements, provide one of the following:

- 1. Acuity Brands, Inc., Lighting Control & Design, Inc.; GR2400.
- 2. General Electric Company, GE Consumer & Industrial - Electrical Distribution; LVRC.
- 3. Touch-Plate Technologies; Control Plus.
- 4. WattStopper, a Legrand Group brand; Lighting Integrator.
- 5. **<Insert manufacturer's name; product name or designation>**.
- 6. or approved equal.

B. Description: Lighting control panels using mechanically latched relays to control lighting and appliances. The panels shall be capable of being interconnected with digital communications to appear to the operator as a single lighting control system.

C. Lighting Control Panels:

- 1. A single enclosure with incoming lighting branch circuits, control circuits, switching relays, and on-board timing and control unit.
- 2. A vertical barrier separating branch circuits from control wiring.

Not all manufacturers place all features, listed in "Main Control Unit" Paragraph below, into the main network panel. Instead, some features may be repeated in each slave panel. Revise paragraph below as necessary, depending on manufacturers.

- D. Main Control Unit: Installed in the main lighting control panel only; powered from the branch circuit of the standard control unit.
1. Ethernet Communications: Comply with **[MS Windows TCP/IP] <Insert network protocol>** protocol. The main control unit shall provide for programming of all control functions of the main and all networked slave lighting control panels including timing, sequencing, and overriding.

Retain "Compliance with ASHRAE 135" Subparagraph below for DDC system for HVAC control network. Revise as required for other network protocols.

See "Communication Networks for Lighting Controls" Article in the Evaluations for discussion of communication network options.

2. Compliance with ASHRAE 135: Controllers shall support serial MS/TP and Ethernet IP communications, and shall be able to communicate directly via BAS RS-485 serial networks and Ethernet 10Base-T networks as a native device.
3. Web Server: Display information listed below over a standard Web-enabled server for displaying information over a standard browser.
 - a. A secure, password-protected login screen for modifying operational parameters, accessible to authorized users via Web page interface.
 - b. Panel summary showing the master and slave panels connected to the controller.
 - c. Controller diagnostic information.
 - d. Show front panel mimic screens for setting up controller parameters, input types, zones, and operating schedules. These mimic screens shall also allow direct breaker control and zone overrides.
4. Timing Unit:
 - a. 365-day calendar, astronomical clock, and automatic adjustments for daylight savings and leap year.
 - b. Clock configurable for 12-hour (A.M./P.M.) or 24-hour format.
 - c. **[Four] <Insert number>** independent schedules, each having **[24] <Insert number>** time periods.
 - d. Schedule periods settable to the minute.
 - e. Day-of-week, day-of-month, day-of-year with one-time or repeating capability.
 - f. **[16] <Insert number>** special date periods.

In "Time Synchronization" Subparagraph below, the typical value ranges from one hour to 24 hours.

5. Time Synchronization: The timing unit shall be updated not less than every **<Insert number>** hour(s) with the network time server.
6. Sequencing Control with Override:

- a. Automatic sequenced on and off switching of selected relays at times set at the timing unit, allowing timed overrides from external switches.
 - b. Sequencing control shall operate relays one at a time, completing the operation of all connected relays in not more than 10 seconds.
 - c. Override control shall allow any relay connected to it to be switched on or off by a field-deployed manual switch or by an automatic switch, such as an occupancy sensor.
 - d. Override control "blinking warning" shall warn occupants approximately [**five minutes**] <Insert time> before actuating the off sequence.
 - e. Activity log, storing previous relay operation, including the time and cause of the change of status.
 - f. Download firmware to the latest version offered by manufacturer.
- E. Standard Control Unit, Installed in All Lighting Control Panels: Contain electronic controls for programming the operation of the relays in the control panel, contain the status of relays, and contain communications link to enable the digital functions of the main control unit. Comply with UL 916.
1. Electronic control for operating and monitoring individual relays, and display relay on-time.
 2. Nonvolatile memory shall retain all setup configurations. After a power failure, the controller shall automatically reboot and return to normal system operation.
 3. Integral keypad and digital-display front panel for local setup, including the following:
 - a. Blink notice, time adjustable from software.
 - b. Ability to log and display relay on-time.
 - c. Capability for accepting downloadable firmware so that the latest production features may be added in the future without replacing the module.

Retain "Relays" paragraph below. Not all listed manufacturers can comply with requirements when retaining second paragraph. Two-pole relays are available from some manufacturers. See Evaluations for discussion of additional relay features.

- F. Relays: Electrically operated, mechanically held single-pole switch, rated at 20 A at 120-V tungsten, 30 A at 277-V ballast, 1.5 hp at 120 V, and 3 hp at 277 V. Short-circuit current rating shall be not less than 14 kA. Control shall be [**three-wire, 24-V ac**] [**digital control network**].
- G. Power Supply: NFPA 70, Class 2, UL listed, sized for connected equipment, plus not less than 20 percent spare capacity. Powered from a dedicated branch circuit of the panelboard that supplies power to the line side of the relays, sized to provide control power for the local panel-mounted relays, bus system, low-voltage inputs, field-installed occupancy sensors, and low-voltage photo sensors.
- H. Operator Interface: At the main control unit, provide interface for a tethered connection of [**a portable PC running MS Windows**] <Insert digital device and operating system> for configuring all networked lighting control panels using setup software designed for the specified operating system. Include one portable device for initial

programming of the system and training of Owner's personnel. That device shall remain the property of Owner.

I. Software:

1. Menu-driven data entry.
2. Online and offline programming and editing.
3. Provide for entry of the room or space designation for the load side of each relay.
4. Monitor and control all relays, showing actual relay state and the name of the automatic actuating control, if any.
5. Size the software appropriate to the system.

2.5 MANUAL SWITCHES AND PLATES

Coordinate use of manual switches in this article with required control and override functions, with occupancy sensor applications where used, and with switch and wall-plate finish specified in Section 262726 "Wiring Devices."

A. Push-Button Switches: Modular, momentary contact, three wire, for operating one or more relays and to override automatic controls.

1. Match color and style specified in Section 262726 "Wiring Devices."

Retain both subparagraphs below if required.

2. Integral green [LED] [neon] pilot light to indicate when circuit is on.
3. Internal white [LED] [neon] locator light to illuminate when circuit is off.

B. Wall Plates: Single and multigang plates as specified in Section 262726 "Wiring Devices."

C. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

2.6 FIELD-MOUNTED SIGNAL SOURCES

A. Daylight Harvesting Switching Controls: Comply with Section 260923 "Lighting Control Devices." Control power may be taken from the lighting control panel, and signal shall be compatible with the relays.

B. Indoor Occupancy Sensors[**and Extreme-Temperature Occupancy Sensors**]: Comply with Section 260923 "Lighting Control Devices." Control power may be taken from the lighting control panel, and signal shall be compatible with the relays.

2.7 CONDUCTORS AND CABLES

A. Power Wiring to Supply Side of Class 2 Power Source: Not smaller than No. 12 AWG, complying with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

- B. Classes 2 and 3 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 18] [No. 22] [No. 24]** AWG, complying with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Class 1 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 14] [No. 16] [No. 18]** AWG, complying with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Digital and Multiplexed Signal Cables: Unshielded, twisted-pair cable with copper conductors, complying with TIA/EIA-568-B.2, **[Category 5e] [Category 6]** for horizontal copper cable and with Section 271500 "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Receive, inspect, handle, and store panels according to NECA 407.
- B. Examine panels before installation. Reject panels that are damaged or rusted or have been subjected to water saturation.
- C. Examine elements and surfaces to receive panels for compliance with installation tolerances and other conditions affecting performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 WIRING INSTALLATION

- A. Comply with NECA 1.

Retain one of two "Wiring Method" paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings.

- B. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters[**and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used**]. Conceal raceway and cables except in unfinished spaces.

Retain first subparagraph below if retaining option in "Wiring Method" Paragraph above.

1. Install plenum cable in environmental air spaces, including plenum ceilings.
2. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."

- C. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- D. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

3.3 PANEL INSTALLATION

- A. Comply with NECA 1.
- B. Install panels and accessories according to NECA 407.

Retain first paragraph below if seismic controls are required for Project. Coordinate with Drawings.

- C. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

Ensure that, whatever height is retained for top of trim in first paragraph below, the operating handle of topmost switch or circuit breaker, in on position, is not higher than 79 inches (2000 mm) above finished floor or grade.

- D. Mount top of trim [90 inches (2286 mm)] <Insert dimension> above finished floor unless otherwise indicated.
- E. Mount panel cabinet plumb and rigid without distortion of box.
- F. Install filler plates in unused spaces.

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with Section 260553 "Identification for Electrical Systems."
- C. Create a directory to indicate loads served by each relay; incorporate Owner's final room designations. Obtain approval before installing. Use a PC or typewriter to create directory; handwritten directories are unacceptable.
- D. Lighting Control Panel Nameplates: Label each panel with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.5 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.6 PROTECTION

- A. Provide final protection to ensure that moisture does not enter lighting control equipment assembly.

3.7 FIELD QUALITY CONTROL

Retain "Testing Agency," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate testing requirements with Section 262416 "Panelboards."

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- C. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
- D. Acceptance Testing Preparation:
 - 1. Test continuity of each circuit.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. Lighting control panel will be considered defective if it does not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- F. Prepare test and inspection reports, including a certified report that identifies lighting control panels and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.8 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Confirm correct communications wiring, initiate communications between panels, and program the lighting control system according to approved configuration schedules, time-of-day schedules, and input override assignments.
 - 3. **<Insert startup steps if any>**.

3.9 ADJUSTING

- A. Occupancy Adjustments: When requested within [**twelve (12)**] **<Insert number>** months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.10 SOFTWARE SERVICE AGREEMENT

Services in this article may not be allowed for publicly funded projects.

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for [**two (2)**] **<Insert number>** years.
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within [**two (2)**] **<Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: At least [**thirty (30)**] **<Insert number>** days to allow Owner to schedule and access the system and to upgrade computer equipment if necessary.

3.11 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the control unit and operator interface.

1. Schedule training with Owner, through DEN Product Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 260943.23

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SECTION 261116 - SECONDARY UNIT SUBSTATIONS

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes indoor and outdoor secondary unit substations, each consisting of the following:

Edit to suit Project.

1. Primary incoming section.
2. Transformer.
3. Secondary distribution section.

- B. Related Sections include the following:

List below only products and equipment that the reader might expect to find in this Section but are specified elsewhere.

1. Section 260513 "Medium-Voltage Cables" for requirements of terminating cables in incoming section of substation.
2. Section 260573 "Overcurrent Protective Device Coordination Study" for short-circuit rating of devices and for setting of overcurrent protective devices.
3. Section 260913 "Electrical Power Monitoring and Control" for communication features of power distribution system devices.
4. Section 261300 "Medium-Voltage Switchgear" for metering and instrument transformers.
5. Section 262500 "Enclosed Bus Assemblies" for busway connections between transformers and secondary distribution equipment.

6. Section 263533 "Power Factor Correction Equipment" for capacitors to be located in secondary section.
7. Section 263600 "Transfer Switches" for transfer switches that may be located in secondary distribution section.
8. Section 264313 "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits" for transient voltage surge suppressors for low-voltage power, control, and communication equipment that may be located in secondary section.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

- A. NETA ATS: Acceptance Testing Specification.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, furnished specialties, and accessories.
 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 1. Wiring Diagrams: Power, signal, and control wiring.
 2. Dimensioned plans and elevations showing major components and features.
 3. One-line diagram.
 4. List of materials.
 5. Nameplate legends.
 6. Size and number of bus bars and current rating for each bus, including mains and branches of phase, neutral, and ground buses.
 7. Short-time and short-circuit current ratings of secondary unit substations and components.
 8. Ratings of individual protective devices.

Curves below are required to coordinate devices upstream and downstream from secondary unit substation.

- C. Time-Current Characteristic Curves: For overcurrent protective devices.
- D. Primary Fuses: Submit recommendations and size calculations.

1.5 INFORMATIONAL SUBMITTALS

Retain paragraph below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

Edit subparagraphs below to suit Project.

1. Dimensioned concrete base, outline of secondary unit substation, conduit entries, and ground rod locations.
2. Location of structural supports for structure-supported raceways[, **busways,**] **[and seismic bracing]**.
3. Location of lighting fixtures, sprinkler piping and heads, ducts, and diffusers.

Coordinate paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For testing agency.

Retain first paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

Coordinate seismic requirements with DEN Project Manager.

- C. Manufacturer Seismic Qualification Certification: Submit certification that transformer assembly and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- D. Product Certificates: For secondary unit substations, signed by product manufacturer.

Delete test reports below if not required.

- E. Material Test Reports: For secondary unit substations.

Retain paragraph above or below.

- F. Factory test reports.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- G. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For secondary unit substations and accessories to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below, before installation begins, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Revise first subparagraph below to suit Project. Spare medium-voltage fuses are contained within primary switch.

1. Spare fuses: **[Six (6)] <Insert number>** of each type and rating of fuse and fusible device used, except for medium-voltage fuses **[and fuses associated with network protector]**. Include spares for the following:
 - a. Primary disconnect fuses.
 - b. Potential transformer fuses.
 - c. Control power fuses.
 - d. Fuses and fusible devices for fused circuit breakers.
 - e. Fuses for secondary fusible devices.
2. Spare Indicating Lights: Six of each type installed.
3. Touchup Paint: **[Three (3)] <Insert number>** half-pint containers of paint

- matching enclosure's exterior finish.
4. Primary Switch Contact Lubricant: **[One (1)] <Insert number>** container(s).
 5. **[One (1)] <Insert number>** set(s) of spare mounting gaskets for bushings, handholes, and the gasket between relief cover and flange of pressure relief device.

1.8 QUALITY ASSURANCE

If an independent testing agency is required, see Division 01 Section "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use first paragraph below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain paragraph and subparagraph below if Contractor or manufacturer selects testing agency.

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
- B. Source Limitations: Obtain secondary unit substation through one source from a single manufacturer.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Correlate with Division 01 requirements.

- C. Product Options: Drawings indicate size, profiles, and dimensional requirements of secondary unit substations and are based on the specific system indicated. Refer to Section 016000 "Product Requirements."
- D. Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Comply with IEEE C2.
- F. Comply with IEEE C37.121.
- G. Comply with NFPA 70.

1.9 DELIVERY, STORAGE, AND HANDLING

Delete first paragraph below if no known obstacles to movement of normal shipping, lengths of secondary unit substations, and substation sections. Coordinate with Drawings.

- A. Deliver in shipping splits in sizes that can be moved past obstructions in delivery path.
- B. Coordinate delivery of secondary unit substations to allow movement into designated

space.

- C. Store secondary unit substation components [**protected from weather and**] so condensation will not form on or in units. Provide temporary heating according to manufacturer's written instructions.
- D. Handle secondary unit substation components according to manufacturer's written instructions. Use factory-installed lifting provisions.

1.10 PROJECT CONDITIONS

- A. Field Measurements: Indicate measurements on Shop Drawings.

Delete first paragraph and subparagraphs below if no interruption of existing electric service is required.

- B. Interruption of Existing electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 - 2. Do not proceed with interruption of electric service without DEN Project Manager's written permission.
- C. Any electrical work penetrating concrete walls or floors shall require saw cutting and/or core drilling and shall require approval by the DEN Project Manager. The contractor shall submit shop drawings of any saw cutting or core drilling to the DEN Project Manager prior to performing the work. Refer to Section 017300 "Execution."
- D. Service Conditions: IEEE C37.121, usual service conditions, except for the following:

Select and modify conditions below and specify features required to provide satisfactory service.

- 1. Exposure to significant solar radiation.
- 2. Altitudes above 5500 feet (1677 m).
- 3. Exposure to fumes, vapors, or dust.
- 4. Exposure to explosive environments.
- 5. Exposure to hot and humid climate or to excessive moisture, including steam, salt spray, and dripping water.
- 6. Exposure to seismic shock or to abnormal vibration, shock, or tilting.
- 7. Exposure to excessively high or low temperatures: -30° F to 120° F
- 8. Unusual transportation or storage conditions.
- 9. Unusual grounding resistance conditions.
- 10. Unusual space limitations.

1.11 COORDINATION

Edit first paragraph below to delete or add types of construction that should be submitted as part of Contractor's layout.

- A. Coordinate layout and installation of secondary unit substations with other construction that penetrates floors and ceilings, or is supported by them, including light fixtures, HVAC equipment, and fire-suppression-system components.
- B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - GENERAL

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 - 1. ABB Control, Inc.
 - 2. Cooper Industries, Inc.; Cooper Power Systems Division.
 - 3. Cutler-Hammer.
 - 4. GE Electrical Distribution & Control.
 - 5. Siemens Energy & Automation, Inc.
 - 6. Square D; Schneider Electric.
 - 7. <Insert manufacturer>
 - 8. or approved equal.

2.2 MANUFACTURED UNITS

- A. Indoor Unit Arrangement: Single assembly.

Retain paragraph above or first paragraph below for indoor units.

- B. Indoor Unit Arrangement: Separate secondary distribution equipment connected with busway.

- C. Outdoor Unit Arrangement: Single assembly Separate secondary distribution equipment connected with busway.
 - 1. Weatherproof, listed for installation outdoors, complying with IEEE C37.20.1.
 - 2. Aisleless Construction: Full-height doors in front of basic weatherproof equipment.
- D. Enclosure Finish: Factory-applied finish in manufacturer's standard color, including under surfaces treated with corrosion-resistant undercoating.

Select paragraph above for outdoor units or below for indoor units.

- E. Enclosure Finish: Factory-applied finish in manufacturer's standard gray over a rust-inhibiting primer on treated metal surface.

2.3 INCOMING SECTION

Retain one of three "Primary Incoming Section" paragraphs and associated subparagraphs below. Additional primary incoming section equipment includes metal-clad, circuit-breaker switchgear with vacuum or SF6 circuit breakers. This equipment can be adapted from Division 26 Section "Medium-Voltage Switchgear" for use in this Section.

- A. Primary Incoming Section: Terminal assembly with adequate space for incoming-cable terminations and surge arresters.
- B. Primary Incoming Section: Transformer cover-mounted bushings.
- C. Primary Incoming Section: Enclosed, air-interrupter, dual primary primary switch.
 - 1. Three pole, single throw, dead front, metal enclosed, with manual stored energy operator, **[with fuses mounted on a single frame] [without fuses]**, complying with IEEE C37.20.3.
 - 2. Key interlocking system to prevent fuse access door from being opened unless switch is open. **[Additionally, interlock air-interrupter switch with transformer secondary main circuit breaker, preventing switch from being opened or closed unless secondary main circuit breaker is open.]**
 - 3. Phase Barriers: Located between blades **[and fuses]** of each phase, designed for easy removal, allows visual inspection of switch components when barrier is in place.
 - 4. Window: Permits viewing switch-blade positions when door is closed.
 - 5. Accessory Set: Tools and miscellaneous items required for interrupter switchgear test, inspection, maintenance, and operation. Include fuse-handling tool as recommended by switchgear manufacturer.

Continuous-current and short-circuit ratings listed below are for commonly available switches; adjust if required to suit Project conditions.

- 6. Continuous-Current Rating: 600 A.
- 7. Short-Circuit Rating:
 - a. Short-time momentary asymmetrical fault rating of 40 kA.

- b. 3-second symmetrical rating of 25-kA RMS.
 - c. Fault close asymmetrical rating of 40 kA.
8. Fuses: Sizes recommended by secondary unit substation manufacturer, considering fan cooling, temperature-rise specification, and cycle loading. Comply with the following:
- a. Current-limiting type, rated for not less than 50-kA RMS symmetrical current-interrupting capacity.
 - b. Indicator integral with each fuse to show when it has blown.
 - c. Spares: Include three fuses in use and three spare fuses in storage clips in each switch.

Revise paragraph below to specify station or intermediate-class arresters if Project conditions require.

- D. Surge Arresters: Comply with IEEE C62.11, Distribution class; metal-oxide-varistor type, with ratings as indicated, connected in each phase of incoming circuit and ahead of any disconnecting device.

2.4 LIQUID-FILLED TRANSFORMER SECTION

Retain this Article for liquid-filled transformers or delete and retain "Dry-Type Transformer Section" Article.

See the Evaluations in Division 26 Section "Medium-Voltage Transformers" for guidance on editing this Article.

- A. Description: IEEE C57.12.00 and UL 1062, liquid-filled, 2-winding, secondary unit substation transformer.
- B. Insulating Liquid: Mineral oil complying with ASTM D 3487, Type II, and tested according to ASTM D 117.

Delete paragraph above if less-flammable insulating liquid is required. Select one of three insulating liquids below; verify availability with selected manufacturers. Transformer primary voltage must be 35 kV or less for less-flammable liquids. See the Evaluations in Division 26 Section "Medium-Voltage Transformers" for discussion of transformer liquids.

- C. Insulating Liquid: Less flammable, edible-seed-oil based, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
- D. Insulating Liquid: Less flammable, dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
- E. Insulating Liquid: Less flammable, silicone-based dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall have low toxicity and be nonhazardous.

Retain one of first two paragraphs below if appropriate temperature rise for Project is other-than-standard 55 deg C.

- F. Basic Impulse Level: Comply with UL 1062.

Retain paragraph above or below. See Evaluations for standard Basic Impulse Level values.

Retain one of first two paragraphs below. First is NEMA standard.

- G. Full-Capacity Voltage Taps: 4 nominal 2.5 percent taps, 2 above and 2 below rated primary voltage; with externally operable tap changer for de-energized use and with position indicator and padlock hasp.
- H. Cooling System: Class **[OA, liquid cooled] [OA/FA, liquid cooled, and with forced-air rating] [OA/FFA, liquid cooled, and with provisions for future forced-air rating]**. Cooling systems shall include auxiliary cooling equipment, automatic controls, and status indicating lights.

Delete paragraph below if transformer noise is not important. If retaining, adjust allowable level.

- I. Sound level may not exceed 58 dB, without fans.

Delete first paragraph below if manufacturer's standard impedance is adequate according to system analysis. See Evaluations for typical impedance values. Revise to suit Project and verify availability with manufacturers.

- J. Impedance: **<Insert value>** percent.
- K. Accessories: Grounding pads, lifting lugs, and provisions for jacking under base. Transformers shall have a steel base and frame allowing use of pipe rollers in any direction, and an insulated, low-voltage, neutral bushing with removable ground strap. Include the following additional accessories:
1. Liquid-level gage.
 2. Pressure-vacuum gage.
 3. Liquid temperature indicator.
 4. Drain and filter valves.
 5. Pressure relief device.

2.5 DRY-TYPE TRANSFORMER SECTION

See the Evaluations in Division 26 Section "Medium-Voltage Transformers" for guidance on editing this Article. Retain IEEE C57.12.50 for dry-type transformers rated up to 500 kVA, IEEE C57.12.51 for dry-type transformers rated 501 kVA and larger, or IEEE C57.12.52 for sealed dry-type transformers rated 501 kVA and larger.

- A. Description: IEEE C57.12.01, **[IEEE C57.12.50] [IEEE C57.12.51] [IEEE C57.12.52]**, NEMA ST 20, and dry-type, 2-winding, secondary unit substation transformer.
- B. Enclosure: **[Indoor, ventilated] [Outdoor, ventilated] [Totally enclosed, nonventilated]**, cast coil/encapsulated coil, with primary and secondary windings individually cast in epoxy; with insulation system rated at 185 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.

Select paragraph above or first paragraph below. See Evaluations for discussion of cast-coil/encapsulated-coil and vacuum-pressure impregnated options.

- C. Enclosure: [**Indoor, ventilated**] [**Outdoor, ventilated**] [**Totally enclosed, nonventilated**], vacuum-pressure, impregnated type and with insulation system rated at 220 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.
- D. Cooling System: Class AA, air cooled , complying with IEEE C57.12.01.

If retaining first option in paragraph above, delete both subparagraphs below.

- 1. Automatic forced-air cooling system controls, including thermal sensors, fans, control wiring, temperature controller with test switch, power panel with current-limiting fuses, indicating lights, alarm, and alarm silencing relay.

If retaining second option in paragraph above, delete subparagraph below.

- 2. Include mounting provision for fans.

- E. Insulation Materials: IEEE C57.12.01, rated 220 deg C.
- F. Insulation Temperature Rise: [**80**] [**115**] [**150**] deg C, maximum rise above 40 deg C.

See Evaluations for standard Basic Impulse Level values.

- G. Basic Impulse Level: [**60**] [**75**] [**95**] [**110**] kV.

Retain one of two paragraphs below. First is NEMA standard.

- H. Full-Capacity Voltage Taps: 4 nominal 2.5 percent taps, 2 above and 2 below rated primary voltage.

Delete paragraph below if transformer noise is not important. If retaining, consider listing acceptable level. See Editing Instruction No. 2 in the Evaluations for discussion of sound levels.

- I. Sound level may not exceed <Insert maximum dBA level>, without fans operating.

Delete paragraph below if manufacturer's standard impedance is adequate according to system analysis. See Evaluations for typical impedance values.

- J. Impedance: <Insert value> percent.

If retaining paragraph below, coordinate with Drawings and provide external power and signal connections.

- K. High-Temperature Alarm: Sensor at transformer with local audible and visual alarm and contacts for remote alarm.

2.6 SECONDARY DISTRIBUTION SECTION

Retain one of first five paragraphs below.

- A. Secondary Terminal Compartment: Bus **[bars mounted on standoff insulators] [duct flange for close coupling with busway]**.
- B. Distribution Panelboard: Panelboards as specified in Section 262416 "Panelboards."
- C. Network Protectors:
 - 1. Rated for continuous service in an ambient temperature of up to 40 deg C, applied to 3-phase, 4-wire, solidly grounded wye secondary networks. Comply with IEEE C57.12.44.
 - 2. Dead-front, drawout design with externally mounted fuses, using hand-cranked rail system. Relay and control panel located on a separate drawout module.
 - 3. Protector Operator: **[Spring-close] [and] [or] [stored-energy]** mechanism, rated to close on a **[25,000] [40,000]** RMS symmetrical load.
 - 4. Control Voltage: Not more than 125 V.

Adjust relay requirements below to suit Project conditions.

- 5. Control microprocessor-based, three-phase, tripping relay with features and functions as follows:
 - a. Close protector if positive sequence power flows into the network. Adjustable closing range shall be from 0.5 to 3.5 V in phase difference between network and transformer voltages.
 - b. Trip protector if there is a net, three-phase, reverse power flow through protector. Trip protectors shall be adjustable from 0.05 to 5 percent of continuous-current rating of current transformers within protector.
 - c. Trip protector if there is a flow of reverse magnetizing current of its associated transformer.
 - d. Field-adjustable relay parameters and watt or watt-var trip values.
- 6. Protector shall not open under any fault on network side of protector.
- 7. Current-limiting fuses shall have interrupting capacity of 150,000 A on network side of protector for protection against switchboard bus faults.
- 8. Mechanical interlocks shall prevent racking in and racking out when protector is closed.
- 9. Auxiliary contacts shall be remotely tripped and locked out by four-wire remote pilot devices.
- 10. Network protectors shall have not less than two spare auxiliary dry contacts.
- 11. Network Switchgear-Mounted Disconnect Switch: Supply each network-protector circuit with a switchgear-mounted fuse truck, with Class L fuses rated for 200-kA interrupting capacity, and key interlocked with each associated protector.

Select subparagraph above or below.

2.7 IDENTIFICATION DEVICES

Coordinate this Article with Drawings.

- A. Compartment Nameplates: Engraved, laminated-plastic or metal nameplate for each compartment, mounted with corrosion-resistant screws. Nameplates and label

products are specified in Section 260553 "Identification for Electrical Systems."

2.8 SOURCE QUALITY CONTROL

- A. Factory Tests: Perform design and routine tests according to standards specified for components. Conduct transformer tests according to IEEE C57.12.90. Conduct switchgear and switchboard tests according to ANSI C37.51.
- B. Factory Tests: Perform the following factory-certified tests on each secondary unit substation:
 - 1. Resistance measurements of all windings on the rated voltage connection and on tap extreme connections.
 - 2. Ratios on the rated voltage connection and on tap extreme connections.
 - 3. Polarity and phase relation on the rated voltage connection.
 - 4. No-load loss at rated voltage on the rated voltage connection.
 - 5. Exciting current at rated voltage on the rated voltage connection.
 - 6. Impedance and load loss at rated current on the rated voltage connection and on tap extreme connections.
 - 7. Applied potential.
 - 8. Induced potential.

Tests below are optional; select to suit Project conditions. If Project covers more than one unit of a given kilovolt-ampere rating, consider testing one unit only.

- 9. Temperature Test: If a transformer is supplied with auxiliary cooling equipment to provide more than one rating, test at lowest kilovolt-ampere Class OA or Class AA rating and highest kilovolt-ampere Class FA rating.
 - a. Temperature test is not required if a record of a temperature test on an essentially duplicate unit is available.

Delete subparagraph below if Owner does not want tests to be witnessed.

- 10. Owner will witness all required factory tests. Notify DEN Project Manager at least fourteen (14) days before date of tests and indicate their approximate duration.

PART 3 - PRODUCTS

3.1 EXAMINATION

- A. Examine areas and space conditions for compliance with requirements for secondary unit substations and other conditions affecting performance of work.
- B. Examine roughing-in of conduits and grounding systems to verify the following:
 - 1. Wiring entries comply with layout requirements.
 - 2. Entries are within conduit-entry tolerances specified by manufacturer and no feeders will have to cross section barriers to reach load or line lugs.

- C. Examine walls, floors, roofs, and concrete bases for suitable conditions for secondary unit substation installation.

Adjust 5-ohm value in first paragraph below to suit Project conditions.

- D. Verify that ground connections are in place and that requirements in Section 260526 "Grounding and Bonding for Electrical Systems" have been met. Maximum ground resistance shall be 5 ohms at secondary unit substation location.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install secondary unit substations on concrete bases.

If appropriate, retain subparagraph below for projects in areas of seismic activity.

1. Anchor secondary unit substations to concrete bases according to manufacturer's written instructions, seismic codes at Project, and requirements in Section 260529 "Hangers and Supports for Electrical Systems" and Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Edit subparagraphs below to suit Project. Consider indoor and outdoor transformer locations and seismic requirements, if any.

2. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit and 4 inches (100 mm) high.
 3. Use [3000-psi (20.7-MPa)] <Insert other>, 28-day compressive-strength concrete and reinforcement as specified in Section "[033000 Cast-in-Place Concrete] [033053 Miscellaneous Cast-in-Place Concrete]."
 4. Install dowel rods to connect concrete bases to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.
 5. Install epoxy-coated anchor bolts for anchoring equipment to the concrete base.
 6. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 7. Bolt transformers to channel-iron sills embedded in concrete bases. Install sills level and grout flush with floor or base.
- B. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

3.3 IDENTIFICATION

- A. Identify field-installed wiring and components and provide warning signs as specified in Section 260553 "Identification for Electrical Systems."
- B. Operating Instructions: Frame printed operating instructions for secondary unit

substations, including key interlocking, control sequences, elementary single-line diagram, and emergency procedures. Fabricate frame of finished wood or metal and cover instructions with clear acrylic plastic. Mount on front of secondary unit substation.

3.4 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 CLEANING

- A. After completing equipment installation and before energizing, inspect unit components. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish. Vacuum interiors of secondary unit substation sections.

3.6 FIELD QUALITY CONTROL

Retain paragraph below to require a factory-authorized service representative to perform, or assist Contractor with, field inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect [, **test, and adjust**] field-assembled components and equipment installation, including connections[, **and to assist in field testing**]. Report results in writing.
- B. Perform the following field tests and inspections and prepare test reports:

Retain subparagraphs below with either of last two paragraphs above. Edit to suit Project.

1. Perform each visual and mechanical inspection and electrical test according to NETA ATS. Certify compliance with test parameters.
2. After installing secondary unit substation but before primary is energized, verify that grounding system at the substation tested at the specified value or less.
3. After installing secondary unit substation and after electrical circuitry has been energized, test for compliance with requirements.
4. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
5. Remove and replace malfunctioning units and retest as specified above.

3.7 FOLLOW-UP SERVICE

- A. Voltage Monitoring and Adjusting: After Substantial Completion, if requested by Owner, but not more than six (6) months after Final Acceptance, perform the following voltage monitoring:
1. During a period of normal load cycles as evaluated by Owner, perform seven days of three-phase voltage recording at the outgoing section of each secondary unit substation. Use voltmeters with calibration traceable to the National Institute of Science and Technology standards and with a chart speed of not less than 1 inch (25 mm) per hour. Voltage unbalance greater than 1 percent between phases, or deviation of any phase voltage from the nominal value by more than plus or minus 5 percent during the test period, is unacceptable.
 2. Corrective Action: If test results are unacceptable, perform the following corrective action, as appropriate:
 - a. Adjust transformer taps.
 - b. Rebalance loads.
 - c. Prepare written request for voltage adjustment by electric utility.
 3. Retests: Repeat monitoring, after corrective action has been performed, until satisfactory results are obtained.
 4. Report: Prepare a written report covering monitoring performed and corrective action taken.
- B. Infrared Scanning: Perform as specified in Section 261300 "Medium-Voltage Switchgear."

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain systems. Refer to Section 017900 "Demonstration and Training."
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Seco.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 261116

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SECTION 261200 – MEDIUM-VOLTAGE TRANSFORMERS

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes the following types of transformers with medium-voltage primaries:

Edit to suit Project.

1. Liquid-filled distribution and power transformers.
2. Dry-type distribution and power transformers.
3. Pad-mounted, liquid-filled transformers.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

- A. NETA ATS: Acceptance Testing Specification.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features, location of each field connection, and performance for each type and size of transformer indicated.
1. Include data substantiating that materials comply with requirements.
- B. Include outline and support point dimensions of enclosures and accessories, unit weight, voltage, KVA, K-FACTOR and impedance ratings and characteristics, loss data, efficiency at 25, 50, 75 and 100 percent rated load, sound level, tap configurations, insulation system type, and rated temperature rise.

Edit paragraph below to suit Project. Power, signal, and control wiring are applicable to forced-cooling systems of liquid-filled and dry-type transformers and to high-temperature alarm of dry-type transformers.

- C. Shop Drawings: Diagram power **[signal]** **[and]** **[control]** wiring.

1.5 INFORMATIONAL SUBMITTALS

Retain paragraph and subparagraphs below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

Edit subparagraphs below to suit Project.

1. Underground **[primary]** **[secondary]** **[primary and secondary]** conduit stub-up location.
2. Dimensioned concrete base, outline of transformer, and required clearances.
3. Ground rod and grounding cable locations.
4. **<Insert details.>**

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

Coordinate seismic requirements with DEN Project Manager.

- B. Manufacturer Seismic Qualification Certification: Submit certification that transformer assembly and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition

is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Coordinate first paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- C. Qualification Data: For testing agency.
- D. Source quality-control test reports.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- E. Field quality-control test reports.
- F. Follow-up service reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For transformer and accessories to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

If an independent testing agency is required, see Division 01 Section "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use paragraph below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain paragraph and subparagraph below if Contractor or manufacturer selects testing agency.

- A. Testing Agency Qualifications: An independent testing agency, with the experience

and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

1. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Division 01 requirements.

- B. Product Options: Drawings indicate size, profiles, and dimensional requirements of transformers and are based on the specific system indicated. Refer to Section 016000 "Product Requirements."
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- D. Comply with IEEE C2.
- E. Comply with ANSI C57.12.10, ANSI C57.12.28, IEEE C57.12.70, and IEEE C57.12.80.
- F. Comply with NFPA 70.

1.8 DELIVERY, STORAGE, AND HANDLING

Delete this Article unless indoor-type units are specified. Verify that heating may be deleted if this Section includes dry-type transformers.

- A. Store transformers [**protected from weather and**] so condensation will not form on or in units. Provide temporary heating according to manufacturer's written instructions.
- B. Handle transformers using only lifting eyes and brackets provided for that purpose. Protect units against entrance of rain, sleet, or snow if handled in inclement weather

1.9 PROJECT CONDITIONS

- A. Service Conditions: IEEE C37.121, usual service conditions except for the following:

Select and revise conditions below to suit Project; specify features required to provide satisfactory service. See Editing Instruction No. 3 in the Evaluations for discussion of service conditions.

1. Exposure to significant solar radiation.
2. Altitude: **5,500 feet** (1677 m)
3. Ambient temperature range **-30 deg F** (-35 deg C) to **120 deg F** (49 deg C)
4. Exposure to fumes, vapors, or dust.
5. Exposure to explosive environments.

6. Exposure to hot and humid climate or to excessive moisture, including steam, salt spray, and dripping water.
7. Exposure to seismic shock or to abnormal vibration, shock, or tilting.
8. Exposure to excessively high or low temperatures.
9. Unusual transportation or storage conditions.
10. Unusual grounding-resistance conditions.
11. Unusual space limitations.

B. Power Outages:

1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

1.10 COORDINATION

Delete first paragraph below if no transformers are floor mounted.

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.
- B. Coordinate installation of louvers, doors, spill retention areas, and sumps. Coordinate installation so no piping or conduits are installed in space allocated for medium-voltage transformers except those directly associated with transformers.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

- A. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
 1. Acme Electric Corporation; Power Distribution Products Division.
 2. Cooper Industries; Cooper Power Systems Division.
 3. Cutler-Hammer.
 4. Federal Pacific Transformer Company; Division of Electro-Mechanical Corp.

5. GE Electrical Distribution & Control.
6. Hammond Manufacturing; Transformer Group.
7. Kuhlman Electric Corporation.
8. Pauwels Transformers.
9. Pioneer Transformers.
10. Siemens Energy & Automation, Inc.
11. Square D; Schneider Electric.
12. Uptegraff, R. E. Mfg. Co.
13. Virginia Transformer Corp.
14. Sorgel.
15. Sola/Hevi-Duty.
16. **<Insert manufacturer>**
17. or approved equal.

2.2 LIQUID-FILLED DISTRIBUTION AND POWER TRANSFORMERS

- A. Description: IEEE C57.12.00 and UL 1062, liquid-filled, 2-winding transformers.
- B. Insulating Liquid: Mineral oil, complying with ASTM D 3487, Type II, and tested according to ASTM D 117.

Delete paragraph above if less-flammable insulating liquid is required. Select one of three insulating liquids below; verify availability with selected manufacturers. Transformer primary voltage must be 35 kV or less for less-flammable liquids. See Editing Instruction No. 6 in the Evaluations for discussion of transformer liquids.

- C. Insulating Liquid: Less flammable, edible-seed-oil based, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
- D. Insulating Liquid: Less flammable, dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
- E. Insulating Liquid: Less flammable, silicone-based dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall have low toxicity and be nonhazardous.

Retain one of first two paragraphs below if appropriate temperature rise for Project is other-than-standard 55 deg C.

- F. Insulation Temperature Rise: 65/55 deg C, based on an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C. Insulation system shall be rated to continuously allow an additional 12 percent kilovolt-ampere output, at 65 deg C temperature rise, without decreasing rated transformer life.
- G. Insulation Temperature Rise: 65 deg C, based on an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C.

- H. Basic Impulse Level: Comply with UL 1062.

Retain paragraph above or first paragraph below. See Editing Instruction No. 5 in the Evaluations.

- I. Basic Impulse Level: **[60] [75] [95] [110]** kV.
- J. Full-Capacity Voltage Taps: Four nominal 2.5 percent taps, 2 above and 2 below rated primary voltage; with externally operable tap changer for de-energized use and with position indicator and padlock hasp.

Retain paragraph above or below. Above is NEMA standard.

- K. Full-Capacity Voltage Taps: Four nominal 2.5 percent taps below rated primary voltage, with externally operable tap changer for de-energized use and with position indicator and padlock hasp.

Select class from options in paragraph below. See Editing Instruction No. 4 in the Evaluations for discussion of cooling classes.

- L. Cooling System: Class **[OA, self-cooled] [OA/FA, self-cooled, and with forced-air-cooled rating] [OA/FFA, self-cooled, and with provisions for future forced-air-cooled rating]**. Cooling systems shall include auxiliary cooling equipment, automatic controls, and status indicating lights.

Delete paragraph below if transformer noise is not important. If retaining, consider listing acceptable level. See Editing Instruction No. 2 in the Evaluations for discussion of sound levels.

- M. Sound level may not exceed **[sound levels listed in NEMA TR 1] <Insert acceptable dBA level>**, without fans operating.

1. Maximum guaranteed sound levels are as follows:

KVA Rating:	Sound Level:
1-5	30dB
6-25	40 dB
26-150	42 dB
151-225	43 dB
226-300	47dB
301-500	51dB

Delete first paragraph below if manufacturer's standard impedance is adequate according to system analysis. See Evaluations for typical impedance values.

- N. Impedance: **<Insert value>** percent.
- O. Accessories: Grounding pads, lifting lugs, and provisions for jacking under base. Transformers shall have a steel base and frame allowing use of pipe rollers in any direction, and an insulated, low-voltage, neutral bushing with removable ground strap. Include the following additional accessories:

1. Liquid-level gage.

2. Pressure-vacuum gage.
3. Liquid temperature indicator.
4. Drain and filter valves.
5. Pressure relief device.

2.3 DRY-TYPE DISTRIBUTION AND POWER TRANSFORMERS

In first paragraph below, retain ANSI C57.12.50 for dry-type transformers rated up to 500 kVA, ANSI C57.12.51 for dry-type transformers rated 501 kVA and larger, or ANSI C57.12.52 for sealed dry-type transformers rated 501 kVA and larger. UL 1562 listing covers the range of 1 to 5000 kVA.

- A. Description: NEMA ST 20, IEEE C57.12.01, [**ANSI C57.12.50**] [**ANSI C57.12.51**] [**ANSI C57.12.52**], [**UL 1562 listed and labeled**], dry-type, 2-winding transformers.
1. [**Indoor, ventilated**] [**Outdoor, ventilated**] [**Totally enclosed, nonventilated**], cast coil/encapsulated coil, with primary and secondary windings individually cast in epoxy; with insulation system rated at 185 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.

Retain subparagraph above or below. See Editing Instruction No. 8 in the Evaluations for discussion of cast coil/encapsulated coil and vacuum-pressure-impregnated transformer styles.

2. [**Indoor, ventilated**] [**Outdoor, ventilated**] [**Totally enclosed, nonventilated**], vacuum-pressure impregnated and with insulation system rated at 220 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.
 3. All transformer windings shall be copper.
- B. Enclosure top temperature shall not exceed 35 deg C rise above 40 deg C ambient at its warmest point.
- C. Primary Connection: Air terminal compartment with [**removable**] [**hinged**] door. Tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.

Retain paragraph above or first paragraph below to suit Project.

- D. Primary Connection: Transition terminal compartment with connection pattern to match switchgear.
- E. Secondary Connection: Air terminal compartment with [**removable**] [**hinged**] door. Tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.

Retain paragraph above or first paragraph below to suit Project.

- F. Secondary Connection: Transition terminal compartment with connection pattern to match [**switchgear**] [**bus duct**] <**Insert connection pattern**>.
- G. Insulation Materials: IEEE C57.12.01, rated at 220 deg C.

- H. Insulation Temperature Rise: **[80] [115] [150]** deg C, maximum rise above 40 deg C.

See Editing Instruction No. 5 in the Evaluations for discussion of basic impulse levels.

- I. Basic Impulse Level: **[10] [60] [75] [95] [110]** kV.
- J. Full-Capacity Voltage Taps: Four nominal 2.5 percent taps, 2 above and 2 below rated primary voltage.

Select class from options in paragraph below. See Editing Instruction No. 4 in the Evaluations for discussion of cooling classes.

- K. Cooling System: Class **[AA, self-cooled] [AA/FA, self-cooled, and with forced-air-cooled rating] [AA/FFA, self-cooled, and with provisions for future forced-air-cooled rating]**, complying with IEEE C57.12.01.

If retaining first option in paragraph above, delete both subparagraphs below.

1. Automatic forced-air cooling system controls, including thermal sensors, fans, control wiring, temperature controller with test switch, power panel with current-limiting fuses, indicating lights, alarm, and alarm silencing relay.

If retaining second option in paragraph above, delete subparagraph below.

2. Include mounting provision for fans.
3. Transformer cooling fans, when required shall be of the sealed bearing type.

Delete paragraph below if transformer noise is not important. If retaining, consider listing acceptable level. See Editing Instruction No. 2 in the Evaluations for discussion of sound levels.

- L. Sound level may not exceed **<Insert acceptable dBA level> [sound levels listed in NEMA TR 1]**, without fans operating.

1. Maximum guaranteed sound levels are as follows:

KVA Rating:	Sound Level:
1-5	30dB
6-25	40 dB
26-150	42 dB
151-225	43 dB
226-300	47dB
301-500	51dB

Delete paragraph below if manufacturer's standard impedance is adequate according to system analysis. See Evaluations for typical impedance values.

- M. Impedance: **<Insert value>** percent.

If retaining paragraph below, coordinate with Drawings and provide external power and signal connections.

- N. High-Temperature Alarm: Sensor at transformer with local audible and visual alarm and contacts for remote alarm.

- O. Ground core and coil assembly to enclosure by means of a visible flexible copper-grounding strap.
- P. Mounting: Transformers 30 KVA and larger shall be, floor mounted; Transformers less than 30 KVA shall be designed for either floor or wall mount.
- Q. Isolate transformer-winding assemblies from enclosure using vibration-absorbing mounts.

2.4 DRY TYPE TRANSFORMERS FOR NON-LINEAR LOAD

- A. In addition to the requirements of paragraph 2.02, transformers for non-linear loads shall be three phase, 60 Hertz, with delta connected primary and wye connected secondary windings.
- B. Copper electrostatic shielding shall be inserted between the primary and secondary windings.
- C. The primary winding conductors shall be of sufficient size to limit the temperature rise to its rated value even with the circulating third harmonic current.
- D. The secondary neutral shall be twice the ampacity of the secondary phase conductors.

2.5 PAD-MOUNTED, LIQUID-FILLED TRANSFORMERS

In first paragraph below, retain ANSI C57.12.26 for pad-mounted transformers with dead-front, separable, insulated, high-voltage, load-break cable connectors or IEEE C57.12.22 for pad-mounted transformers with live-front high-voltage bushings.

- A. Description: ANSI C57.12.13, [**ANSI C57.12.26,**]IEEE C57.12.00,[**IEEE C57.12.22,**] pad-mounted, 2-winding transformers. Stainless-steel tank base [**and cabinet**] [, **cabinet, and sills**].
- B. Insulating Liquid: Mineral oil, complying with ASTM D 3487, Type II, and tested according to ASTM D 117.

Delete paragraph above if less-flammable insulating liquid is required. Select one of three insulating liquids below; verify availability with selected manufacturers. Transformer primary voltage must be 35 kV or less for less-flammable liquids. See Editing Instruction No. 6 in the Evaluations for discussion of transformer liquids.

- C. Insulating Liquid: Less flammable, edible-seed-oil based, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
- D. Insulating Liquid: Less flammable, dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.

- E. Insulating Liquid: Less flammable, silicone-based dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall have low toxicity and be nonhazardous.

Retain paragraph below if appropriate temperature rise for Project is other-than-standard 55 deg C.

- F. Insulation Temperature Rise: [55] [65] deg C when operated at rated kVA output in a 40 deg C ambient temperature. Transformer shall be rated to operate at rated kilovolt ampere in an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C without loss of service life expectancy.

If transformers have standard basic impulse level, retain paragraph below. If basic impulse level is other than standard, revise below or delete and note basic impulse level in schedule. See Editing Instruction No. 5 in the Evaluations.

- G. Basic Impulse Level: [30] [60] [95] kV.

Revise paragraph below if other-than-NEMA-standard taps are required. Coordinate with schedule.

- H. Full-Capacity Voltage Taps: Four 2.5 percent taps, 2 above and 2 below rated high voltage; with externally operable tap changer for de-energized use and with position indicator and padlock hasp.

Select one of first two paragraphs below to suit transformer's high-voltage terminal arrangement. Coordinate switch rating with transformer rating, system fault currents, and basic impulse level for associated equipment.

- I. High-Voltage Switch: [200] [300] [400] A, make-and-latch rating of 10-kA RMS, symmetrical, arranged for radial feed with 3-phase, 2-position, gang-operated, load-break switch that is oil immersed in transformer tank with hook-stick operating handle in primary compartment.

Loop-feed arrangement below may be used for radial feed to provide an extra set of terminals for dead-front, insulated, load-break, connector-type surge arresters.

- J. High-Voltage Switch: [200] [300] [400] A, make-and-latch rating of 10-kA RMS, symmetrical, arranged for loop feed with 3-phase, 4-position, gang-operated, load-break switch that is oil immersed in transformer tank with hook-stick operating handle in primary compartment.

Delete paragraph and subparagraphs below if primary fuse is specified in Division 26 Section "Low-Voltage Overhead Electrical Power Systems." Select a primary fusing arrangement acceptable to organization that changes blown fuses and maintains the system. Coordinate fuse rating with transformer rating, system fault currents, and other protective devices; show characteristics on Drawings.

- K. Primary Fuses: 150-kV fuse assembly with fuses complying with IEEE C37.47. [**Rating of current-limiting fuses shall be 50-kA RMS at specified system voltage.**]
1. Current-limiting type in dry-fuse holder wells, mechanically interlocked with liquid-immersed switch in transformer tank to prevent disconnect under load.
 2. Internal liquid-immersed cartridge fuses.
 3. Bay-O-Net liquid-immersed fuses that are externally replaceable without opening

- transformer tank.
4. Bay-O-Net liquid-immersed fuses in series with liquid-immersed current-limiting fuses. Bay-O-Net fuses shall be externally replaceable without opening transformer tank.
 5. Bay-O-Net liquid-immersed current-limiting fuses that are externally replaceable without opening transformer tank.

Delete paragraph below if dead-front arrangement is selected. Select and specify arrester rating to suit primary system parameters. See Editing Instruction No. 7 in the Evaluations for discussion on applying surge arresters.

- L. Surge Arresters: Distribution class, one for each primary phase; complying with IEEE C62.11 and NEMA LA 1; support from tank wall within high-voltage compartment. Transformers shall have **[three arresters for radial-feed] [three arresters for loop-feed] [six arresters for loop-feed]** circuits.

Select from first two paragraphs below.

- M. High-Voltage Terminations and Equipment: Live front with externally clamped porcelain bushings and cable connectors suitable for terminating primary cable.

For dead-front arrangement in paragraph below, specify insulated, high-voltage, load-break cable connectors in Division 26 Section "Medium-Voltage Cables."

- N. High-Voltage Terminations and Equipment: Dead front with universal-type bushing wells for dead-front bushing-well inserts, complying with IEEE 386 and including the following:
1. Bushing-Well Inserts: One for each high-voltage bushing well.

Delete items below if not applicable.

2. Surge Arresters: Dead-front, elbow-type, metal-oxide-varistor units.
3. Parking Stands: One for each high-voltage bushing well.
4. Portable Insulated Bushings: Arranged for parking insulated, high-voltage, load-break cable terminators; one for each primary feeder conductor terminating at transformer.

- O. Accessories:

Delete items below if not required. Coordinate with Drawings.

1. Drain Valve: 1 inch (25 mm), with sampling device.
2. Dial-type thermometer.
3. Liquid-level gage.
4. Pressure-vacuum gage.
5. Pressure Relief Device: Self-sealing with an indicator.
6. Mounting provisions for low-voltage current transformers.
7. Mounting provisions for low-voltage potential transformers.

If retaining either item below, provide detailed requirements here or on Drawings.

8. Busway terminal connection at low-voltage compartment.

9. Alarm contacts for gages and thermometer listed above.

2.6 IDENTIFICATION DEVICES

Coordinate this Article with Drawings.

- A. Nameplates: Engraved, laminated-plastic or metal nameplate for each transformer, mounted with corrosion-resistant screws. Nameplates and label products are specified in Section 260553 "Identification for Electrical Systems."
 1. Include transformer connection data and overload capacity based on rated allowable temperature rise.

2.7 SOURCE QUALITY CONTROL

In first paragraph below, ANSI C57.12.50 applies to ventilated dry-type distribution transformers 1 to 500 kVA, single phase, and 15 to 500 kVA, 3 phase, with high voltage 601 to 34,500 V and low voltage 208Y/120 to 4160 V. ANSI C57.12.51 applies to ventilated dry-type power transformers 501 kVA and larger, 3 phase, with high voltage 601 to 34,500 V and low voltage 208Y/120 to 4160 V. IEEE C57.12.90 applies to liquid-filled transformers. IEEE C57.12.91 applies to dry-type distribution and power transformers.

- A. Factory Tests: Perform design and routine tests according to standards specified for components. Conduct transformer tests according to **[ANSI C57.12.50] [ANSI C57.12.51] [IEEE C57.12.90] [IEEE C57.12.91]**.
- B. Factory Tests: Perform the following factory-certified tests on each transformer:
 1. Resistance measurements of all windings on rated-voltage connection and on tap extreme connections.
 2. Ratios on rated-voltage connection and on tap extreme connections.
 3. Polarity and phase relation on rated-voltage connection.
 4. No-load loss at rated voltage on rated-voltage connection.
 5. Excitation current at rated voltage on rated-voltage connection.
 6. Impedance and load loss at rated current on rated-voltage connection and on tap extreme connections.
 7. Applied potential.
 8. Induced potential.

Temperature test below is optional; revise to suit Project. If Project includes more than one transformer of a given kilovolt-ampere rating, consider testing one unit only.

9. Temperature Test: If transformer is supplied with auxiliary cooling equipment to provide more than one rating, test at lowest kilovolt-ampere Class OA or Class AA rating and highest kilovolt-ampere Class OA/FA or Class AA/FA rating.
 - a. Temperature test is not required if record of temperature test on an essentially duplicate unit is available.

Delete subparagraph below if Owner does not want to witness tests.

10. Owner will witness all required factory tests. Notify DEN Project Manager at least fourteen (14) days before date of tests and indicate their approximate duration.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for medium-voltage transformers.
- B. Examine roughing-in of conduits and grounding systems to verify the following:
 1. Wiring entries comply with layout requirements.
 2. Entries are within conduit-entry tolerances specified by manufacturer and no feeders will have to cross section barriers to reach load or line lugs.
- C. Examine walls, floors, roofs, and concrete bases for suitable mounting conditions where transformers will be installed.

Adjust 5-ohm value in first paragraph below to suit Project.

- D. Verify that ground connections are in place and that requirements in Section 260526 "Grounding and Bonding for Electrical Systems" have been met. Maximum ground resistance shall be 5 ohms at location of transformer.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Transformers 30 KVA and larger shall be floor mounted. Transformers less than 30KVA shall be floor or wall mounted.
- B. Install transformers on concrete bases.

If appropriate, retain subparagraph below for projects in areas of seismic activity.

1. Anchor transformers to concrete bases according to manufacturer's written instructions, seismic codes at Project, and requirements in Section 260529 "Hangers and Supports for Electrical Systems."
2. Set transformer plumb and level.

Edit subparagraphs below to suit Project. Consider indoor and outdoor transformer locations and seismic requirements, if any.

3. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit and 4 inches (100 mm) high.
4. Use [3000-psi (20.7-MPa)] <Insert other>, 28-day compressive-strength concrete and reinforcement as specified in Section[s] [033000 "Cast-in-Place Concrete"]

[033053 "Miscellaneous Cast-in-Place Concrete"].

5. Install dowel rods to connect concrete bases to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.
 6. Install epoxy-coated anchor bolts, for supported equipment, that extend through concrete base and anchor into structural concrete floor.
 7. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 8. Tack-weld or bolt transformers to channel-iron sills embedded in concrete bases. Install sills level and grout flush with floor or base.
- C. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.
- D. Use flexible conduit, 3 feet maximum length, for connections to transformer case. Make conduit connections to side panel of enclosure.
- E. Mount transformers on vibration isolating pads suitable for isolating the transformer noise from the building structure.
- F. Use a copper busbar bolted to the transformer case to bond XO, Primary feeder grounding conductor, secondary grounding conductor, and grounding electrode conductor with copper conductor sized according to table 250-66 in the NEC.

3.3 IDENTIFICATION

- A. Identify field-installed wiring and components and provide warning signs as specified in Section 260553 "Identification for Electrical Systems."

3.4 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

Retain paragraph below to require a factory-authorized service representative to perform, or assist Contractor with, field inspections, tests, and adjustments. Retain one of two options to suit Project; delete both to require only an inspection before field testing.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect[, **test, and adjust**] field-assembled components and equipment installation,

including connections[, **and to assist in field testing**]. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

Edit to suit Project. Delete subparagraphs if testing will be performed by Owner-engaged testing and inspecting agency.

1. After installing transformers but before primary is energized, verify that grounding system at substation is tested at specified value or less.
2. Check for damage and tighten connections prior to energizing transformer. Submit torque values and check list to the DEN Project Manager. .
3. After installing transformers and after electrical circuitry has been energized, test for compliance with requirements.
4. Perform visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
6. Remove and replace malfunctioning units and retest as specified above.

C. Test Reports: Prepare written reports to record the following:

1. Test procedures used.
2. Test results that comply with requirements.
3. Test results that do not comply with requirements and corrective actions taken to achieve compliance with requirements.

3.6 FOLLOW-UP SERVICE

A. Voltage Monitoring and Adjusting: If requested by Owner, perform the following voltage monitoring after Substantial Completion but not more than six (6) months after Final Acceptance:

1. During a period of normal load cycles as evaluated by Owner, perform seven days of three-phase voltage recording at secondary terminals of each transformer. Use voltmeters with calibration traceable to National Institute of Science and Technology standards and with a chart speed of not less than 1 inch (25 mm) per hour. Voltage unbalance greater than 1 percent between phases, or deviation of any phase voltage from nominal value by more than plus or minus 5 percent during test period, is unacceptable.
2. Corrective Actions: If test results are unacceptable, perform the following corrective actions, as appropriate:
 - a. Adjust transformer taps.
 - b. Prepare written request for voltage adjustment by electric utility.
3. Retests: After corrective actions have been performed, repeat monitoring until satisfactory results are obtained.
4. Report: Prepare written report covering monitoring and corrective actions performed.

- B. Infrared Scanning: Perform as specified in Section 261300 "Medium-Voltage Switchgear."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 261200

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SECTION 261300 - MEDIUM-VOLTAGE SWITCHGEAR

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES ARE TO BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes metal-clad, circuit-breaker switchgear with the following optional components, features, and accessories:

Edit to suit Project.

1. **[Copper, silver-plated main bus at connection points] [Copper, tin-plated main bus].**
2. Communication modules.
3. Provisions for future devices.
4. Control battery system.
5. Mimic bus.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviations that remain after this Section has been edited.

- A. ATS: Acceptance Testing Specifications.

B. GFCI: Ground-Fault Circuit Interrupter.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

A. Product Data: For each type of switchgear and related equipment, include the following:

1. Rated capacities, operating characteristics, furnished specialties, and accessories for individual circuit breakers.
2. Time-current characteristic curves for overcurrent protective devices, including circuit-breaker relay trip devices.
3. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For each type of switchgear and related equipment, include the following:

1. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show method of field assembly and location and size of each field connection. Include the following:
 - a. Tabulation of installed devices with features and ratings.
 - b. Outline and general arrangement drawing showing dimensions, shipping sections, and weights of each assembled section.
 - c. Drawing of cable termination compartments showing preferred locations for conduits and indicating space available for cable terminations.
 - d. Floor plan drawing showing locations for anchor bolts [**and leveling channels**].
 - e. Current ratings of buses.
 - f. Short-time and short-circuit ratings of switchgear assembly.
 - g. Nameplate legends.
 - h. Mimic-bus diagram.

Retain subparagraph below if required.

- i. Utility company's metering provisions with indication of approval by utility company.

Retain first subparagraph below if products are required to withstand specific design loads and DEN Project Manager either has delegated design responsibility to Contractor or wants to review structural data as another way to verify products' compliance with performance requirements. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

2. Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting seismic restraints.
3. Wiring Diagrams: For each type of switchgear and related equipment, include the following:
 - a. Power, signal, and control wiring.

- b. Three-line diagrams of current and future secondary circuits showing device terminal numbers and internal diagrams.
- c. Schematic control diagrams.
- d. Diagrams showing connections of component devices and equipment.
- e. Schematic diagrams showing connections to remote devices[including SCADA remote terminal unit].

Retain first paragraph below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- C. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around switchgear where piping and ducts are prohibited. Show switchgear layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Identify field measurements.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager.

Coordinate sample requirements with DEN Project Manager.

- D. Samples: Representative portion of mimic bus with specified finish. Manufacturer's color charts showing colors available for mimic bus.

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For installer and product manufacturers.
- B. Source quality-control test reports.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- C. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For switchgear and switchgear components to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - 1. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

2. Time-current curves, including selectable ranges for each type of overcurrent protective device.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

A. Factory Testing and Witness Testing:

1. Furnish all test equipment and personnel, and perform all tests as may be required and as specified herein.
2. The manufacturer shall perform all tests normally conducted in accordance with the manufacturer's standard test procedures for all substations. In addition, the manufacturer shall perform all supplementary testing as defined throughout this specification for all substations. All normal and supplemental testing, which is not witnessed by the DEN Project Manager, shall be documented in certified test reports and shall be submitted to the DEN Project Manager for review within two weeks of the performance of the testing.
3. The following tests shall be performed at the factory and shall be witnessed by the Engineer of Record and DEN Project Manager, or their duly authorized representative:
 - a. A complete visual inspection of the equipment, both internally and externally.
 - b. A complete test of all automatic transfer schemes including all operation and failure modes.
 - c. A complete test of all control panels and controls including dry contact outputs.
 - d. Verification of proper operation of all metering.
 - e. Verify mechanical operation; interlocks and interchangeability of selected breakers.
4. The testing outlined in item "A" above shall be performed only on one main switchgear. In order to perform such testing, all breakers shall be shipped to the switchboard factory and installed in their respective cubicles in a completely assembled Distribution Section
5. Test 208 volt and /or 480 volt, 3-phase power sources shall be connected to the incoming side of each secondary main such that the sources may be individually applied and removed to completely simulate and test all features of the distribution sections.
6. Submit to the DEN Project Manager ninety (90) calendar days prior to scheduled testing all test procedures for approval, and notify the DEN Project Manager four (4) weeks prior to scheduled testing what the expected duration of the tests will be.
7. Provide four (4) copies of the factory test report within two (2) weeks of the

completion of such witness tests.

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use one of first two paragraphs below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain first paragraph and subparagraph below if Contractor selects testing agency.

- B. Source Limitations: Obtain each type of switchgear and associated components through one source from a single manufacturer.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Section 016000 "Product Requirements."

- C. Product Options: Drawings indicate size, profiles, and dimensional requirements of switchgear and are based on the specific system indicated. Refer to Section 016000 "Product Requirements."
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Comply with IEEE C2.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver in sections of lengths that can be moved past obstructions in delivery path as indicated.

Retain one of two paragraphs below and edit to suit Project.

- B. Store switchgear indoors in clean dry space with uniform temperature to prevent condensation. Protect switchgear from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- C. If stored in areas subjected to weather, cover switchgear to provide protection from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside switchgear; install electric heating (250 W per section) to prevent condensation.
- D. Handle in accordance with manufacturer's written instructions. Lift only with lugs provided for the purpose. Handle carefully to avoid damage to switchgear internal components, enclosure, and finish.

1.9 PROJECT CONDITIONS

Medium-voltage switchgear assemblies are designed for application at rated continuous load current where altitude above sea level does not exceed 3300 feet (1005 m), ambient air temperature does not

exceed 40 deg C, and effects of solar radiation can be neglected. Edit paragraph and subparagraphs below for Project conditions exceeding these parameters.

- A. Environmental Limitations: Rate equipment for continuous operation at indicated ampere ratings for the following conditions:
1. Ambient temperature range: -30 deg F (-35 deg C) to 120 deg F (49 deg C)
 2. Altitude: 5500 feet (1677 m) above sea level.
 3. Excessive solar radiation.
 4. **<Insert unusual service conditions.>**

Revise paragraph below to describe specific requirements for moving switchgear into place. Where appropriate, indicate alterations to existing facilities that may be required to accommodate an indicated delivery path. Coordinate with Drawings.

- B. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.

Retain paragraph below if installation space for switchgear is limited; show maximum dimensions on Drawings.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear and adjacent surfaces and other items. Comply with indicated maximum dimensions.

Retain paragraph and subparagraphs below if interruption of existing utility service is required.

- D. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 2. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.

1.10 COORDINATION

Edit first paragraph below to delete or add types of construction that penetrate or are supported by ceilings.

- A. Coordinate layout and installation of switchgear and components with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required clearances for workspace and equipment access doors and panels.
- B. Coordinate size and location of concrete bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.11 EXTRA MATERIALS

Extra materials may not be allowed for publicly funded projects.

Coordinate extra stock requirements with DEN Project Manager.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fuses: **[Six (6)]** <Insert number> of each type and rating used. Include spares for future transformers, control power circuits, and fusible devices.
 - 2. Indicating Lights: **[Six (6)]** <Insert number> of each type installed.
 - 3. Touchup Paint: **[Three (3)]** <Insert number> containers of paint matching enclosure finish, each **0.5 pint** (250 mL).
- B. Maintenance Tools: Furnish tools and miscellaneous items required for interrupter switchgear test, inspection, maintenance, and operation. Include the following:
 - 1. Fuse-handling tool.
 - 2. Extension rails, lifting device, transport or dockable dolly or mobile lift, and all other items necessary to remove circuit breaker from housing and transport to remote location.
 - 3. Racking handle to move circuit breaker manually between connected and disconnected positions, and a secondary test coupler to permit testing of circuit breaker without removal from switchgear.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

Edit this Article with other Part 2 articles in which manufacturers are named. See Section 016000 "Product Requirements" for an explanation of the terms "Available Manufacturers" and "Manufacturers" and the effect these terms have on "Comparable Product" and "Product Substitution" requirements.

- A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following manufacturers:
 - a. **<Insert manufacturer>**
 - b. or approved equal.

2.2 MANUFACTURED UNITS

- A. Description: Factory assembled and tested, and complying with IEEE C37.20.1.

Revise first paragraph below to suit system in which switchgear will be installed.

- B. Ratings: Suitable for application in 3-phase, 60-Hz, solidly grounded-neutral system.
- C. System Voltage: **[4.16 kV nominal; 4.76 kV maximum] [7.2 kV nominal; 15 kV maximum] [13.8 kV nominal; 15 kV maximum] [34.5 kV nominal; 38 kV maximum] <Insert other voltage>**.

Coordinate paragraph and list below with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.

Retain first paragraph below for conventional switchgear; retain first two paragraphs for arc-resistant switchgear. See Evaluations for description of each switchgear type. Verify availability with manufacturers.

Delete subparagraph below if ampere rating is shown on Drawings.

Specify fuses in paragraph below and indicate both available-source fault current and required fuse interrupting ratings on Drawings.

Retain one of two subparagraphs below.

2.3 METAL-CLAD, CIRCUIT-BREAKER SWITCHGEAR

Coordinate paragraph and list below with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.

- A. Subject to compliance with requirements, provide products by one of the following:
 1. ABB Control, Inc.
 2. Eaton Corporation; Cutler-Hammer Products.
 3. General Electric Distribution & Control.
 4. Siemens Energy & Automation, Inc.
 5. Square D; Schneider Electric.
 6. **<Insert manufacturer>**
 7. or approved equal.

Retain first paragraph below for conventional switchgear; retain first two paragraphs for arc-resistant switchgear. See Evaluations for description of each switchgear type. Verify availability with manufacturers.

- B. Comply with IEEE C37.20.3.
- C. Comply with IEEE C37.20.7. Provide arc-resistant switchgear, Type [1] [2] [1C] [2C].
- D. Nominal Interrupting-Capacity Class: [250] [350] [500] [750] [1000] MVA.
- E. Ratings: Comply with IEEE C37.04.

Delete subparagraph below if ampere rating is shown on Drawings.

- F. Circuit Breakers: Three-pole, single-throw, electrically operated, drawout-mounting units using three individual, [vacuum-sealed] [sulfur hexafluoride insulated and sealed] interrupter modules and including the following features:

Retain subparagraph below if sulfur hexafluoride circuit breakers are used.

Retain and revise first three subparagraphs below to suit Project.

- 1. Operating Mechanism: Electrically charged, mechanically and electrically trip-free, stored-energy operated.
 - a. Design mechanism to permit manual charging and slow closing of contacts for inspection or adjustment.

Retain one of first two subparagraphs below and select from control power options. See Evaluations for discussion.

- 1) Control Power: [48] [125] <Insert voltage>-V dc for closing and tripping.

Retain remaining paragraphs and subparagraphs if required to suit Project.

- G. Test Accessories: Relay and meter test plugs.

Coordinate paragraph below with Drawings.

- H. Low-DC-Voltage Alarm: Switchgear shall have a monitor for dc control power voltage with a remote alarm located where indicated. Alarm shall sound if voltage falls to an adjustable value to indicate an impending battery failure. Factory set alarm value at 80 percent of full-charge voltage.

Retain paragraph and subparagraphs below if required by serving utility company or by medium-voltage maintenance and testing agency serving Project facility. Utility requirements below are examples only; revise to suit Project.

- I. Grounding and Testing Device: Suitable for phasing out, testing, and grounding switchgear bus or feeder if device is installed in place of circuit breaker. Include the following:
 - 1. Portable Grounding and Testing Device: Interchangeable with drawout-mounting, medium-voltage circuit breakers to provide interlocked electrical access to either bus or feeder; electrically operated.

2. System control cabinet permanently mounted near switchgear.
3. Portable Remote-Control Station: For grounding and testing device.
4. Control-Cabinet Coupler Cable: Of adequate length to connect device inserted in any switchgear cubicle and control cabinet.
5. Remote-Control Coupler Cable: **50 feet** (15 m) long to connect control cabinet and portable remote-control station.
6. Permanent Control Power Wiring: From control cabinet to power source.
7. Protective Cover: Fabricated of heavy-duty plastic and fitted to device.
8. Approval of Grounding and Testing Device System: Obtain approval of final system design from utility company and agency designated by Owner to handle future maintenance of medium-voltage switchgear.

Coordinate first paragraph below with Drawings.

- J. Circuit-Breaker Test Cabinet: Separately mounted and containing push buttons for circuit-breaker closing and tripping, control relay, fuses, and secondary coupler with cable approximately **108 inches** (2740 mm) long. Include a set of secondary devices for operating circuit breaker if removed from switchgear and moved near test cabinet. Include provision for storage of test and maintenance accessories in cabinet.
- K. Remote-Tripping Device: Wall-mounting emergency control station to open circuit breakers; located in red cast-metal box with break-glass operation.

2.4 FABRICATION

- A. Indoor Enclosure: Steel.

Retain paragraph above or first paragraph and subparagraphs below, or both; edit to suit Project. Consider local experience and practice, especially for outdoor switchgear.

- B. Outdoor Enclosure: Galvanized steel, weatherproof construction; integral structural-steel base frame with factory-applied asphaltic undercoating.
 1. Each compartment shall have the following features:
 - a. Structural design and anchorage adequate to resist loads imposed by **[125-mph (200-km/h)] <Insert wind speed>** wind.
 - b. Space heater operating at one-half or less of rated voltage, sized to prevent condensation.
 - c. Louvers equipped with insect and rodent screen and filter, and arranged to permit air circulation while excluding rodents and exterior dust.

Delete first three subparagraphs below if weatherproof internal aisle construction is retained.

- d. Power for heaters, lights, and receptacles to be provided **[by control power transformer] [as indicated]**.

Retain subparagraph and associated subparagraphs below for weatherproof internal aisle construction.

2. Weatherproof internal aisle construction shall have the following features:

- a. Common internal aisle of sufficient width to permit protective-device withdrawal, disassembly, and servicing in aisle.
- b. Aisle access doors at each end with exterior locking provisions and interior panic latches.
- c. Aisle space heaters operating at one-half or less of rated voltage, thermostatically controlled.
- d. Vaporproof fluorescent aisle lights with low-temperature ballasts, controlled by wall switch at each entrance.
- e. GFCI duplex receptacles, a minimum of two, located in aisle.

Revise subparagraph below if forced rather than natural ventilation is required.

- f. Aisle ventilation louvers equipped with insect and rodent screen and filter, and arranged to permit air circulation while excluding rodents and exterior dust.

- C. Finish: Manufacturer's standard gray finish over rust-inhibiting primer on phosphatizing-treated metal surfaces.
- D. Bus Transition Unit: Arranged to suit bus and adjacent units.
- E. Incoming-Line Unit: Arranged to suit incoming line.
- F. Outgoing Feeder Units: Arranged to suit distribution feeders.
- G. Auxiliary Compartments: Arranged to suit house meters, relays, controls, and auxiliary equipment; isolated from medium-voltage components.
- H. Key Interlocks: Arranged to effect interlocking schemes indicated.
- I. Provisions for Future Key Interlocks: Mountings and hardware required for future installation of locks, where indicated.

2.5 COMPONENTS

- A. Main Bus: **[Copper, silver plated at connection points] [Copper, tin plated]**; full length of switchgear.
- B. Ground Bus: Copper, silver plated or copper, tin plated; minimum size **1/4 by 2 inches** (6 by 50 mm); full length of switchgear.
- C. Bus Insulation: Covered with flame-retardant insulation.
- D. Instrument Transformers: Comply with IEEE C57.13.
 1. Potential Transformers: Secondary voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.

Coordinate subparagraph below with Drawings.

2. Current Transformers: Burden and accuracy class suitable for connected relays, meters, and instruments.

Delete paragraph and subparagraphs below if conventional analog-meter installation is required.

- E. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems, listed and labeled by an NRTL, and with the following features:
1. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 2. Switch-selectable digital display with the following features:
 - a. Phase Currents, Each Phase: Plus or minus 1 percent.
 - b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - d. Three-Phase Real Power: Plus or minus 2 percent.
 - e. Three-Phase Reactive Power: Plus or minus 2 percent.
 - f. Power Factor: Plus or minus 2 percent.
 - g. Frequency: Plus or minus 0.5 percent.
 - h. Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.

Retain subparagraph below if required.

- i. Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.

Coordinate first subparagraph below with Section 260913 "Electrical Power Monitoring and Control" or with other remote monitoring system.

3. Communications module suitable for remote monitoring of meter quantities and functions. Interface communication and metering requirements according to Section 260913 "Electrical Power Monitoring and Control."
4. Mounting: Display and control unit that is flush or semiflush mounted in instrument compartment door.

Delete paragraph and subparagraphs below if multifunction digital-metering monitor above is specified.

Delete option in first subparagraph below for three-wire systems.

Revise demand interval and other characteristics in two subparagraphs and associated subparagraphs below to suit Project.

Delete paragraph below unless relays that are not integral with circuit breakers or circuit-breaker trip units are required. Specify relay functions and characteristics below or indicate on Drawings.

Retain paragraph and subparagraphs below if system analysis shows arresters are required at switchgear. Show ratings of arresters on Drawings.

Retain paragraph below if required. Coordinate with Drawings.

- F. Provision for Future Devices: Equip compartments with rails, mounting brackets, supports, necessary appurtenances, and bus connections.

Retain first paragraph below for installation in tropical environments.

G. Control Power Supply: DC battery system.

Retain paragraph above or first paragraph and subparagraphs below. If retaining above, retain "Control Battery System" Article.

Retain subparagraph below for electrically interlocked main and tie circuit breakers.

Retain one of first two subparagraphs below.

H. Control Wiring: Factory installed, complete with bundling, lacing, and protection; and complying with the following:

1. Flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.
2. Conductors sized according to NFPA 70 for duty required.

2.6 CONTROL BATTERY SYSTEM

Retain this Article if dc control power source is required. Revise if battery other than lead-calcium type below is specified.

Coordinate first paragraph below with Drawings or, preferably, revise to specify number of cells and required minimum ampere-hour capacity of battery.

- A. System Requirements: Battery shall have number of cells and ampere-hour capacity based on an initial specific gravity of 1.210 at 25 deg C with electrolyte at normal level and minimum ambient temperature of 13 deg C. Cycle battery before shipment to guarantee rated capacity on installation. Arrange battery to operate ungrounded.
- B. Battery: Lead-calcium type in sealed, clear plastic or glass containers, complete with electrolyte, fully charged and arranged for shipment with electrolyte in cells. Limit weight of each container to not more than **70 lb** (32 kg) and cells per container to not more than 3. System batteries shall be suitable for service at an ambient temperature ranging from minus 18 to 25 deg C. Limit variation of current output to 0.8 percent for each degree below 25 deg C down to minus 8 deg C.

Coordinate first two paragraphs and associated subparagraphs below with Drawings.

- C. Rack: Two-step rack with electrical connections between battery cells and between rows of cells; include two flexible connectors with bolted-type terminals for output leads. Rate battery rack, cell supports, and anchorage for seismic requirements.
- D. Accessories:
1. Thermometers with specific-gravity correction scales.
 2. Hydrometer syringes.
 3. Set of socket wrenches and other tools required for battery maintenance.
 4. Wall-mounting, nonmetallic storage rack fitted to store above items.
 5. Set of cell numerals.

- E. Charger: Static-type silicon rectifier equipped with automatic regulation and provision for manual and automatic adjustment of charging rate. Unit shall automatically maintain output voltage within 0.5 percent from no load to rated charger output current, with ac input-voltage variation of plus or minus 10 percent and input-frequency variation of plus or minus 3 Hz. Other features of charger include the following:
1. DC ammeter.
 2. DC Voltmeter: Maximum error of 5 percent at full-charge voltage; operates with toggle switch to select between battery and charger voltages.
 3. Ground Indication: Two appropriately labeled lights to indicate circuit ground, connected in series between negative and positive terminals, with midpoint junction connected to ground by normally open push-button contact.
 4. Capacity: Sufficient to supply steady load, float-charge battery between 2.20 and 2.25 V per cell and equalizing charge at 2.33 V per cell.
 5. Charging-Rate Switch: Manually operated switch provides for transferring to higher charging rate. Charger operates automatically after switch operation until manually reset.
 6. AC power supply is 120 V, 60 Hz, subject to plus or minus 10 percent variation in voltage and plus or minus 3-Hz variation in frequency. After loss of ac power supply for any interval, charger automatically resumes charging battery. Charger regulates rate of charge to prevent damage due to overload and to prevent fuses or circuit breakers from opening.
 7. Protective Feature: Current-limiting device or circuit, which limits output current to rating of charger but does not disconnect charger from either battery or ac supply; to protect charger from damage due to overload, including short circuit on output terminals.
 8. Electrical Filtering: Reduces charger's audible noise to less than 26 dB.

2.7 IDENTIFICATION

- A. Materials: Refer to Section 260553 "Identification for Electrical Systems." Identify units, devices, controls, and wiring.
- B. Nameplates shall give item designation and circuit number as well as frame ampere size and appropriate trip rating. Furnish Master nameplate giving switchgear designation, voltage ampere rating, short circuit rating, manufacturer's name, general order number and item number.

Retain paragraph and subparagraphs below if required.

- C. Mimic Bus: Continuous mimic bus applied to front of switchgear, arranged in single-line diagram format, using symbols and lettered designations consistent with approved final mimic-bus diagram.
1. Mimic-bus segments coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
 2. Medium: Painted graphics, as approved.

3. Color: Contrasting with factory-finish background; selected by DEN Project Manager.

2.8 SOURCE QUALITY CONTROL

Add a paragraph to this Article if factory testing is to be witnessed by Owner's representative or others. Indicate which portions of testing are to be witnessed.

- A. Before shipment of equipment, perform the following tests and prepare test reports:
 1. Production tests on circuit breakers according to ANSI C37.09.
 2. Production tests on completed switchgear assembly according to IEEE C37.20.2.
- B. Assemble switchgear and equipment in manufacturer's plant and perform the following:
 1. Functional tests of all relays, instruments, meters, and control devices by application of secondary three-phase voltage to voltage circuits and injection of current in current transformer secondary circuits.
 2. Functional test of all control and trip circuits. Connect test devices into circuits to simulate operation of controlled remote equipment such as circuit-breaker trip coils, close coils, and auxiliary contacts. Test proper operation of relay targets.
- C. Prepare equipment for shipment.
 1. Provide suitable crating, blocking, and supports so equipment will withstand expected domestic shipping and handling shocks and vibration.
 2. Weatherproof equipment for shipment. Close connection openings to prevent entrance of foreign material during shipment and storage.

2.9 FACTORY FINISHES

- A. Finish: Manufacturer's standard color finish applied to equipment before shipping.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine elements and surfaces to receive switchgear for compliance with requirements for installation tolerances, required clearances, and other conditions affecting performance.
 1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 AUTOMATIC THROWOVER CONTROL SCHEME

A. Sequence of Operation:

1. If Service #1 is selected as the preferred service, Breaker 52M1 will be closed and Breaker 52M2 will be open. Switchboard will be supported by Service #1.
2. If Service #2 is selected as the preferred service, Breaker 52M2 will be closed and Breaker 52M1 will be open. Switchboard will be supported by Service #2.
3. If Service #1 is selected as the preferred service, and Service #1 fails with Service #2 available and Breaker 52M1 not tripped due to a fault (bell alarm lockout) proceed as follows:
 - a. After an adjustable time delay (1.5 - 15 seconds) trip Breaker 52M1.
 - b. Once Breaker 52M1 is open, close Breaker 52M2. Note that this is an open transition transfer with no paralleling.
 - c. Continue to operate entire switchboard on Service #2.
4. If Service #1 is selected as the preferred service, Step "3" has occurred, and Service #1 returns to service, proceed as follows:
 - a. Initiate an adjustable time delay (6 - 60 minutes).
 - b. Upon expiration of the time delay trip Breaker 52M2.
 - c. After an adjustable time delay (.2-60 seconds) close Breaker 52M1.
 - d. System is restored to normal.
5. Service #2 is selected as the preferred service, and Service #2 fails with Service #1 available and Breaker 52M2 not tripped due to a fault (bell alarm lockout), proceed as follows:
 - a. After an adjustable time delay (1.5 - 15 seconds) trip Breaker 52M2.
 - b. Once Breaker 52M2 is open, close Breaker 52M1. Note that this is an open transition transfer with no paralleling.
 - c. Continue to operate entire Switchboard on Service #1.
6. If Service #2 is selected as the preferred service, step "5" has occurred and Service #2 returns to service, proceed as follows:
 - a. Initiate an adjustable time delay (6 - 60 minutes).
 - b. Upon expiration of the time delay trip Breaker 52M1.
 - c. After an adjustable time delay (.2 - 60 seconds) close Breaker 52M2.
 - d. System is restored to normal.
7. Remote service equipment shutdown. (86 relay)
 - a. In case of an emergency, the service equipment main circuit breakers 52 M1 and 52 M2, to be remotely disconnected and to remain in open position until manually reset locally by a trained electrician. Remote indicator lights shall be located at outside entrance to switchgear room to indicate when the (86 relay) is engaged.

B. Additional Features:

1. Provide bell alarm lockouts such that upon a fault in the distribution bus, both main breakers shall be given trip signals and locked out from closing until reset.
2. Provide electrical interlocks to ensure that only one of the two main breakers can be closed at the same time.
3. A manual/auto selector switch to completely disable the automatic throwover scheme.
4. A time delay bypass switch on retransfer to normal to allow immediate return to normal configuration upon restoration of the failed transformer (momentary contact).
5. A selector switch to advise the automatic throwover scheme as to which transformer is preferred.
6. Provide a control power transfer scheme. Control power transformers shall be connected on the line side of each secondary main breaker and the scheme shall automatically transfer to the source that is available to supply control power to the switchboard.
7. Provide control switches for Breakers 52M1 and 52M2.
8. Provide pilot lights for the following conditions:
 - a. Automatic mode.
 - b. Manual mode (flashing).
 - c. Breaker 52M1 open.
 - d. Breaker 52M1 closed.
 - e. Breaker 52M1 trip.
 - f. Breaker 52M2 open.
 - g. Breaker 52M2 closed.
 - h. Breaker 52M2 trip.
 - i. Service #1 preferred.
 - j. Service #2 preferred.
 - k. Service #1 available.
 - l. Service #2 available.
 - m. Switchboard on alternate transformer (flashing).
 - n. Remote indicators outside of main switchgear electrical room.
 - 1) Remote disconnect engaged.
 - 2) M1 open.
 - 3) M2 open.
9. Push to test feature on all pilot lights.
10. Dry contact relay outputs for the following conditions:
 - a. Manual-auto switch-auto.
 - b. Manual-auto switch-manual.
 - c. Switchboard on alternate service.
 - d. Alternate service unavailable.
 - e. Preferred service failed.
 - f. Breaker 52M1 tripped (bell alarm).
 - g. Breaker 52M2 tripped (bell alarm).
 - h. Outage on switchboard.

- i. Control power failed.
 11. All necessary relays, selector switches, pilot lights (except for potential transformers and control transformers) and other components for the automatic throwover and emergency remote service equipment shutdown scheme shall be located in a cubicle shown on the drawings.
 12. Mount all control switches and pilot lights on the cubicle door such that they are accessible from outside. Provide suitable nameplates for all devices.
 13. Provide a complete relay schedule listing all relays and controls as well as a complete circuit operation description. Indicate in detail the operation of all relays and contacts for all contingencies.
 14. All device numbering should conform to ANSI/IEEE Standards.
- C. Breakers 52M1 and 52M2:
1. Provide the following features and accessories on Breakers 52M1 and 52M2 to interface with the automatic throwover control scheme:
 - a. All auxiliary contacts required for the operation of the automatic throwover and emergency remote service equipment shutdown control scheme.
 - b. Four spare sets of Form "C" (normally open/normally closed auxiliary contacts)
 - c. 120 volt electric operators. Note that these breakers will be operated by relay logic. Do not provide local (at breaker) push buttons or controls. In addition, make provisions to block local manual closing to prevent override of interlocking scheme.

3.3 INSTALLATION

- A. Anchor switchgear assembly to 4-inch (100-mm), channel-iron sill embedded in concrete base and attach by bolting.
1. Sills: Select to suit switchgear; level and grout flush into concrete base.

Retain subparagraph below if Project is in seismic area.

2. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 260548 "Vibration and Seismic Controls for Electrical Systems" for seismic-restraint requirements.

Retain subparagraph below if concrete bases are used. Coordinate with Drawings.

3. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no less than 3 inches (75 mm) in all directions beyond the maximum dimensions of switchgear, unless otherwise indicated or unless required for seismic anchor support. Construct concrete bases according to Section 260529 "Hangers and Supports for Electrical Systems."
- B. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from switchgear units and components.

3.4 IDENTIFICATION

- A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section 260553 "Identification for Electrical Systems."
- B. Diagram and Instructions:
 - 1. Frame under clear acrylic plastic on front of switchgear.
 - a. Operating Instructions: Printed basic instructions for switchgear, including control and key-interlock sequences and emergency procedures.
 - b. System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads.
 - 2. Storage for Maintenance: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

3.5 CONNECTIONS

- A. Cable terminations at switchgear are specified in Section 260513 "Medium-Voltage Cables."
- B. Tighten bus joints, electrical connectors, and terminals according to manufacturer's published torque-tightening values.
- C. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables" and Section 260513 "Medium-Voltage Cables."

3.6 FIELD QUALITY CONTROL

Retain paragraph and subparagraphs below to require Contractor to prepare switchgear and related components for manufacturer's field service technician and for acceptance testing.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Prepare for acceptance tests as follows:
 - 1. Test insulation resistance for each switchgear bus, component, connecting supply, feeder, and control circuit.
 - 2. Test continuity of each circuit.

Retain paragraph and subparagraphs below to require a factory-authorized service representative to perform, or assist Contractor with, field inspections, tests, and adjustments. For switchgear and related components, supervision by personnel familiar with equipment may be important.

- B. Perform the following field tests and inspections and prepare test reports:

Retain subparagraphs below with either of last two paragraphs above. Edit to suit Project. Delete subparagraphs if testing will be performed by Owner-engaged testing and inspecting agency.

1. Perform each electrical test and visual and mechanical inspection stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for each of the following NETA categories:
 - a. Switchgear.
 - b. Circuit breakers.
 - c. Instrument transformers.
 - d. Metering and instrumentation.
 - e. Ground-fault systems.
 - f. Battery systems.
 - g. Capacitors.

C. Remove and replace malfunctioning units and retest as specified above.

Edit paragraph and subparagraphs below to suit types of switchgear specified.

D. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform infrared scan of each switchgear. Remove front and rear panels so joints and connections are accessible to portable scanner.

1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchgear 11 months after date of Substantial Completion.
2. Instrument: Use an infrared-scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
3. Record of Infrared Scanning: Prepare a certified report that identifies switchgear checked and that describes infrared-scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.7 ADJUSTING

Delete this Article if only load interrupter switchgear is specified. Select option in paragraph below if coordination study is responsibility of Contractor and is included in Section 260573 "Overcurrent Protective Device Coordination Study."

- A. Set field-adjustable, protective-relay trip characteristics [**according to results in Section 260573 "Overcurrent Protective Device Coordination Study."**][.]

3.8 CLEANING

- A. On completion of installation, inspect interior and exterior of switchgear. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair damaged finishes.

3.9 PROTECTION

- A. Temporary Heating: Apply temporary heat to switchgear, according to manufacturer's written instructions, throughout periods when switchgear environment is not controlled for temperature and humidity within manufacturer's stipulated service conditions.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain switchgear. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 261300

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SECTION 262200 - LOW-VOLTAGE TRANSFORMERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes the following types of dry-type transformers rated 600 V and less, with capacities up to 1000 kVA:
 - 1. Distribution transformers.
 - 2. Buck-boost transformers.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.3 ACTION SUBMITTALS

- A. Product Data: Include rated nameplate data, capacities, weights, dimensions,

minimum clearances, installed devices and features, and performance for each type and size of transformer indicated.

1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
1. Wiring Diagrams: Power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Coordinate seismic requirements with DEN Project Manager.

- A. Manufacturer Seismic Qualification Certification: Submit certification that transformers, accessories, and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For testing agency.
- C. Source quality-control test reports.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- D. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For transformers to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7.
- B. Source Limitations: Obtain each transformer type through one source from a single manufacturer.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- D. Comply with IEEE C57.12.91, "Test Code for Dry-Type Distribution and Power Transformers."

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Temporary Heating: Apply temporary heat according to manufacturer's written instructions within the enclosure of each ventilated-type unit, throughout periods during which equipment is not energized and when transformer is not in a space that is continuously under normal control of temperature and humidity.
- B. Handle using only lift eyes and provided brackets. Protect equipment in inclement weather.

1.8 COORDINATION

- A. For floor-mounted transformers, coordinate size and location of concrete bases with actual transformer provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.
- B. For wall-mounted and structure-mounted transformers, coordinate installation of wall-mounting and structure-hanging supports with actual transformer provided.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products.
See Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. **Manufacturers: Match existing equipment in the vicinity, if applicable. Subject to compliance with requirements, provide products by one of the following:**
1. Eaton Electrical Inc.; Cutler-Hammer Products.
 2. General Electric Company.
 3. Square D; Schneider Electric.
 4. or approved equal.

2.2 GENERAL TRANSFORMER REQUIREMENTS

- A. Description: Factory-assembled and -tested, air-cooled units for 60-Hz service.
- B. Cores: Grain-oriented, non-aging silicon steel.
- C. Coils: Continuous windings without splices except for taps.
1. Internal Coil Connections: Brazed or pressure type.

Usually retain aluminum option in subparagraph below. See Evaluations for discussion of copper vs. aluminum winding material.

2. Coil Material:
3. Transformers rated up to 45kVA: **Copper or Aluminum.**
 - a. Transformers rated above 45kVA: Copper windings are required."

2.3 DISTRIBUTION TRANSFORMERS

- A. Comply with NFPA 70, and list and label as complying with UL 1561.

Retain first paragraph below if seismic bracing is required. Coordinate with Parts 1 and 3.

- B. Provide transformers that are constructed to withstand seismic forces specified in Section 260548.16 "Seismic Controls for Electrical Systems."

- C. Cores: One leg per phase.

If all transformers have same enclosure, retain one of two "Enclosure" paragraphs below. Retain first paragraph for indoor transformers; second, for outdoor transformers. If several types of enclosures are required for Project, delete paragraphs and indicate enclosure type on Drawings.

- D. Enclosure: [**Ventilated**] [**Totally enclosed, nonventilated**], NEMA 250, Type 2.
1. Core and coil shall be encapsulated within resin compound, sealing out moisture and air.
- E. Enclosure: [**Ventilated**] [**Totally enclosed, nonventilated**], . NEMA 250, [**Type 3R**] [**Type 4X, stainless steel**].
1. Core and coil shall be encapsulated within resin compound, sealing out moisture and air.

Retain Paragraph and subparagraph below for custom finish.

- F. Transformer Enclosure Finish: Comply with NEMA 250.
1. Finish Color: Gray.
- G. Taps for Transformers Smaller than 3 kVA: **None**.
- H. Taps for Transformers 7.5 to 24 kVA: **"One 5 percent tap above and one 5 percent tap below normal full capacity.**
- I. Taps for Transformers 25 kVA and Larger: **Two 2.5 percent taps above and two 2.5 percent taps below normal full capacity.**

See Editing Instruction No. 2 in the Evaluations for discussion of insulation classes. See "Energy Considerations" Article in the Evaluations for discussion of relative efficiencies. If 115 or 80 deg C rating is retained in paragraph below and all transformers are 15 kVA or larger, delete "Energy Efficiency for Transformers Rated 15 kVA and Larger" Paragraph.

- J. Insulation Class: 220 deg C, UL-component-recognized insulation system with a maximum of [**115**] [**80**] deg C rise above 40 deg C ambient temperature.

Retain features in seven paragraphs below to suit Project. Coordinate with Drawings.

Retain paragraph and subparagraphs below for energy-efficient transformers complying with NEMA TP 1. See Evaluations for discussion of energy efficiency. NEMA TP 1 excludes dry-type transformers rated below 15 kVA.

- K. Energy Efficiency for Transformers Rated 15 kVA and Larger:
1. Complying with NEMA TP 1, Class 1 efficiency levels.
 2. Tested according to NEMA TP 2.

Retain paragraph and subparagraphs below for transformers that will supply significant nonsinusoidal load current. Show transformer K-factor on Drawings or in schedule. See Evaluations for discussion of

K-factors.

- L. K-Factor Rating: Transformers indicated to be K-factor rated shall comply with UL 1561 requirements for nonsinusoidal load current-handling capability to the degree defined by designated K-factor.
1. Unit shall not overheat when carrying full-load current with harmonic distortion corresponding to designated K-factor.
 2. Indicate value of K-factor on transformer nameplate.

Shielding in paragraph below reduces conducted, common-mode, high-frequency transient noise to sensitive loads. See Evaluations for discussion of shielding.

- M. Electrostatic Shielding: Each winding shall have an independent, single, full-width copper electrostatic shield arranged to minimize interwinding capacitance.
1. Arrange coil leads and terminal strips to minimize capacitive coupling between input and output terminals.
 2. Include special terminal for grounding the shield.
 3. Shield Effectiveness:
 - a. Capacitance between Primary and Secondary Windings: Not to exceed 33 picofarads over a frequency range of 20 Hz to 1 MHz.
 - b. Common-Mode Noise Attenuation: Minimum of minus 120 dBA at 0.5 to 1.5 kHz; minimum of minus 65 dBA at 1.5 to 100 kHz.
 - c. Normal-Mode Noise Attenuation: Minimum of minus 52 dBA at 1.5 to 10 kHz.

Indicate wall-mounting transformers on Drawings. Generally, factory-made wall-mounting brackets are available for transformers up to 75 kVA. High-efficiency, shielding, and K-factor construction increase transformer weight. Verify that wall brackets are available from specified manufacturers for specified sizes. Verify compliance with seismic requirements.

- N. Wall Brackets: Manufacturer's standard brackets.

Retain one of two paragraphs below. Retain first if equipment sound-level ratings are required to be lower than those in NEMA ST 20. NEMA ST 20 sound levels are as follows: Up to 9 kVA: 40 dBA; 30 to 50 kVA: 45 dBA; 51 to 150 kVA: 50 dBA; 151 to 300 kVA: 55 dBA; 301 to 500 kVA: 60 dBA; 501 to 700 kVA: 62 dBA; 701 to 1000 kVA: 64 dBA. See Editing Instruction No. 3 in the Evaluations for discussion of sound generated by transformers.

- O. Low-Sound-Level Requirements: Minimum of 3 dBA less than NEMA ST 20 standard sound levels when factory tested according to IEEE C57.12.91. Maximum sound levels shall be as follows:
1. 1 to 5 kVA: 37dB.
 2. 6 to 25 kVA: 42dB.
 3. 26 to 150 kVA: 47dB.
 4. 151 to 225 kVA: 52dB.
 5. 226 to 300 kVA: 52dB.
 6. 301 to 500 kVA: 57dB.

2.4 BUCK-BOOST TRANSFORMERS

- A. Description: Self-cooled, two-winding dry type, rated for continuous duty and with wiring terminals suitable for connection as autotransformer. Transformers shall comply with NEMA ST 1 and shall be listed and labeled as complying with UL 506 or UL 1561.
- B. Enclosure: Ventilated, NEMA 250, Type 2.
 - 1. Finish Color: **Gray**] [**ANSI 49 gray**] [**ANSI 61 gray**].

2.5 IDENTIFICATION DEVICES

Retain this article to specify nameplates. Coordinate names of transformers with Drawings and schedules.

- A. Nameplates: Engraved, laminated-plastic or metal nameplate for each **distribution** and **buck-boost** transformer, mounted with corrosion-resistant screws. Nameplates and label products are specified in Section 260553 "Identification for Electrical Systems."
 - 1. Include transformer connection data and overload capacity based on rated allowable temperature rise.

2.6 SOURCE QUALITY CONTROL

- A. Test and inspect transformers according to IEEE C57.12.91.
- B. Factory Sound-Level Tests: Conduct sound-level tests on equipment for this Project.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine conditions for compliance with enclosure- and ambient-temperature requirements for each transformer.
- B. Verify that field measurements are as needed to maintain working clearances required by NFPA 70 and manufacturer's written instructions.
- C. Examine walls, floors, roofs, and concrete bases for suitable mounting conditions where transformers will be installed.

Revise 5-ohm value in first paragraph below to suit Project.

- D. Verify that ground connections are in place and requirements in Section 260526 "Grounding and Bonding for Electrical Systems" have been met. Maximum ground resistance shall be 5 ohms at location of transformer.

- E. Environment: Enclosures shall be rated for the environment in which they are located. Covers for NEMA 250, Type 4X enclosures shall not cause accessibility problems.
- F. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

Verify seismic-bracing requirements with authorities having jurisdiction. Wall-mounted transformers may not be appropriate in areas of seismic activity.

- A. Install wall-mounted transformers level and plumb with wall brackets fabricated by transformer manufacturer.
 - 1. Brace wall-mounted transformers as specified in Section 260548.16 "Seismic Controls for Electrical Systems."
- B. Install transformers level and plumb on a concrete base with vibration-dampening supports. Locate transformers away from corners and not parallel to adjacent wall surface.
- C. Construct concrete bases and anchor floor-mounting transformers according to manufacturer's written instructions, **seismic codes applicable to Project**, and requirements in Section 260529 "Hangers and Supports for Electrical Systems."

3.3 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

Retain one of first two paragraphs below that identify who shall perform tests and inspections. Retain requirements for field quality-control test reports in "Informational Submittals" article.

Coordinate inspection and testing requirements with DEN Project Manager.

Retain first paragraph below to require Contractor to perform tests and inspections.

- A. Perform tests and inspections and prepare test reports.

Retain "Manufacturer's Field Service" Subparagraph below, if required by the DEN Project Manager, to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including

connections, and to assist in testing.

Retain "Tests and Inspections" Paragraph below to describe tests and inspections to be performed by any of the entities in three paragraphs above.

B. Tests and Inspections:

Tests referenced in subparagraph below are from NETA Acceptance Testing Specification and include inspection procedures to verify proper installation. They also include tests and measurements of insulation resistance and turns ratios. Cost of extensive testing may not be warranted for some projects. Revise subparagraph to suit Project.

1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS for dry-type, air-cooled, low-voltage transformers. Certify compliance with test parameters.

C. Remove and replace units that do not pass tests or inspections and retest as specified above.

D. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of transformer connections.

1. Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2. Perform two (2) follow-up infrared scans of transformers, one at four months and the other at 11 months after Substantial Completion.
3. Prepare a certified report identifying transformer checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.

E. Test Labeling: On completion of satisfactory testing of each unit, attach a dated and signed "Satisfactory Test" label to tested component.

3.5 ADJUSTING

A. Record transformer secondary voltage at each unit for at least 48 hours of typical occupancy period. Adjust transformer taps to provide optimum voltage conditions at secondary terminals. Optimum is defined as not exceeding nameplate voltage plus 10 percent and not being lower than nameplate voltage minus 3 percent at maximum load conditions. Submit recording and tap settings as test results.

B. Connect buck-boost transformers to provide nameplate voltage of equipment being served, plus or minus 5 percent, at secondary terminals.

C. Output Settings Report: Prepare a written report recording output voltages and tap settings.

3.6 CLEANING

- A. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262200

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SECTION 262300 - LOW-VOLTAGE SWITCHGEAR

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes metal-enclosed, low-voltage power circuit-breaker switchgear rated 1000 V and less for use in ac systems.
- B. Related Sections include the following:

List below only products, construction, and equipment that the reader might expect to find in this Section but are specified elsewhere.

Retain subparagraph below if Project includes requirements for electrical power monitoring and control.

- 1. Section 260913 "Electrical Power Monitoring and Control" for interfacing communication and metering requirements.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviations that remain after this Section has been edited.

- A. ATS: Acceptance Testing Service.
- B. GFCI: Ground-fault circuit interrupter.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of switchgear, circuit breaker, accessory, and component indicated. Include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, and finishes.
 - 1. Include data substantiating that materials comply with requirements.
 - B. Shop Drawings: For each type of switchgear and related equipment.
 - 1. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Include the following:
 - a. Tabulation of installed devices with features and ratings.
 - b. Enclosure types and details.
 - c. Outline and general arrangement drawing showing dimensions, shipping sections, and weights of each assembled section.
 - d. Bus configuration with size and number of conductors in each bus run, including phase, neutral, and ground conductors of main and branch buses.
 - e. Current rating of buses.
 - f. Short-time and short-circuit current rating of switchgear assembly.
 - g. Nameplate legends.
 - h. Mimic-bus diagram.
 - i. Utility company's metering provisions with indication of approval by utility company.
 - 2. Wiring Diagrams: Power, signal, and control wiring.
- Retain first subparagraph below if series rating of overcurrent protective devices is used.
- j. UL listing for series rating of installed devices.
 - k. Features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: Representative portion of mimic bus with specified finish. Manufacturer's color charts showing colors available for mimic bus.

1.5 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around switchgear where pipe and ducts are prohibited. Show switchgear layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548.16 "Seismic Controls for Electrical Systems."

- B. Manufacturer Seismic Qualification Certification: Submit certification that switchgear, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems." Include the following:
1. Basis of Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Coordinate paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- C. Qualification Data: For testing agency.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- D. Field quality-control test reports.
- E. Updated mimic-bus diagram reflecting field changes after final switchgear load connections have been made, for record.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For switchgear and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
1. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
 2. Time-current curves, including selectable ranges for each type of overcurrent protective device.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

Revise this Article to suit Project. Spare-fuse cabinets are specified in Section 262813 "Fuses."

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fuses: **[Six (6)]** <Insert number> of each type and rating used. Include spares for potential transformer fuses, control power fuses, and fuses and fusible devices for fused circuit breakers.
 2. Indicating Lights: **[Six (6)]** <Insert number> of each type installed.
 3. Touchup Paint: **[Three (3)]** <Insert number> containers of paint matching enclosure finish, each **0.5 pint** (250 mL).

1.8 QUALITY ASSURANCE

- A. Factory Testing and Witness Testing:
1. Furnish all test equipment and personnel, and perform all tests as may be required and as specified herein.
 2. The manufacturer shall perform all tests normally conducted in accordance with the manufacturer's standard test procedures for all substations. In addition, the manufacturer shall perform all supplementary testing as defined throughout this specification for all substations. All normal and supplemental testing, which is not witnessed by the DEN Project Manager, shall be documented in certified test reports and shall be submitted to the DEN Project Manager for review within two (2) weeks of the performance of the testing.

3. The following tests shall be performed at the factory and shall be witnessed by the DEN Project Manager, or their duly authorized representative:
 - a. A complete visual inspection of the equipment, both internally and externally.
 - b. A complete test of all automatic transfer schemes including all operation and failure modes.
 - c. A complete test of all control panels and controls including dry contact outputs.
 - d. Verification of proper operation of all metering.
 - e. Verify mechanical operation; interlocks and interchangeability of selected breakers.
4. The testing outlined in paragraph "3" above shall be performed only on one main switchgear. In order to perform such testing, all breakers shall be shipped to the switchboard factory and installed in their respective cubicles in a completely assembled Distribution Section
5. Test 208 volt and /or 480 volt, 3-phase power sources shall be connected to the incoming side of each secondary main such that the sources may be individually applied and removed to completely simulate and test all features of the distribution sections.
6. Submit to the DEN Project Manager ninety (90) calendar days prior to scheduled testing all test procedures for approval, and notify the DEN Project Manager four (4) weeks prior to scheduled testing what the duration of the tests will be.
7. Provide four (4) copies of the factory test report within two (2) weeks of the completion of such witness tests.

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use first paragraph below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

- B. Source Limitations: Obtain switchgear through one source from a single manufacturer.

Retain paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Section 016000 "Product Requirements" requirements.

- C. Product Options: Drawings indicate size, profiles, and dimensional requirements of switchgear and are based on the specific system indicated. Refer to Section 016000 "Product Requirements."

Retain first paragraph below if labeling of switchgear is required. See Editing Instruction No. 2 in the Evaluations.

- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Comply with NFPA 70.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver switchgear in sections of lengths that can be moved past obstructions in delivery path.

Retain one of two paragraphs below.

- B. Store switchgear indoors in clean dry space with uniform temperature to prevent condensation. Protect switchgear from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- C. If stored in areas subjected to weather, cover switchgear to provide protection from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside switchgear; install electric heating (250 W per section) to prevent condensation.
- D. Handle in accordance with manufacturer's written instructions. Lift only with lugs provided for the purpose. Handle carefully to avoid damage to switchgear internal components, enclosure, and finish.

1.10 PROJECT CONDITIONS

Revise paragraph below to describe specific requirements for moving switchgear into place. Where appropriate, indicate alterations to existing facilities that may be required to accommodate an indicated delivery path. Coordinate with Drawings.

- A. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.

Retain paragraph and subparagraphs below if interruption of existing electrical service is required.

- B. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 - 2. Do not proceed with interruption of electric service without DEN Project Manager's written permission.

Retain paragraph below if installation space for switchgear is limited; show maximum dimensions on Drawings.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear, and adjacent surfaces and other items. Comply with indicated maximum dimensions.

Specify unusual environmental or service conditions here. See Editing Instruction No. 3 in the Evaluations. Otherwise, indicate typical environmental conditions as follows: For switchgear installed outdoors, indicate minimum ambient temperature and expected humidity range and specify compliance with IEEE C37.24.

- D. Environmental Limitations: Rate equipment for continuous operation under the following conditions, unless otherwise indicated:
1. Ambient temperature range: 30 deg F (-35 deg C) to 120 deg F (49 deg C).
 2. Altitude: 5500 feet (1677 m).
 3. Excessive solar radiation.

1.11 COORDINATION

Edit first paragraph below to delete or add types of construction that penetrate or are supported by ceilings.

- A. Coordinate layout and installation of switchgear and components with other construction that penetrates ceilings or is supported by them, including conduit, piping, equipment, and adjacent surfaces. Maintain required clearances for workspace and equipment access doors and panels.
- B. Coordinate size and location of concrete bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

Retain below for semiproprietary specification. Refer to Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Cutler-Hammer, Inc.; Eaton Corporation.
 2. General Electric Company.
 3. Square D; Schneider Electric.
 4. or approved equal.

2.2 RATINGS

Delete this Article if ratings are indicated on Drawings. Drawings are generally the preferred location for this data.

- A. Nominal System Voltage: **[480V, 3-Phase, 3-Wire] [480/277V, 3-Phase, 4-Wire] [208/120V, 3-Phase, 4-Wire] [240/120V, 1-Phase, 3-Wire]** 60 Hz.

IEEE C37.20.1 lists main-bus ratings only through 4000 A, but some manufacturers will provide bus ratings through 5000 A. However, circuit breakers are available only through 4000 A.

- B. Main-Bus Continuous: **[4000] [3200] [2000] [1600]** <Insert other> A.
- C. Short-Time and Short-Circuit Current: Match rating of highest-rated circuit breaker in switchgear assembly.

2.3 FABRICATION

- A. Factory assembled and tested and complying with IEEE C37.20.1.
- B. Indoor Enclosure Material: Steel.

Retain paragraph above or first paragraph below or both, and revise to suit Project. See Editing Instruction No. 4 in the Evaluations.

- C. Outdoor Enclosure Material: Galvanized steel.
- D. Outdoor Enclosure Fabrication Requirements: Weatherproof; integral structural-steel base frame with factory-applied asphaltic undercoating; and each compartment equipped with the following features:
1. Structural design and anchorage adequate to resist loads imposed by **[125-mph (200-km/h)] <Insert wind speed>** wind.
 2. Space heater operating at one-half or less of rated voltage, sized to prevent condensation.
 3. Louvers equipped with insect and rodent screen and filter; arranged to permit air circulation while excluding insects, rodents, and exterior dust.

Delete first three subparagraphs below if weatherproof internal aisle construction is specified.

4. Hinged front door with padlocking provisions.
5. Interior light with switch.
6. Weatherproof duplex receptacle.
7. Common internal aisle of sufficient width to permit protective-device withdrawal, disassembly, and servicing in aisle.
8. Aisle access doors with outside padlocking provisions and interior panic latches.
9. Aisle space heaters operating at one-half or less of rated voltage, thermostatically controlled.
10. Vaporproof fluorescent aisle lights with low-temperature ballasts, controlled by wall switch at each entrance.
11. GFCI duplex receptacles, a minimum of two, located in aisle.

Revise subparagraph below if forced ventilation rather than convection ventilation is required.

12. Aisle ventilation louvers equipped with insect and rodent screen and filter and arranged to permit air circulation while excluding insects, rodents, and exterior dust.
- E. Finish: IEEE C37.20.1, manufacturer's standard gray finish over a rust-inhibiting primer on phosphatizing-treated metal surfaces.
 - F. Section barriers between main and tie circuit-breaker compartments shall be extended to rear of section.
 - G. Bus isolation barriers shall be arranged to isolate line bus from load bus at each main and tie circuit breaker.
 - H. Circuit-breaker compartments shall be equipped to house drawout-type circuit breakers and shall be fitted with hinged outer doors.
 - I. Fabricate enclosure with removable, hinged, rear cover panels to allow access to rear interior of switchgear.
 - J. Auxiliary Compartments: Match and align with basic switchgear assembly. Include the following:
 1. Utility metering compartment that complies with utility company requirements.

Coordinate first subparagraph below with Drawings. Pull section is not usually required in low-voltage power switchgear. Metering provisions and main circuit-breaker connections may influence space available for incoming lines. Edit to suit Project.

2. Bus transition sections.
3. Incoming-line pull sections.
4. Hinged front panels for access to metering, accessory, and blank compartments.
5. Pull box on top of switchgear for extra room for pulling cable, with removable top, front, and side covers and ventilation provisions adequate to maintain air temperature in pull box within same limits as switchgear.

Retain first subparagraph below if top-mounted, circuit-breaker removal mechanism is used.

- a. Set pull box back from front to clear circuit-breaker lifting mechanism.
- b. Bottom: Insulating, fire-resistant material with separate holes for cable drops into switchgear.
- c. Cable Supports: Arranged to ease cabling and adequate to support cables indicated, including those for future installation.

Coordinate paragraph and subparagraphs below with Drawings.

- K. Bus bars connect between vertical sections and between compartments. Cable connections are not permitted.
 1. Main Phase Bus: Uniform capacity the entire length of assembly.

See Editing Instruction No. 7 in the Evaluations.

2. Neutral Bus: **[50] [100]** percent of phase-bus ampacity, except as indicated. Equip bus with pressure-connector terminations for outgoing circuit neutral conductors. Include braces for neutral-bus extensions for busway feeders.

Retain subparagraph below if switchgear assembly includes spare circuit breakers and spaces for future circuit breakers. See Editing Instruction No. 6 in the Evaluations.

3. Vertical Section Bus Size: Comply with IEEE C37.20.1, including allowance for spare circuit breakers and spaces for future circuit breakers.

Retain one of first three subparagraphs below for main-bus material, or delete all and make selection Contractor's option.

4. Phase- and Neutral-Bus Material: Hard-drawn copper of 98 percent minimum conductivity, with copper feeder circuit-breaker line connections.
5. Use silver-plated copper or tin-plated aluminum for connecting circuit-breaker line to aluminum bus.

Retain subparagraph above or first subparagraph below as required by bus-material specification.

6. Use copper for connecting circuit-breaker line to copper bus.
7. Contact Surfaces of Buses: Silver plated.
8. Feeder Circuit-Breaker Load Terminals: Silver-plated copper bus extensions equipped with pressure connectors for outgoing circuit conductors.
9. Ground Bus: Hard-drawn copper of 98 percent minimum conductivity, with pressure connector for feeder and branch-circuit ground conductors, minimum size **1/4 by 2 inches** (6 by 50 mm).
10. Supports and Bracing for Buses: Adequate strength for indicated short-circuit currents.
11. Neutral bus equipped with pressure-connector terminations for outgoing circuit neutral conductors. Neutral-bus extensions for busway feeders are braced.

Retain first subparagraph below for switchgear with main service disconnect switches. Edit to suit Project. Coordinate with Drawings.

12. Neutral Disconnect Link: Bolted, uninsulated, **1/4-by-2-inch** (6-by-50-mm) copper bus, arranged to connect neutral bus to ground bus.
13. Provide for future extensions from either end of main phase, neutral, and ground bus by means of predrilled bolt-holes and connecting links.

IEEE and UL standards may require air insulation only. Retain subparagraph and associated subparagraphs below if insulated bus is required.

14. Bus-Bar Insulation: Individual bus bars wrapped with factory-applied, flame-retardant tape or spray-applied, flame-retardant insulation.
 - a. Sprayed Insulation Thickness: **3 mils** (0.08 mm), minimum.
 - b. Bolted Bus Joints: Insulate with secure joint covers that can easily be removed and reinstalled.

2.4 COMPONENTS

- A. Instrument Transformers: Comply with IEEE C57.13.

1. Potential Transformers: Secondary-voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.

Coordinate subparagraph below with Drawings.

2. Current Transformers: Ratios as indicated; burden and accuracy class suitable for connected relays, meters, and instruments.

Delete paragraph and subparagraphs below if conventional analog-meter installation is required. See Editing Instruction No. 5 in the Evaluations.

- B. Multifunction Digital-Metering Monitor: UL-listed or -recognized, microprocessor-based unit suitable for three- or four-wire systems and with the following features:
1. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 2. Switch-selectable digital display of the following:
 - a. Phase Currents, Each Phase: Plus or minus 1 percent.
 - b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - d. Three-Phase Real Power: Plus or minus 2 percent.
 - e. Three-Phase Reactive Power: Plus or minus 2 percent.
 - f. Power Factor: Plus or minus 2 percent.
 - g. Frequency: Plus or minus 0.5 percent.
 - h. Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.
 - i. Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
 3. Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.

Delete paragraph below unless relays not integral with circuit breakers or circuit-breaker trip units are required. Specify relay functions and characteristics below or indicate on Drawings.

- C. Relays: Comply with IEEE C37.90, types and settings as indicated; with test blocks and plugs.

Retain paragraph and subparagraphs below if system analysis shows arresters are required at switchgear. Show ratings of arresters on Drawings.

- D. Surge Arresters: Distribution class, metal-oxide-varistor type. Comply with IEEE C62.11 and NEMA LA 1.
1. Install in cable termination compartments and connect in each phase of circuit.
 2. Coordinate rating with circuit voltage.

Delete paragraph below if not required. If retaining, coordinate with Drawings.

- E. Provision for Future Devices: Equip compartments with rails, mounting brackets, supports, necessary appurtenances, and bus connections.

Edit first paragraph and subparagraphs below to accommodate special needs such as dc control, battery, or uninterruptible power supply for control.

- F. Control Power Supply: Control power transformer supplying 120-V control circuits through secondary disconnect devices. Include the following features:
1. Dry-type transformers, in separate compartments for units larger than 3 kVA, including primary and secondary fuses.

Retain subparagraph below for electrically interlocked main and tie circuit breakers.

2. Two control power transformers in separate compartments with necessary interlocking relays; each transformer connected to line side of associated main circuit breaker.

Retain one of first two subparagraphs below.

- a. Secondary windings connected through a relay or relays to control bus to effect an automatic transfer scheme.
 - b. Secondary windings connected through an internal automatic transfer switch to switchgear control power bus.
3. Control Power Fuses: Primary and secondary fuses with current-limiting and overload protection.
 4. Fuses are specified in Section 262813 "Fuses."
- G. Control Wiring: Factory installed, complete with bundling, lacing, and protection; and complying with the following:
1. Flexible conductors for No. 8 AWG and smaller, for conductors across hinges and for conductors for interconnections between shipping units.
 2. Conductors sized according to NFPA 70 for duty required.

2.5 CIRCUIT BREAKERS

- A. Description: Comply with IEEE C37.13.

Coordinate first paragraph below with Drawings.

- B. Ratings: As indicated for continuous, interrupting, and short-time current ratings for each circuit breaker; voltage and frequency ratings same as switchgear.
- C. Operating Mechanism: Mechanically and electrically trip-free, stored-energy operating mechanism with the following features:
1. Normal Closing Speed: Independent of both control and operator.
 2. Slow Closing Speed: Optional with operator for inspection and adjustment.
 3. Stored-Energy Mechanism: **[Manually charged] [Electrically charged, with optional manual charging].**
 4. Operation counter.

- D. Trip Devices: Solid-state, overcurrent trip-device system consisting of one or two current transformers or sensors per phase, a release mechanism, and the following features:

Delete subparagraphs below not required.

1. Functions: Long-time-delay, short-time-delay, and instantaneous-trip functions, independent of each other in both action and adjustment.
2. Temperature Compensation: Ensures accuracy and calibration stability from minus 5 to plus 40 deg C.
3. Field-adjustable, time-current characteristics.
4. Current Adjustability: Dial settings and rating plugs on trip units or sensors on circuit breakers, or a combination of these methods.
5. Three bands, minimum, for long-time- and short-time-delay functions; marked "minimum," "intermediate," and "maximum."
6. Pickup Points: Five minimum, for long-time- and short-time-trip functions. Equip short-time-trip function for switchable I2t operation.
7. Pickup Points: Five minimum, for instantaneous-trip functions.

Coordinate first subparagraph and associated subparagraphs below with Drawings. Indicate circuits with ground-fault protection. Show type of protection for each circuit where switchgear has more than one type.

8. Ground-fault protection with at least three short-time-delay settings and three trip-time-delay bands; adjustable current pickup. Arrange to provide protection for the following:
 - a. Three-wire circuit or system.
 - b. Four-wire circuit or system.
 - c. Four-wire, double-ended substation.
9. Trip Indication: Labeled, battery-powered lights or mechanical targets on trip device to indicate type of fault.

Delete first paragraph below if not required. If retaining, coordinate with Drawings.

- E. Auxiliary Contacts: For interlocking or remote indication of circuit-breaker position, with spare auxiliary switches and other auxiliary switches required for normal circuit-breaker operation, quantity as indicated. Each consists of two Type "a" and two Type "b" stages (contacts) wired through secondary disconnect devices to a terminal block in stationary housing.
- F. Drawout Features: Circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in connected, test, and disconnected positions. Include the following features:
1. Interlocks: Prevent movement of circuit breaker to or from connected position when it is closed, and prevent closure of circuit breaker unless it is in connected, test, or disconnected position.
 2. Circuit-Breaker Positioning: An open circuit breaker may be racked to or from connected, test, and disconnected positions only with the associated compartment door closed unless live parts are covered by a full dead-front

shield. An open circuit breaker may be manually withdrawn to a position for removal from the structure with the door open. Status for connection devices for different positions includes the following:

- a. Test Position: Primary disconnect devices disengaged, and secondary disconnect devices and ground contact engaged.
 - b. Disconnected Position: Primary and secondary devices and ground contact disengaged.
- G. Arc Chutes: Readily removable from associated circuit breaker when it is in disconnected position, and arranged to permit inspection of contacts without removing circuit breaker from switchgear.
- H. Padlocking Provisions: For installing at least three padlocks on each circuit breaker to secure its enclosure and prevent movement of drawout mechanism.

Delete first paragraph below if not required.

- I. Operating Handle: One for each circuit breaker capable of manual operation.
- J. Electric Close Button: One for each electrically operated circuit breaker.

First paragraph below limits competition because some manufacturers will not provide mechanical interlocks. Edit to suit Project. See Editing Instruction No. 8 in the Evaluations.

- K. Mechanical Interlocking of Circuit Breakers: Uses a mechanical tripping lever or equivalent design and electrical interlocks.
- L. Key Interlocks: Arranged so keys are attached at devices indicated. Mountings and hardware are included where future installation of key-interlock devices is indicated.
- M. Undervoltage Trip Devices: Instantaneous, with adjustable pickup voltage.

Retain paragraph above or first paragraph below.

- N. Undervoltage Trip Devices: Adjustable time-delay and pickup voltage.
- O. Shunt-Trip Devices: Where indicated.

Retain first paragraph and subparagraphs below for fused circuit breakers.

- P. Fused Circuit Breakers: Circuit breaker and fuse combinations complying with requirements for circuit breakers and trip devices and with the following:
 1. Fuses: NEMA FU 1, Class L current limiting, sized to coordinate with and protect associated circuit breaker.

Delete nonapplicable items in first two subparagraphs below.

2. Circuit Breakers with Frame Size 1600 A and Smaller: Fuses on line side of associated circuit breaker, on a common drawout mounting, arranged so fuses are accessible only when circuit breaker is in disconnected position.

3. Circuit Breakers with Frame Sizes More Than 1600 A: Fuses and circuit breakers may be installed in separate compartments on separate drawout mountings. Fuse drawout element is interlocked with associated power circuit breaker to prevent drawing out fuse element unless circuit breaker is in open position.
 4. Open-Fuse Trip Device: Positive means of tripping and holding circuit breaker in open position when a fuse opens. Open-fuse status is indicated at front of circuit breaker or fuse drawout element.
- Q. Indicating Lights: To indicate circuit breaker is open or closed, for main and bus tie circuit breakers interlocked either with each other or with external devices.

2.6 ACCESSORIES

Retain paragraph and subparagraphs below if required.

- A. Accessory Set: Furnish tools and miscellaneous items required for circuit-breaker and switchgear test, inspection, maintenance, and operation.
1. Racking handle to manually move circuit breaker between connected and disconnected positions.
 2. Portable test set for testing all functions of circuit-breaker, solid-state trip devices without removal from switchgear.
 3. Relay and meter test plugs suitable for testing switchgear meters and switchgear class relays.

Retain one of two, or both, apparatus paragraphs below. Coordinate apparatus space requirements with Drawings.

- B. Circuit-Breaker Removal Apparatus: Portable, floor-supported, roller-base, elevating carriage arranged for moving circuit breakers in and out of compartments.

If paragraph below is used for outdoor switchgear, it must be walk-in aisle type. Coordinate apparatus space requirements with Drawings.

- C. Circuit-Breaker Removal Apparatus: Overhead-circuit-breaker lifting device, track mounted at top front of switchgear and complete with hoist and lifting yokes matching each size of drawout circuit breaker installed.

Coordinate first paragraph below with Drawings.

- D. Spare-Fuse Cabinet: Identified and compartmented steel box or cabinet with lockable door.
- E. Storage for Manual: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.
- F. Fire Alarm Signal Sender: Include a set of dry contacts in the control section equipped to send a supervisory signal to the fire alarm system

2.7 IDENTIFICATION

Delete this Article if not required.

- A. Mimic Bus: Continuous mimic bus, arranged in single-line diagram format, using symbols and lettered designations consistent with approved mimic-bus diagram.
 - 1. Mimic-bus segments coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
 - 2. Medium: Painted graphics, as selected by DEN Project Manager.
 - 3. Color: Contrasting with factory-finish background; as selected by DEN Project Manager from manufacturer's full range.
- B. System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads. Include as-built data for low-voltage power switchgear and connections as follows:
 - 1. Frame size of each circuit breaker.
 - 2. Trip rating for each circuit breaker.
 - 3. Conduit and wire size for each feeder.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine elements and surfaces where switchgear will be installed for compliance with installation tolerances, required clearances, and other conditions affecting performance.
 - 1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 AUTOMATIC THROWOVER CONTROL SCHEME

- A. Sequence of Operation:
 - 1. If Service #1 is selected as the preferred service, Breaker 52M1 will be closed and Breaker 52M2 will be open. Switchboard will be supported by Service #1.
 - 2. If Service #2 is selected as the preferred service, Breaker 52M2 will be closed and Breaker 52M1 will be open. Switchboard will be supported by Service #2.
 - 3. If Service #1 is selected as the preferred service, and Service #1 fails with Service #2 available and Breaker 52M1 not tripped due to a fault (bell alarm lockout) proceed as follows:
 - a. After an adjustable time delay (1.5 - 15 seconds) trip Breaker 52M1.
 - b. Once Breaker 52M1 is open, close Breaker 52M2. Note that this is an open transition transfer with no paralleling.

- c. Continue to operate entire switchboard on Service #2.
4. If Service #1 is selected as the preferred service, Step "3" has occurred, and Service #1 returns to service, proceed as follows:
 - a. Initiate an adjustable time delay (6 - 60 minutes).
 - b. Upon expiration of the time delay trip Breaker 52M2.
 - c. After an adjustable time delay (.2-60 seconds) close Breaker 52M1.
 - d. System is restored to normal.
5. Service #2 is selected as the preferred service, and Service #2 fails with Service #1 available and Breaker 52M2 not tripped due to a fault (bell alarm lockout), proceed as follows:
 - a. After an adjustable time delay (1.5 - 15 seconds) trip Breaker 52M2.
 - b. Once Breaker 52M2 is open, close Breaker 52M1. Note that this is an open transition transfer with no paralleling.
 - c. Continue to operate entire Switchboard on Service #1.
6. If Service #2 is selected as the preferred service, step "5" has occurred and Service #2 returns to service, proceed as follows:
 - a. Initiate an adjustable time delay (6 - 60 minutes).
 - b. Upon expiration of the time delay trip Breaker 52M1.
 - c. After an adjustable time delay (.2 - 60 seconds) close Breaker 52M2.
 - d. System is restored to normal.
7. Remote service equipment shutdown. (86 relay)
 - a. In case of an emergency, the service equipment main circuit breakers 52 M1 and 52 M2, to be remotely disconnected and to remain in open position until manually reset locally by a trained electrician. Remote indicator lights shall be located at outside entrance to switchgear room to indicate when the (86 relay) is engaged.

B. Additional Features:

1. Provide bell alarm lockouts such that upon a fault in the distribution bus, both main breakers shall be given trip signals and locked out from closing until reset.
2. Provide electrical interlocks to ensure that only one of the two main breakers can be closed at the same time.
3. A manual/auto selector switch to completely disable the automatic throwover scheme.
4. A time delay bypass switch on retransfer to normal to allow immediate return to normal configuration upon restoration of the failed transformer (momentary contact).
5. A selector switch to advise the automatic throwover scheme as to which transformer is preferred.
6. Provide a control power transfer scheme. Control power transformers shall be connected on the line side of each secondary main breaker and the scheme shall

- automatically transfer to the source that is available to supply control power to the switchboard.
7. Provide control switches for Breakers 52M1 and 52M2.
 8. Provide pilot lights for the following conditions:
 - a. Automatic mode.
 - b. Manual mode (flashing).
 - c. Breaker 52M1 open.
 - d. Breaker 52M1 closed.
 - e. Breaker 52M1 trip.
 - f. Breaker 52M2 open.
 - g. Breaker 52M2 closed.
 - h. Breaker 52M2 trip.
 - i. Service #1 preferred.
 - j. Service #2 preferred.
 - k. Service #1 available.
 - l. Service #2 available.
 - m. Switchboard on alternate transformer (flashing).
 - n. Remote indicators outside of main switchgear electrical room:
 - 1) Remote disconnect engaged.
 - 2) M1 open.
 - 3) M2 open.
 9. Push to test feature on all pilot lights.
 10. Dry contact relay outputs for the following conditions:
 - a. Manual-auto switch-auto.
 - b. Manual-auto switch-manual.
 - c. Switchboard on alternate service.
 - d. Alternate service unavailable.
 - e. Preferred service failed.
 - f. Breaker 52M1 tripped (bell alarm).
 - g. Breaker 52M2 tripped (bell alarm).
 - h. Outage on switchboard.
 - i. Control power failed.
 - j. PLC trouble
 11. All necessary relays, selector switches, pilot lights (except for potential transformers and control transformers) and other components for the automatic throwover and emergency remote service equipment shutdown scheme shall be located in a cubicle shown on the drawings.
 12. Mount all control switches and pilot lights on the cubicle door such that they are accessible from outside. Provide suitable nameplates for all devices.
 13. Provide a complete relay schedule listing all relays and controls as well as a complete circuit operation description. Indicate in detail the operation of all relays and contacts for all contingencies.
 14. All device numbering should conform to ANSI/IEEE Standards.

C. Breakers 52M1 and 52M2

1. Provide the following features and accessories on Breakers 52M1 and 52M2 to interface with the automatic throwover control scheme:
 - a. All auxiliary contacts required for the operation of the automatic throwover and emergency remote service equipment shutdown control scheme.
 - b. Four spare sets of Form "C" (normally open/normally closed auxiliary contacts)
 - c. 120 volt electric operators: Note that these breakers will be operated by relay logic. Do not provide local (at breaker) push buttons or controls. In addition, make provisions to block local manual closing to prevent override of interlocking scheme.

3.3 INSTALLATION

- A. Comply with applicable portions of NECA 400.
- B. Anchor switchgear assembly to 4-inch (100-mm), channel-iron floor sill embedded in concrete base and attach by bolting.
 1. Sills: Select to suit switchgear; level and grout flush into concrete base.

Retain subparagraph below if Project is in seismic area.

2. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 260548.16 "Seismic Controls for Electrical Systems" for seismic-restraint requirements.

Delete subparagraph below if not required. If retaining, coordinate with Drawings.

3. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no more than 3 inches (75 mm) in all directions beyond the maximum dimensions of switchgear unless otherwise indicated or unless required for seismic anchor support. Construct concrete bases according to Section 260529 "Hangers and Supports for Electrical Systems."
- C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, brackets, and temporary blocking of moving parts from switchgear units and components.

3.4 IDENTIFICATION

- A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section 260553 "Identification for Electrical Systems."
- B. Diagram and Instructions:
 1. Frame and mount under clear acrylic plastic on the front of switchgear.
 - a. Operating Instructions: Printed basic instructions for switchgear, including control and key-interlock sequences and emergency procedures.
 - b. System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads.

2. Storage for Maintenance: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

3.5 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.6 FIELD QUALITY CONTROL

Retain paragraph and subparagraphs below to require Contractor to prepare switchgear and related components for manufacturer's field service technician and for acceptance testing.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Prepare for acceptance tests as follows:
 1. Test insulation resistance for each switchgear bus, component, connecting supply, feeder, and control circuit.
 2. Test continuity of each circuit.

Retain paragraph and subparagraphs below to require a factory-authorized service representative to perform, or assist Contractor with, field inspections, tests, and adjustments.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing:
- C. Perform the following field tests and inspections and prepare test reports:

Retain subparagraphs below with either of last two paragraphs above. Edit to suit Project. Delete subparagraphs if testing will be performed by Owner-engaged testing and inspecting agency.

1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for each of the following NETA categories:
 - a. Switchgear.
 - b. Circuit breakers.
 - c. Protective relays.
 - d. Instrument transformers.
 - e. Metering and instrumentation.
 - f. Ground-fault systems.
 - g. Battery systems.
 - h. Surge arresters.
 - i. Capacitors.

2. Remove and replace malfunctioning units and retest as specified above.
- D. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switchgear. Remove front and rear panels so joints and connections are accessible to portable scanner.
1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchgear 11 months after date of Substantial Completion.
 2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
 3. Record of Infrared Scanning: Prepare a certified report that identifies switchgear checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.7 ADJUSTING

Retain one of two paragraphs below. Retain first if coordination study is responsibility of Contractor and is included in Section 260573 "Overcurrent Protective Device Coordination Study."

- A. Set field-adjustable, protective-relay trip characteristics according to results in Section 260573 "Overcurrent Protective Device Coordination Study."
- B. Set field-adjustable, protective-relay trip characteristics.

3.8 CLEANING

- A. On completion of installation, inspect interior and exterior of switchgear. Remove paint splatters and other spots. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair exposed surfaces to match original finish.

3.9 PROTECTION

- A. Temporary Heating: Apply temporary heat to switchgear, according to manufacturer's written instructions, throughout periods when switchgear environment is not controlled for temperature and humidity within manufacturer's stipulated service conditions.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain switchgear. Refer to Section 017900 "Demonstration and Training."
- B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262300

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SECTION 262313 - PARALLELING LOW-VOLTAGE SWITCHGEAR

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes metal-clad, [low] [medium]-voltage, circuit-breaker switchgear rated [1000] [5000] [15000] V and less, and associated control systems, for paralleling generators on an isolated bus and for distributing power in ac systems.
- B. Related Sections include the following:

List below only products, construction, and equipment that the reader might expect to find in this Section but are specified elsewhere.

Retain first subparagraph below if Project includes requirements for electrical power monitoring and control.

1. Section 260913 "Electrical Power Monitoring and Control" for interfacing communication and metering requirements.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. ATS: Acceptance Testing Specification.
- B. GFCI: Ground-fault circuit interrupter.
- C. HMI: Human machine interface.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of paralleling low-voltage switchgear.
 - 1. Technical data on features, performance, electrical characteristics, ratings, and finishes.
 - 2. Rated capacities, operating characteristics, furnished specialties, and accessories for individual circuit breakers.
 - 3. Features, characteristics, ratings, factory settings, and time-current characteristic curves for individual relays and overcurrent protective devices.
 - 4. Description of sequence of operation for paralleling controls.
 - 5. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each type of switchgear and related equipment, include the following:
 - 1. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Include the following:
 - a. Tabulation of installed devices with features and ratings.
 - b. Enclosure types and details.
 - c. Outline and general arrangement drawing showing dimensions, shipping sections, and weights of each assembled section.
 - d. Floor plan drawing showing locations for anchor bolts[**and leveling channels**].
 - e. Bus configuration with current rating, size, and number of conductors in each bus run, including phase, neutral, and ground conductors of main and branch buses.
 - f. Short-time and short-circuit current rating of switchgear assembly.
 - g. Features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
 - h. Nameplate legends.
 - i. Mimic-bus diagram.

Delete first subparagraph below for medium-voltage switchgear or if series rating of overcurrent protective devices is not used for low-voltage switchgear.

- j. UL listing for series rating of installed devices.
2. Wiring Diagrams: For switchgear, paralleling control system, and related equipment, include the following:
 - a. Power, signal, and control wiring.
 - b. Schematic control diagrams.
 - c. Diagrams showing connections of component devices and equipment.

Retain two subparagraphs below and revise to suit Project.

- d. Three-line diagrams of current and future circuits showing device terminal numbers and internal diagrams.
- e. Schematic diagrams showing connections to remote devices[**including SCADA remote terminal unit**].

Retain subparagraph below if products are required to withstand specific seismic loads and DEN Project Manager either has delegated design responsibility to Contractor or wants to review structural data as another way to verify products' compliance with performance requirements. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

3. Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting seismic restraints.

Retain "Samples" Paragraph below if mimic bus is required.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: Representative portion of mimic bus with specified finish. Manufacturer's color charts showing colors available for mimic bus.

1.5 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around switchgear where pipe and ducts are prohibited. Show switchgear layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Coordinate seismic requirements with DEN Project Manager.

- B. Manufacturer Seismic Qualification Certification: Submit certification that switchgear, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:

1. Basis of Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- C. Qualification Data: For testing agency.
- D. Source quality-control reports.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- E. Field quality-control reports.

Retain paragraph below if mimic bus is required.

- F. Updated mimic bus diagram reflecting field changes after final switchgear load connections have been made, for record.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For switchgear and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017825 "Operation and Maintenance Data," include the following:
 1. Manufacturer's written instructions for sequence of operation.
 2. Manufacturer's sample system checklists and log sheets.
 3. Manufacturer's written instructions for testing and adjusting relays[**and overcurrent protective devices**].
 4. Time-current curves, including selectable ranges for each type of relay[**and overcurrent protective device**].

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fuses: **[Six (6)] <Insert number>** of each type and rating used. Include spares for **[potential transformers] [control power circuits] [and] [fusible devices]**. Fuses are specified in Section 262813 "Fuses."
 2. Indicating Lights: **[Six (6)] <Insert number>** of each type installed.
 3. Touchup Paint: **[Three (3)] <Insert number>** containers of paint matching enclosure finish, each **0.5 pint** (250 mL).
- B. Maintenance Tools: Furnish tools and miscellaneous items required for switchgear test, inspection, maintenance, and operation. Include the following:
1. **[Traveling-type lifting device, rail mounted on top of paralleling low-voltage switchgear] [Floor-running transport or dockable dolly with manual lifting mechanism]** and all other items necessary to remove circuit breaker from housing and transport it to remote location.

Retain subparagraph below for optional extra materials for medium-voltage switchgear.

2. Racking handle to move circuit breaker manually between connected and disconnected positions, and a secondary test coupler to permit testing of circuit breaker without removal from switchgear..

1.8 QUALITY ASSURANCE

- A. Factory Testing and Witness Testing:
1. Furnish all test equipment and personnel, and perform all tests as may be required and as specified herein.
 2. The manufacturer shall perform all tests normally conducted in accordance with the manufacturer's standard test procedures for all substations. In addition, the manufacturer shall perform all supplementary testing as defined throughout this specification for all substations. All normal and supplemental testing, which is not witnessed by the DEN Project Manager, shall be documented in certified test reports and shall be submitted to the DEN Project Manager for review within two (2) weeks of the performance of the testing.
 3. The following tests shall be performed at the factory and shall be witnessed by

the Engineer of Record and DEN Project Manager, or their duly authorized representative:

- a. A complete visual inspection of the equipment, both internally and externally.
 - b. A complete test of all automatic transfer schemes including all operation and failure modes.
 - c. A complete test of all control panels and controls including dry contact outputs.
 - d. Verification of proper operation of all metering.
 - e. Verify mechanical operation; interlocks and interchangeability of selected breakers.
4. The testing outlined in item "A" above shall be performed only on one main switchgear. In order to perform such testing, all breakers shall be shipped to the switchboard factory and installed in their respective cubicles in a completely assembled Distribution Section
 5. Test 208 volt and /or 480 volt, 3-phase power sources shall be connected to the incoming side of each secondary main such that the sources may be individually applied and removed to completely simulate and test all features of the distribution sections.
 6. Submit to the DEN Project Manager ninety (90) calendar days prior to scheduled testing all test procedures for approval, and notify the DEN Project Manager four (4) weeks duration of the tests.
 7. Provide four (4) copies of the factory test report within two (2) weeks of the completion of such witness tests.

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use one of first two paragraphs below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain first paragraph and subparagraph below if Contractor selects testing agency.

- B. Source Limitations: Obtain switchgear through one source from a single manufacturer.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Section 016000 "Product Requirements."

- C. Product Options: Drawings indicate size, profiles, and dimensional requirements of switchgear and are based on the specific system indicated. Refer to Section 016000 "Product Requirements."
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Comply with NFPA 70.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver switchgear in sections of lengths that can be moved past obstructions in delivery path.

Retain one of two paragraphs below and edit to suit Project.

- B. Store switchgear indoors in clean dry space with uniform temperature to prevent condensation. Protect switchgear from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- C. If stored in areas subjected to weather, cover switchgear to provide protection from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside switchgear; install electric heating (250 W per section) to prevent condensation.

1.10 PROJECT CONDITIONS

Revise paragraph below to describe specific requirements for moving switchgear into place. Where appropriate, indicate alterations to existing facilities that may be required to accommodate an indicated delivery path. Coordinate with Drawings.

- A. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.

Retain paragraph and subparagraphs below if interruption of existing utility service is required.

- B. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 2. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.

Retain paragraph below if installation space for equipment is limited; show maximum dimensions on Drawings.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear and adjacent surfaces and other items. Comply with indicated maximum dimensions.

Medium-voltage switchgear assemblies are designed for application at rated continuous load current where altitude above sea level does not exceed 3300 feet (1005 m), ambient air temperature does not exceed 40 deg C, and effects of solar radiation do not need to be considered. Switchgear operating at 1000 V and less is designed for same conditions except that altitude above sea level must not exceed 6600 feet (2011 m). Edit paragraph and subparagraphs below for Project conditions exceeding these

parameters. For switchgear located outdoors, include expected humidity range and specify compliance with IEEE C37.24 if solar radiation is a factor.

Consult manufacturer of generator paralleling control equipment for more stringent restrictions on environmental conditions. Edit paragraph and subparagraphs to suit these restrictions.

- D. Environmental Limitations: Rate equipment for continuous operation at indicated ampere ratings for the following conditions:
1. Ambient temperature range -30 deg F (-35 deg C) to 120 deg F (49 deg C) <Insert ambient temperature>.
 2. Altitude of 5,500 feet (1677 m) above sea level.
 3. <Insert unusual service conditions.>

1.11 COORDINATION

Edit first paragraph below to delete or add types of construction that penetrate or are supported by ceilings.

- A. Coordinate layout and installation of switchgear and components with other construction that penetrates ceilings or is supported by them, including conduit, piping, equipment, and adjacent surfaces. Maintain required clearances for workspace and equipment access doors and panels.
- B. Coordinate size and location of concrete bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

Edit this Article with other Part 2 articles in which manufacturers are named. See Section 016000 "Product Requirements" for an explanation of the terms "Available Manufacturers" and "Manufacturers" and the effect these terms have on "Comparable Product" and "Product Substitution" requirements.

2.2 GENERATOR PARALLELING MONITOR AND CONTROL SYSTEM

- A. Coordinate paragraph and list below with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.
- B. Subject to compliance with requirements, provide products by one of the following:
1. Caterpillar; Engine Div.
 2. Emerson; ASCO Power Technologies, LP.
 3. GE Zenith Controls.
 4. Kohler Co.; Generator Division.
 5. Onan Corp.; Cummins Inc.; Industrial Business Group.
 6. Russelectric.
 7. **<Insert manufacturer>**
 8. or approved equal.

Type and location of individual control components and manner in which control functions are accomplished vary among manufacturers. Some manufacturers accomplish control functions listed in paragraph and subparagraphs below by locating all control equipment at the generator control panel. Others locate some of the equipment required to accomplish the listed functions in the paralleling switchgear control section. If specific locations are required for individual control components, revise below to suit Project.

Features included for generator control and monitoring panel in paragraph and subparagraphs below partially duplicate, but expand on, those included in Section 263213 "Engine Generators." Coordinate features specified here with that Section.

- C. Individual Generator Control and Monitoring Panel: Provide each generator with a control and monitoring panel that allows the operator to view status and control operation of respective generator. Provide panel with the following features and characteristics:
1. Generator Metering: 1 percent accuracy class or better.
 - a. Ammeter, Voltmeter, Frequency Meter, Wattmeter, Kilowatt-Hour Meter, and Power Factor Meter:
 - 1) For three-phase and four-wire systems, indicate line-to-line and line-to-neutral conditions on voltmeter.
- Retain first subparagraph below if analog meters are preferable to digital devices.
- 2) Provide analog devices for voltmeter and frequency meters.
 - 3) Provide switches or other provisions to allow reading of both generator and bus voltages and frequencies from this metering set.
- b. Synchroscope and "Generator Set Synchronized" Indication:
 - 1) Provide lamp or LED indication of synchronization.
 - 2) Provide 360-degree analog movement synchroscope.
 - c. Engine run-time meter, start counter, rpm meter, and battery voltage meter.

- d. Engine oil temperature gage and engine coolant temperature gage.
2. Generator Protective and Control Switches: Provide oiltight, industrial-grade switches in generator control and monitoring panel.
 - a. Mode Selector Switch (Run/Off/Auto):
 - 1) "Run" mode to start and accelerate unit to rated speed and voltage, but not close paralleling circuit breaker.
 - 2) "Off" mode to prevent generator from starting or to immediately shutdown generator if running.
 - 3) "Auto" mode to allow generator to start on receipt of remote start signal.
 - b. Circuit-Breaker Trip/Close Switch: Interlocked with system control so that circuit-breaker closure is impossible unless the following occurs:
 - 1) Mode selector switch is in "Run" position.
 - 2) Generator set is synchronized with system bus.
 - c. Control/reset push button with flashing lamp to indicate generator is locked out due to fault condition.
 - d. Lamp test push button to simultaneously test all lamps on panel.
 - e. Control Panel Illumination: DC lamps to illuminate panel when lighting from surrounding environment is not available.
 - f. Emergency Stop Push Button: Red mushroom-head switch maintaining its position until manually reset.
 - g. Voltage and Frequency Raise/Lower Switches:
 - 1) Allow plus/minus 5 percent adjustment when generator set is operating but not paralleled.

Some manufacturers accomplish control functions listed in first subparagraph and associated subparagraphs below by means of integrated, microprocessor-based controllers. Others use a series of electronic devices, each of which provides a specific control function. If specific types of devices are required for individual control components, revise below to suit Project.

3. Generator Protective and Control Devices: Solid-state industrial relays, integrated microprocessor-based control devices, and other accessories and devices located either in generator control and monitoring panel or in switchgear control section to provide the following features and functions:
 - a. Kilowatt Load Sharing Control:
 - 1) Operates engine governors during synchronizing and provides isochronous load sharing when paralleled.
 - 2) Allows generator set to ramp up to kilowatt load level signaled by system master controller.
 - b. Load-Demand Governing Control:

- 1) Causes generator set to ramp down to zero load when signaled to shut down in load-demand mode.
 - 2) Causes generator set to ramp up to a proportional share of total bus load.
- c. Kilovolt Ampere Rating Load Sharing Control:
- 1) Operates alternator excitation system while generator set is paralleled.
 - 2) Causes sharing of reactive load among all generator sets to within 1 percent of equal levels without voltage drop.
- d. Sync-Check and Paralleling Monitor and Control:
- 1) Monitors and verifies that generator set has reached 90 percent of nominal voltage and frequency before closing to bus.
 - 2) Prevents out-of-phase paralleling if two or more generator sets reach operating conditions simultaneously, by sending "inhibit" signal to sets not designated by system as "first to close to bus."
 - 3) Recognizes failure of "first-to-close" generator set and signals system paralleling to continue.
 - 4) Prevents out-of-phase closure to bus due to errant manual or automatic operation of synchronizer.
- e. Synchronizer Control:
- 1) Adjusts engine governor to match voltage, frequency, and phase angle of paralleling bus.
 - 2) Maintains generator-set voltage within 1 percent of bus voltage, and phase angle within 20 electrical degrees of paralleling bus for 0.5 seconds before circuit-breaker closing.
 - 3) Provides "fail-to-synchronize time delay" adjustable from 10 to 120 seconds; with field selectivity to either initiate alarm or shut down generator set on failure condition.
- f. Reverse Power Monitor and Control:
- 1) Prevents sustained reverse power flow in generator set.
 - 2) Trips generator circuit breaker and initiates generator set shutdown when reverse power condition exceeds 10 percent of generator set kilowatt for three seconds.
- g. Phase Rotation Monitor and Control:
- 1) Verifies generator set and paralleling bus phase rotation match prior to closing paralleling circuit breaker.

Protection provided in first two subparagraphs and associated subparagraphs below is in addition to that provided by generator-output circuit breaker. Specify generator-output circuit breaker in Section 263213 "Engine Generators."

- h. Electronic Alternator Overcurrent Alarm and Shutdown Control:
 - 1) Monitors current flow at generator-set output terminals.
 - 2) Initiates alarm when load current on generator set is more than 110 percent of rated current for more than 60 seconds.
 - 3) Provides overcurrent shutdown function matched to thermal damage curve of alternator. Provide without instantaneous-trip function.
 - i. Electronic Alternator Short-Circuit Protection:
 - 1) Provides shutdown when load current is more than 175 percent of rated current and combined time/current approaches thermal damage curve of alternator. Provide without instantaneous-trip function.
 - j. Loss of Excitation Monitor:
 - 1) Initiates alarm when sensing loss of excitation to alternator while paralleled to system bus.
 - k. Generator-Set Start Contacts: Redundant system, 10 A at 32-V dc.
 - l. Cool-Down Time-Delay Control: Adjustable, 0 to 600 seconds.
 - m. Start Time-Delay Control: Adjustable, 0 to 300 seconds.
 - n. Paralleling Circuit-Breaker Monitor and Control:
 - 1) Monitors circuit-breaker auxiliary contacts.
 - 2) Initiates fault signal if circuit breaker fails to close within adjustable time-delay period (0.5 to 15 seconds).
 - 3) Trips open and locks out paralleling circuit breaker upon paralleling circuit breaker failure to close, until manually reset.
4. Engine Protection and Local Annunciation:
- a. Provide annunciation and shutdown control modules for alarms indicated.
 - b. Provide visual alarm status indicator and alarm horn with silence/acknowledge push button on generator control and monitoring panel.
 - c. Annunciate the following conditions:
 - 1) Status, Light Only (Nonlatching):
 - a) Generator engine control switch not in auto (red).
 - b) Generator engine control switch in auto (green).
 - c) Emergency mode (red).
 - d) Generator circuit breaker closed (red).
 - e) Generator circuit breaker open (green).
 - f) Engine stopped (green).
 - g) Engine running (red).
 - h) Engine cool-down (amber).

- 2) Pre-Alarm, Light and Horn (Nonlatching):
 - a) Pre-high coolant temperature (amber).
 - b) Pre-low oil pressure (amber).
 - c) Low coolant temperature (amber).
 - d) Engine low battery (amber).
 - e) Engine low fuel (amber).
 - f) Generator fails to synchronize (amber).

- 3) Shutdown Alarm, Light and Horn (Latching):
 - a) Engine overcrank (red).
 - b) Engine overspeed (red).
 - c) Engine low oil pressure (red).
 - d) Engine high coolant temperature (red).
 - e) Engine low coolant level (red).
 - f) Engine remote emergency shutdown (red).
 - g) Generator circuit breaker tripped (red).
 - h) Generator loss of field (red).
 - i) Generator reverse power (red).
 - j) Generator undervoltage (red).
 - k) Generator overvoltage (red).
 - l) Generator underfrequency (red).
 - m) Generator overfrequency (red).

- D. Master Control System and Monitoring Equipment: Paralleling and monitoring equipment, components, and accessories for multiple generators with the following features and characteristics:

Master control system may be located in a separate enclosure. Most manufacturers provide it as a separate cubicle in switchgear lineup. If a separate enclosure is required, revise paragraph above and first subparagraph below to suit Project.

1. Components and devices shall be mounted in the switchgear control section of the switchgear lineup.
2. Paralleled System Metering: 1 percent accuracy class or better to monitor total output of generator bus.
 - a. Ammeter, voltmeter, frequency meter, wattmeter, kilowatt-hour meter, power factor meter, kilovolt ampere, kilovolt ampere rating, and kilowatt demand meters.
 - 1) For three-phase/four-wire systems, indicate line-to-line and line-to-neutral conditions on voltmeter.
 - 2) Display all functions on the HMI device.
3. Full-Color HMI Device: Touchscreen with minimum viewing area of 60 square inches.
 - a. Allows operator to monitor and control the complete system of paralleled generator sets.

- b. Screens shall include the following:
- 1) Main Menu: Include date, time, and system status messages with screen push buttons to access one-line diagram, system controls, load controls, alarms, bus metering, and individual generator-set data.
 - 2) One-Line Diagram Screen: Depicting system configuration and system status by screen animation, screen colors, text messages, or pop-up indicators. Indicate the following minimum system conditions:
 - a) Generator sets, buses, and paralleling circuit breakers energized/de-energized.
 - b) Generator-set mode (run/off/auto).
 - c) Generator-set status (normal/warning/shutdown/load-demand stop).
 - d) Paralleling circuit-breaker status (open/closed/tripped).
 - e) Bus conditions (energized/de-energized).
 - f) Provide access to other screens.
 - 3) AC Metering Screen: Displays the following minimum meter data for the paralleling bus:
 - a) Phase volts and amperes, kilowatt, kilovolt ampere, kilovolt ampere rating, power factor, frequency, kilowatt hour, and kilowatt demand.
 - b) Real-time trend chart for system kilowatts and volts updated on not less than one-second intervals.
 - c) A minimum of one historical trend chart for total system loads with intervals no shorter than five minutes and a minimum duration of four hours.
 - 4) Generator-Set Control Screen: Provides control over individual generator sets from master system control panel. Includes the following minimum functions:
 - a) Generator manual start/stop control (functional only when generator-set mounted control switch is in "Auto" position).
 - b) Generator-set alarm reset.
 - c) Manual paralleling and circuit-breaker controls.
 - 5) Generator-Set Data Display Screen: Provide the following minimum parameters:
 - a) Engine speed, oil pressure and temperature, coolant temperature, and engine operating hours.
 - b) Three-phase voltage and current, kilowatt, power factor, and kilowatt hour.
 - c) Generator control switch position and paralleling circuit-breaker position.
 - d) All generator-set alarms.

- 6) System Control Screen: Password protected and with the following minimum functions:
 - a) System Test Modes: Test with load/test without load/normal/retransfer time-delay override.
 - b) Test with Load: Starts and synchronizes generator sets on paralleling bus; all loads are transferred to bus.
 - c) Test without Load: Starts and synchronizes generator sets on paralleling bus but does not transfer loads to bus.
 - d) Time adjustments for retransfer time delay, transfer time delay, system time delay on stopping, and system time delay on starting.

- 7) Load-Demand Control Screen: Monitors total load on system bus and controls number of generator sets running so that capacity tracks load demand.
 - a) Load-Demand Control: On/off.
 - b) Load-Demand Pickup Set Point: Adjustable from 90 to 40 percent in 5 percent increments.
 - c) Load-Demand Dropout Set Point: Adjustable from 20 to 70 percent in 5 percent increments.

- 8) Manual Load Control Screen: Allows operator to manually add or delete generator sets from paralleled system in response to system load parameters.
 - a) Indication of system available in kilowatts and amperes.
 - b) Control functions allow manual addition/removal of generator sets on system, and activation of load-shed/load-restore functions.

- 9) Load-Add/Load-Shed Sequence Screen: Password protected and with the following minimum functions:
 - a) Assigns "load-add sequence priority" to each load control relay with designation for relay operation after a set number of generator sets are online.
 - b) Assigns "load-shed sequence priority" to each load control relay with designation for relay operation depending on number of generator sets online.

- 10) Alarm Summary and Run Report Screen:
 - a) Lists most recent alarm conditions and status changes.
 - b) Lists a minimum of the most recent 32 alarm conditions by name and time/date; acknowledges alarm conditions with time/date.

- c) For each start signal, lists start time and date, stop time and date, maximum kilowatt and ampere load on system during run time, and start and stop times of individual generator sets.

4. Solid-State System Status Panel:

- a. Provides visual alarm status indicator and alarm horn with silence/acknowledge push button.
- b. Annunciates the following conditions:
 - 1) Status, Light Only:
 - a) Running Status: Display generator set number and "green" running-status light.
 - b) Load demand mode (green).
 - c) Priority Load Status: Display load number and "green" on-status light.
 - d) System test (green).
 - e) Remote system start (red).
 - f) Normal source available (green).
 - g) Connected to normal (green).
 - h) Generator source available (green).
 - i) Connected to generator source (green).
 - 2) Status, Light and Alarm:
 - a) Load-Shed Level Status: Displays load number and red load-shed, status light.
 - b) Generator Alarm Status: Displays generator number and red "Check Generator" status light.
 - c) Controller malfunction (red).
 - d) Check station battery (red).
 - e) Bus overload (red).
 - f) System not in auto (red).

E. Description of System Operation:

1. Loss of Normal Power:
 - a. System receives "start" signal; all generator sets start and achieve rated voltage and frequency.
 - b. System closes the first generator set achieving 90 percent of rated voltage to paralleling bus.
 - c. "Priority load add" controls prevent overloading of system.
 - d. Remaining generator sets switched to synchronizers that control and then allow closure of generator sets to paralleling bus.
 - e. On closure to paralleling bus, each generator set assumes its proportional share of total load.
2. Failure of a Generator Set to Start or Synchronize:

- a. After expiration of overcrank time delay, generator set shuts down and alarm is initiated.
 - b. Priority controller prevents overload of system bus.
 - c. Manual override of priority controller at HMI allows addition of low-priority load to bus.
 - d. Bus overload monitor protects bus from manual overloading.
3. Bus Overload:
- a. On bus overload, load-shed control initiates load shedding.
 - b. If bus does not return to normal frequency within adjustable time period, additional load continues to be shed until bus returns to normal frequency.
 - c. Loads shed can be reconnected to bus only by manual reset at HMI.
4. Load-Demand Mode:
- a. With "load-demand" function activated, controller continuously monitors total bus load.
 - b. If bus load is below preset limits for 15 minutes, demand controller shuts down generator sets in predetermined order until minimum number of sets are operating.
 - c. On sensing available bus capacity diminished to set point, controller starts and closes generator sets to bus to accommodate load.
5. Return to Normal Power:
- a. Process starts on removal of start signals from system.
 - b. When no load remains on paralleling bus, all generator breakers open, go through cool-down period, and shut down.
 - c. If start signal is received during cool-down period, one generator set is reconnected to bus, and system operation follows that of "loss of normal power."

2.3 MANUFACTURED UNITS

Switchgear assemblies described in this Article and in the two articles that follow can be used for paralleling generator sets and for distributing generated power through feeder breakers located in same or separate switchgear lineups.

- A. Description: Factory assembled and tested and complying with IEEE C37.20.1.
 - B. Ratings: Suitable for application in 3-phase, 60-Hz, solidly grounded neutral system.
 - C. Indoor Enclosure Material: Steel.
 - D. Outdoor Enclosure Fabrication Requirements: Galvanized steel, weatherproof; integral structural-steel base frame with factory-applied asphaltic undercoating.
1. Provide each compartment or group of compartments with the following features:

- a. Structural design and anchorage adequate to resist loads imposed by [125-mph (200-km/h)] <Insert wind speed> wind.
- b. Space heater operating at one-half or less of rated voltage, sized to prevent condensation.
- c. Louvers equipped with insect and rodent screen and filter; arranged to permit air circulation while excluding insects, rodents, and exterior dust.

Delete first three subparagraphs below if weatherproof internal aisle construction is specified.

- d. Hinged front door with locking provisions.
- e. Interior light with switch.
- f. Weatherproof GFCI duplex receptacle.
- g. Power for heaters, lights, and receptacles to be provided [by control power transformer] [as indicated].

Retain subparagraph and associated subparagraphs below for weatherproof internal aisle construction.

2. Provide weatherproof internal aisle construction with the following features:
 - a. Common internal aisle of sufficient width to permit protective-device withdrawal, disassembly, and servicing in aisle.
 - b. Aisle access doors with exterior padlocking provisions and interior panic latches.
 - c. Aisle space heaters operating at one-half or less of rated voltage, thermostatically controlled.
 - d. Vaporproof fluorescent aisle lights with low-temperature ballasts, controlled by wall switch at each entrance.
 - e. GFCI duplex receptacles, a minimum of two, located in aisle.

Revise subparagraph below if forced ventilation rather than convection ventilation is required.

- f. Aisle ventilation louvers equipped with insect and rodent screen and filter; arranged to permit air circulation while excluding insects, rodents, and exterior dust.

- E. Access: Fabricate enclosure with hinged, rear cover panels to allow access to rear interior of switchgear.
- F. Finish: Manufacturer's standard gray finish over a rust-inhibiting primer on phosphatizing-treated metal surfaces.
- G. Phase-, Neutral-, and Ground-Bus Materials: Extend full length of switchgear.
 1. Phase and Neutral Bus: Copper, silver plated at connection points.
 2. Ground Bus: Copper, silver plated; minimum size 1/4 by 2 inches (6 by 50 mm).
- H. Switchgear Components: Incorporate components as indicated on Drawings.
 1. Instrument Transformers: Comply with IEEE C57.13.
 - a. Potential Transformers: Secondary-voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.

Coordinate subparagraph below with Drawings.

- b. Current Transformers: Burden and accuracy class suitable for connected relays, meters, and instruments.

Metering in subparagraph and associated subparagraphs below is independent of metering specified above for generator paralleling monitor and control system. Delete below if conventional analog-meter installation is required.

2. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems, listed and labeled by UL, and with the following features:
 - a. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 - b. Switch-selectable digital display with the following features:
 - 1) Phase Currents, Each Phase: Plus or minus 1 percent.
 - 2) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - 3) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - 4) Three-Phase Real Power: Plus or minus 2 percent.
 - 5) Three-Phase Reactive Power: Plus or minus 2 percent.
 - 6) Power Factor: Plus or minus 2 percent.
 - 7) Frequency: Plus or minus 0.5 percent.
 - 8) Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.

Retain subparagraph below to suit Project.

- 9) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.

Coordinate first subparagraph below with Section 260913 "Electrical Power Monitoring and Control" or with other remote monitoring system.

- c. Communications module suitable for remote monitoring of meter quantities and functions. Interface communication and metering requirements according to Section 260913 "Electrical Power Monitoring and Control."
- d. Mounting: Display and control unit that is flush or semiflush mounted in instrument compartment door.

Delete subparagraph and associated subparagraphs below if multifunction digital-metering monitor above is specified.

3. Analog Instruments: Rectangular, 4-1/2 inches (115 mm) square, accurate within 1 percent; semiflush mounting, with antiparallax 250-degree scale and external zero adjustment; complying with ANSI C39.1.

Delete option in first subparagraph below for three-wire systems.

- a. Voltmeter Selector Switch: Rotary type with off position; provides readings of phase-to-phase and phase-to-neutral voltages.

Revise demand interval and other characteristics in two subparagraphs and associated subparagraphs below to suit Project.

Delete subparagraph below unless relays that are not integral with circuit breakers or circuit-breaker trip units are required. Specify relay functions and characteristics below or indicate on Drawings.

4. Relays: Comply with IEEE C37.90, integrated digital type; with test blocks and plugs.

Retain first subparagraph below to suit Project. Coordinate with Drawings.

5. Provision for Future Devices: Equip compartments with rails, mounting brackets, supports, necessary appurtenances, and bus connections.
6. Control Power Supply: Control power transformer supplies 120-V control circuits through secondary disconnect devices. Include the following features:
 - a. Dry-type transformers, in separate compartments for units larger than 3 kVA, including primary and secondary fuses.

Retain subparagraph below for electrically interlocked main and tie circuit breakers.

- b. Two control power transformers in separate compartments with necessary interlocking relays; each transformer connected to line side of associated main circuit breaker.

Retain one of first two subparagraphs below.

- 1) Secondary windings connected through relay(s) to control bus to effect an automatic transfer scheme.
 - 2) Secondary windings connected through an internal automatic transfer switch to switchgear control power bus.
- c. Control Power Fuses: Primary and secondary fuses provide current-limiting and overload protection.
 - d. Fuses are specified in Section 262813 "Fuses."
7. Control Wiring: Factory installed, complete with bundling, lacing, and protection; and complying with the following:
 - a. Flexible conductors for No. 8 AWG and smaller, for conductors across hinges and for conductors for interconnections between shipping units.
 - b. Conductors sized according to NFPA 70 for duty required.

Retain paragraph and subparagraphs below to suit Project.

- I. Identification: Electrical identification devices and installation requirements are specified in Section 260553 "Identification for Electrical Systems."
 1. Identify units, devices, controls, and wiring.
 2. Mimic Bus: Continuous mimic bus, applied to front of switchgear, arranged in one-line diagram format, using symbols and lettered designations consistent with approved mimic-bus diagram.

- a. Mimic-bus segments coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
- b. Medium: Painted graphics, as selected by DEN Project Manager.
- c. Color: Contrasting with factory-finish background; as selected by DEN Project Manager from manufacturer's full range.

Retain paragraph and subparagraphs below if dc control power source is required for switchgear. Generator paralleling monitor and control system may be powered from this system in lieu of the generator-set batteries. Revise to suit Project. Coordinate with Drawings.

Revise below if battery other than lead-calcium type is specified.

J. Control Battery System:

Coordinate first subparagraph below with Drawings or, preferably, revise to specify number of cells and required minimum ampere-hour capacity of battery.

1. System Requirements: Battery shall have number of cells and ampere-hour capacity based on an initial specific gravity of 1.210 at 25 deg C with electrolyte at normal level and minimum ambient temperature of 13 deg C. Cycle battery before shipment to guarantee rated capacity on installation. Arrange battery to operate ungrounded.
2. Battery: Lead-calcium type in sealed, clear plastic or glass containers, complete with electrolyte, fully charged, and arranged for shipment with electrolyte in cells. Limit weight of each container to not more than 70 lb (32 kg) and cells per container to not more than 3. System batteries shall be suitable for service at an ambient temperature ranging from minus 18 to 25 deg C. Limit variation of current output to 0.8 percent for each degree below 25 deg C down to minus 8 deg C.

Coordinate first two subparagraphs and associated subparagraphs below with Drawings.

3. Rack: Two-step rack with electrical connections between battery cells and between rows of cells; include two flexible connectors with bolted-type terminals for output leads. **[Rate battery rack, cell supports, and anchorage for seismic requirements.]**
4. Accessories:
 - a. Thermometers with specific-gravity correction scales.
 - b. Hydrometer syringes.
 - c. Set of socket wrenches and other tools required for battery maintenance.
 - d. Wall-mounting, nonmetallic storage rack fitted to store above items.
 - e. Set of cell numerals.
5. Charger: Static-type silicon rectifier equipped with automatic regulation and provision for manual and automatic adjustment of charging rate. Unit shall automatically maintain output voltage within 0.5 percent from no load to rated charger output current, with ac input-voltage variation of plus or minus 10 percent and input-frequency variation of plus or minus 3 Hz. Other features of charger include the following:

- a. DC ammeter.
- b. DC Voltmeter: Maximum error of 5 percent at full-charge voltage; operates with toggle switch to select between battery and charger voltages.
- c. Ground Indication: Two appropriately labeled lights to indicate circuit ground, connected in series between negative and positive terminals, and with midpoint junction connected to ground by normally open push-button contact.
- d. Capacity: Sufficient to supply steady load, float-charge battery between 2.20 and 2.25 V per cell and equalizing charge at 2.33 V per cell.
- e. Charging-Rate Switch: Manually operated switch provides for transferring to higher charging rate. Charger operates automatically after switch operation until manually reset.
- f. AC power supply is 120 V, 60 Hz, subject to plus or minus 10 percent variation in voltage and plus or minus 3-Hz variation in frequency. After loss of ac power supply for any interval, charger automatically resumes charging battery. Charger regulates rate of charge to prevent damage due to overload and to prevent fuses or circuit breakers from opening.
- g. Protective Feature: Current-limiting device or circuit, which limits output current to rating of charger but does not disconnect charger from either battery or ac supply; protects charger from damage due to overload, including short circuit on output terminals.
- h. Electrical Filtering: Reduces charger's audible noise to less than 26 dB.

2.4 METAL-CLAD, CIRCUIT-BREAKER SWITCHGEAR (1000 V AND LESS)

Coordinate first paragraph and list below with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.

- A. Subject to compliance with requirements, provide products by one of the following:
 1. ABB Inc.
 2. Cutler-Hammer; Eaton Corporation.
 3. General Electric Company.
 4. Siemens Energy & Automation, Inc.
 5. Square D; Schneider Electric.
 6. <Insert manufacturer>
 7. or approved equal.
- B. Description: Factory assembled and tested, and complying with IEEE C37.20.1.

Delete first three paragraphs below if ratings are indicated on Drawings. Drawings are generally the preferred location for this data.

- C. Nominal System Voltage: 480 V, 3 480/277 V, 4 240 V, 3 208/120 V, 4 wire, 60 Hz.

IEEE C37.20.1 lists main-bus ratings only through 4000 A, but some manufacturers provide bus ratings through 5000 A. However, circuit breakers are available only through 4000 A.

Main-bus rating may vary depending on configuration of paralleling and distribution switchgear. Edit paragraph below accordingly or indicate ratings on Drawings.

D. Main-Bus Continuous: **[4000] [3200] [2000] [1600] <Insert rating> A.**

For isolated bus paralleling of generator sets, ratings in first paragraph below need only accommodate generator fault current plus other sources of fault current available in distribution system. Delete paragraph if values are specified on Drawings.

E. Short-Time and Short-Circuit Current: Match rating of highest-rated circuit breaker in switchgear assembly.

F. Switchgear Fabrication:

1. Bus isolation barriers shall be arranged to isolate line bus from load bus at each main and tie circuit breaker.
2. Circuit-breaker compartments shall be equipped to house drawout-type circuit breakers and shall be fitted with hinged outer doors.

Edit subparagraph and associated subparagraphs below to suit Project.

3. Auxiliary Compartments: Match and align with basic switchgear assembly. Include the following:
 - a. Bus transition sections.
 - b. Pull sections.
 - c. Hinged front panels for access to accessory and blank compartments.
 - d. Pull box on top of switchgear for extra room for pulling cable; with removable top, front, and side covers; and ventilation provisions adequate to maintain air temperature in pull box within same limits as switchgear.

Retain first subparagraph below if top-mounted, circuit-breaker removal mechanism is used.

- 1) Set pull box back from front to clear circuit-breaker lifting mechanism.
- 2) Bottom: Insulating, fire-resistive material with separate holes for cable drops into switchgear.
- 3) Cable Supports: Arranged to ease cabling and adequate to support cables indicated, including those for future installation.

Coordinate first subparagraph and associated subparagraphs below with Drawings.

4. Bus bars connect between vertical sections and between compartments. Cable connections are not permitted.
 - a. Main Phase Bus: Uniform capacity the entire length of assembly.
 - b. Neutral Bus: **[50] [100]** percent of phase-bus ampacity, except as indicated. **[Equip bus with pressure-connector terminations for outgoing neutral conductors] [Include braces for neutral-bus extensions for busway feeders].**
 - c. Vertical Section Bus Size: Comply with IEEE C37.20.1, including allowance for spare circuit breakers and spaces for future circuit breakers.
 - d. Supports and Bracing for Buses: Adequate strength for indicated short-circuit currents.

Retain first subparagraph below if required for distribution sections of switchgear with main service disconnect switches. Edit to suit Project. Coordinate with Drawings.

- e. Neutral Disconnect Link: Bolted, uninsulated, 1/4-by-2-inch (6-by-50-mm) copper bus, arranged to connect neutral bus to ground bus.
- f. Provide for future extensions from either end of main phase, neutral, and ground bus by means of predrilled bolt-holes and connecting links.

IEEE and UL standards may require air insulation only. Retain first subparagraph and associated subparagraphs below if insulated bus is required.

- g. Bus-Bar Insulation: Individual bus bars wrapped with factory-applied, flame-retardant tape or spray-applied, flame-retardant insulation.
 - 1) Sprayed Insulation Thickness: 3 mils (0.08 mm), minimum.
 - 2) Bolted Bus Joints: Insulate with secure joint covers that can easily be removed and reinstalled.
- 5. Circuit-Breaker Terminals for Cable Connections: Silver-plated copper bus extensions equipped with pressure connectors for conductors.

G. Circuit Breakers: Comply with IEEE C37.13.

Coordinate first subparagraph below with Drawings.

- 1. Ratings: As indicated for continuous, interrupting, and short-time current ratings for each circuit breaker; voltage and frequency ratings same as switchgear.
- 2. Operating Mechanism: Mechanically and electrically trip-free, stored-energy operating mechanism with the following features:
 - a. Normal Closing Speed: Independent of both control and operator.
 - b. Slow Closing Speed: Optional with operator for inspection and adjustment.

Retain one of two options in subparagraph below to specify manual or electrical operation for circuit breakers.

- c. Stored-Energy Mechanism: **[Manually charged] [Electrically charged, with optional manual charging].**

Retain first subparagraph below if applicable.

- d. Operation counter.
- 3. Trip Devices: Solid-state, overcurrent trip-device system consisting of one or two current transformers or sensors per phase, a release mechanism, and the following features:

Select from seven subparagraphs below to suit Project. Requirements may vary depending on whether circuit breakers are used for paralleling generators or for distribution circuits.

- a. Functions: Long-time-delay, short-time-delay, and instantaneous-trip functions, independent of each other in both action and adjustment.
- b. Temperature Compensation: Ensures accuracy and calibration stability from minus 5 to plus 40 deg C.
- c. Field-adjustable, time-current characteristics.

- d. Current Adjustability: Dial settings and rating plugs on trip units or sensors on circuit breakers, or a combination of these methods.
- e. Three bands, minimum, for long-time- and short-time-delay functions; marked "minimum," "intermediate," and "maximum."
- f. Pickup Points: Five minimum, for long-time- and short-time-trip functions. Equip short-time-trip function for switchable I2t operation.
- g. Pickup Points: Five minimum, for instantaneous-trip functions.

Coordinate first subparagraph and associated subparagraphs below with Drawings. Indicate circuits with ground-fault protection. Show type of protection for each circuit where switchgear has more than one type.

- h. Ground-fault protection with at least three short-time-delay settings and three trip-time-delay bands; adjustable current pickup. Arrange to provide protection for the following:
 - 1) Three-wire circuit or system.
 - 2) Four-wire circuit or system.
 - 3) Four-wire, double-ended substation.
- i. Trip Indication: Labeled, battery-powered lights or mechanical targets on trip device to indicate type of fault.

Retain first subparagraph below if applicable. Coordinate with Drawings.

- 4. Auxiliary Contacts: For interlocking or remote indication of circuit-breaker position, with spare auxiliary switches and other auxiliary switches required for normal circuit-breaker operation, quantity as indicated. Each consists of two Type "a" and two Type "b" stages (contacts) wired through secondary disconnect devices to a terminal block in stationary housing.
- 5. Drawout Features: Circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in connected, test, and disconnected positions. Include the following features:
 - a. Interlocks: Prevent movement of circuit breaker to or from connected position when it is closed.
 - b. Circuit-Breaker Positioning: An open circuit breaker may be racked to or from connected, test, and disconnected positions only with the associated compartment door closed, unless live parts are covered by a full dead-front shield. An open circuit breaker may be manually withdrawn to a position for removal from the structure with the door open. Status for connection devices for different positions includes the following:
 - 1) Test Position: Primary disconnect devices disengaged, and secondary disconnect devices and ground contact engaged.
 - 2) Disconnected Position: Primary and secondary devices and ground contact disengaged.
- 6. Arc Chutes: Readily removable from associated circuit breaker when it is in disconnected position; arranged to permit inspection of contacts without removing circuit breaker from switchgear.

7. Padlocking Provisions: For installing at least three padlocks on each circuit breaker to secure its enclosure and prevent movement of drawout mechanism.

Retain first subparagraph below if applicable.

8. Operating Handle: One for each circuit breaker capable of manual operation.
9. Electric Close Button: One for each electrically operated circuit breaker.

First subparagraph below limits competition because some manufacturers do not provide mechanical interlocks. Interlocks are normally required for transferring of loads or prohibiting the paralleling of loads. Retain below only if required for specific control function.

10. Mechanical Interlocking of Circuit Breakers: Uses a mechanical tripping lever or equivalent design and electrical interlocks.
11. Key Interlocks: Arranged so keys are attached at devices indicated. Mountings and hardware are included where future installation of key-interlock devices is indicated.
12. Undervoltage Trip Devices: Instantaneous, with adjustable pickup voltage.

Retain subparagraph above or first subparagraph below.

13. Undervoltage Trip Devices: Adjustable time-delay and pickup voltage.
14. Shunt-Trip Devices: Where indicated.
15. Indicating Lights: To indicate circuit breaker is open or closed, for main and bus tie circuit breakers interlocked either with each other or with external devices.

Retain paragraph and subparagraphs below or delete if not applicable.

- H. Accessories: Furnish tools and miscellaneous items required for circuit-breaker and switchgear tests, inspections, maintenance, and operation.
 1. Racking handle to manually move circuit breaker between connected and disconnected positions.
 2. Portable test set for testing all functions of circuit-breaker, solid-state trip devices without removal from switchgear.
 3. Relay and meter test plugs suitable for testing switchgear meters and switchgear class relays.

Delete one of two, or both, apparatus paragraphs below. Coordinate apparatus space requirements with Drawings.

- I. Circuit-Breaker Removal Apparatus: Portable, floor-supported, roller-base, elevating carriage arranged for moving circuit breakers in and out of compartments.

If paragraph below is used for outdoor switchgear, it must be walk-in aisle type. Coordinate apparatus space requirements with Drawings.

- J. Circuit-Breaker Removal Apparatus: Overhead-circuit-breaker lifting device, track mounted at top front of switchgear and complete with hoist and lifting yokes matching each size of drawout circuit breaker installed.

Coordinate first paragraph below with Drawings.

- K. Spare-Fuse Cabinet: Identified and compartmented steel box or cabinet with lockable door.
- L. Storage for Manual: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

2.5 METAL-CLAD, MEDIUM-VOLTAGE, CIRCUIT-BREAKER SWITCHGEAR

Coordinate paragraph and list below with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.

- A. Subject to compliance with requirements, provide products by one of the following:
 - 1. ABB, Inc.
 - 2. Cutler-Hammer; Eaton Corporation.
 - 3. General Electric Company.
 - 4. Siemens Energy & Automation, Inc.
 - 5. Square D; Schneider Electric.
 - 6. **<Insert manufacturer>**
 - 7. or approved equal.

Retain only paragraph below for conventional switchgear; retain first two paragraphs for arc-resistant switchgear.

- B. Comply with IEEE C2 and IEEE C37.20.3.

See Evaluations for description of each switchgear type. Verify availability with manufacturers.

- C. System Voltage: 4.16 kV nominal; 4.76 kV maximum.
- D. Nominal Interrupting-Capacity Class: [250] [350] [500] [750] [1000] MVA.
- E. Ratings: Comply with IEEE C37.04.

Delete subparagraph below if ampere rating is shown on Drawings.

- F. Circuit Breakers: Three-pole, single-throw, electrically operated, drawout-mounting units using three individual, [**vacuum-sealed**] [**sulfur hexafluoride insulated and sealed**] interrupter modules; include the following features:
 - 1. Designed to operate at rated voltage to interrupt fault current within its rating within [**three**] [**five**] cycles of trip initiation. For systems with X/R ratio of 17 or less, transient voltage during interruption shall not exceed twice the rated line-to-ground voltage of system.
 - 2. Contact-Wear Indicator: Readily accessible to field maintenance personnel.
 - 3. Minimum of six Type A and six Type B spare contacts.
 - 4. Interchangeability: Circuit breakers are interchangeable with vacuum circuit breakers of same current and interrupting ratings.

Retain subparagraph below if sulfur hexafluoride circuit breakers are used.

5. Internal sulfur hexafluoride pressure is not to exceed 2.5 bars during normal operation.

Retain first three subparagraphs below and revise to suit Project.

- a. Current Rating of Main Circuit Breaker: 2000 A.
 - b. Continuous Current Rating of Tie Circuit Breaker: 2000 A.
 - c. Continuous Current Rating of Feeder Circuit Breaker: 1200 A.
6. Operating Mechanism: Electrically charged, mechanically and electrically trip-free, stored-energy operated.
 - a. Closing speed of moving contacts to be independent of both control and operator.
 - b. Design mechanism to permit manual charging and slow closing of contacts for inspection or adjustment.

Retain one of first two subparagraphs below and select from control power options. See Evaluations for discussion. Coordinate with requirement for control battery system.

- 1) Control Power: [24] [48] [125] <Insert voltage>-V dc for closing and tripping.

- c. Provide shunt-trip capability independent of overcurrent trip.

- G. Bus Insulation: Covered with flame-retardant insulation.

Retain remaining paragraphs and subparagraphs applicable to Project.

- H. Test Accessories: Relay and meter test plugs.

Coordinate paragraph below with Drawings.

- I. Low-DC-Voltage Alarm: Switchgear shall have a monitor for dc control power voltage with a remote alarm located where indicated. Alarm shall sound if voltage falls to an adjustable value to indicate an impending battery failure. Factory set alarm value at 80 percent of full-charge voltage.

Retain paragraph and subparagraphs below if required by utility company or by medium-voltage maintenance and testing agency serving Project facility. Utility requirements below are examples only; revise to suit Project.

- J. Grounding and Testing Device: Suitable for phasing out, testing, and grounding switchgear bus or feeder if device is installed in place of circuit breaker. Include the following:
 1. Portable Grounding and Testing Device: Interchangeable with drawout-mounting, medium-voltage circuit breakers to provide interlocked electrical access to either bus or feeder; electrically operated.
 2. System control cabinet permanently mounted near switchgear.
 3. Portable Remote-Control Station: For grounding and testing device.

4. Control-Cabinet Coupler Cable: Of adequate length to connect device inserted in any switchgear cubicle and control cabinet.
5. Remote-Control Coupler Cable: **50 feet** (15 m) long to connect control cabinet and portable remote-control station.
6. Permanent Control Power Wiring: From control cabinet to power source.
7. Protective Cover: Fabricated of heavy-duty plastic and fitted to device.
8. Approval of Grounding and Testing Device System: Obtain approval of final system design from utility company and agency designated by Owner to handle future maintenance of medium-voltage switchgear.

Coordinate first paragraph below with Drawings.

- K. Circuit-Breaker Test Cabinet: Separately mounted and containing push buttons for circuit-breaker closing and tripping, control relay, fuses, and secondary coupler with cable approximately **108 inches** (2740 mm) long. Include a set of secondary devices for operating circuit breaker if removed from switchgear and moved near test cabinet. Include provision for storage of test and maintenance accessories in cabinet.
- L. Remote-Tripping Device: Wall-mounting emergency control station to open circuit breakers; located in red cast-metal box with break-glass operation.
- M. Bus Transition Unit: Arranged to suit bus and adjacent units.
- N. Outgoing Feeder Units: Arranged to suit distribution feeders.
- O. Auxiliary Compartments: Arranged to suit house meters, relays, controls, and auxiliary equipment; isolated from medium-voltage components.
- P. Key Interlocks: Arranged to effect interlocking schemes indicated.
- Q. Provisions for Future Key Interlocks: Mountings and hardware required for future installation of locks, where indicated.
- R. Source Quality Control:

Add a subparagraph here if factory testing is to be witnessed by Owner's representative or others. Indicate which portions of testing are to be witnessed.

1. Before shipment of equipment, perform the following tests and prepare test reports:
 - a. Production tests on circuit breakers according to ANSI C37.09.
 - b. Production tests on completed switchgear assembly according to IEEE C37.20.2.
2. Assemble switchgear and equipment in manufacturer's plant and perform the following:
 - a. Functional tests of all relays, instruments, meters, and control devices by application of secondary three-phase voltage to voltage circuits and injection of current in current-transformer secondary circuits.

- b. Functional test of all control and trip circuits. Connect test devices into circuits to simulate operation of controlled remote equipment such as circuit-breaker trip coils, close coils, and auxiliary contacts. Test proper operation of relay targets.
3. Prepare equipment for shipment.
 - a. Provide suitable crating, blocking, and supports so equipment will withstand expected domestic shipping and handling shocks and vibration.
 - b. Weatherproof equipment for shipment. Close connection openings to prevent entrance of foreign material during shipment and storage.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine elements and surfaces where switchgear will be installed for compliance with installation tolerances, required clearances, and other conditions affecting performance.
 1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Comply with applicable portions in NECA 400.
- B. Anchor switchgear assembly to 4-inch (100-mm) channel-iron embedded in concrete base and attach by bolting.
 1. Sills: Select to suit switchgear; level and grout flush into concrete base.

Retain subparagraph below if Project is in seismic area.

2. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 260548 "Vibration and Seismic Controls for Electrical Systems" for seismic-restraint requirements.

Retain subparagraph below to suit Project. Coordinate with Drawings.

3. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no more than 3 inches (75 mm) in all directions beyond the maximum dimensions of switchgear, unless otherwise indicated or unless required for seismic anchor support. Construct concrete bases according to Section 260529 "Hangers and Supports for Electrical Systems."
- C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, brackets, and temporary blocking of moving parts from switchgear units and components.

3.3 IDENTIFICATION

- A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section 260553 "Identification for Electrical Systems."
- B. Diagrams and Instructions:
 - 1. Frame and mount under clear acrylic plastic on front of paralleling low-voltage switchgear.
 - a. Operating Instructions: Printed basic instructions for switchgear, including control and key-interlock sequences and emergency procedures.
 - b. System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads.
 - 2. Storage for Maintenance: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

3.4 CONNECTIONS

- A. Comply with grounding and bonding requirements in Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Comply with wire and cable requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

Retain paragraph below for medium-voltage switchgear applications.

- C. Cable terminations at switchgear are specified in Section 260513 "Medium-Voltage Cables."

3.5 FIELD QUALITY CONTROL

Retain first paragraph below to require Contractor to prepare switchgear and related components for manufacturer's field service technician and for acceptance testing.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Prepare for acceptance tests as follows:
 - 1. Test insulation resistance for each switchgear bus, component, connecting supply, feeder, and control circuit.
 - 2. Test continuity of each circuit.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Perform the following tests and inspections and prepare test reports:
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for each of the following NETA categories:
 - a. Switchgear.
 - b. Circuit breakers.
 - c. Protective relays.
 - d. Instrument transformers.
 - e. Metering and instrumentation.
 - f. Ground-fault systems.
 - g. Battery systems.
 - h. Surge arresters.
 - i. Capacitors.
 - 2. Remove and replace malfunctioning units and retest as specified above.

Revise "Infrared Scanning" Paragraph below to suit types of switchgear specified.

- D. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switchgear. Remove front and rear panels so joints and connections are accessible to portable scanner.
 - 1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchgear 11 months after date of Substantial Completion.
 - 2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
 - 3. Record of Infrared Scanning: Prepare a certified report that identifies switchgear checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.6 ADJUSTING

Retain one of two paragraphs below. Retain first if coordination study is responsibility of Contractor and is included in Section 260573 "Overcurrent Protective Device Coordination Study."

- A. Set field-adjustable, protective-relay trip characteristics according to results in Section 260573 "Overcurrent Protective Device Coordination Study."
- B. Set field-adjustable, protective-relay trip characteristics.

3.7 CLEANING

- A. On completion of installation, inspect interior and exterior of switchgear. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair damaged finishes.

3.8 PROTECTION

- A. Temporary Heating: Apply temporary heat to switchgear, according to manufacturer's written instructions, throughout periods when switchgear environment is not controlled for temperature and humidity within manufacturer's stipulated service conditions.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain paralleling low-voltage switchgear.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262313

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SECTION 262413 - SWITCHBOARDS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Service and distribution switchboards rated 600 V and less.
 - 2. Surge protection devices.
 - 3. Disconnecting and overcurrent protective devices.
 - 4. Instrumentation.
 - 5. Control power.
 - 6. Accessory components and features.
 - 7. Identification.

Mimic bus is not common for switchboards other than large, drawout-type switchboards; it is normally used for switchgear construction.

- 8. Mimic bus.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in

this Section affected by alternates.

1.3 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and SEI/ASCE 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Switchboards shall withstand the effects of earthquake motions determined according to [SEI/ASCE 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of switchboard, overcurrent protective device, transient voltage suppression device, ground-fault protector, accessory, and component indicated. Include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, accessories, and finishes.

1. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: For each switchboard and related equipment.

1. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings.
2. Detail enclosure types for types other than NEMA 250, Type 1.
3. Detail bus configuration, current, and voltage ratings.
4. Detail short-circuit current rating of switchboards and overcurrent protective devices.

Retain first subparagraph below if optional barriers are specified.

5. Include descriptive documentation of optional barriers specified for electrical insulation and isolation.
6. Detail utility company's metering provisions with indication of approval by utility company.

Retain first subparagraph below if series rating of overcurrent protective devices is used.

7. Include evidence of NRTL listing for series rating of installed devices.

8. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.

Retain first subparagraph below if final system short-circuit and coordination studies will be performed by designer or assigned to independent consultant. These curves are also beneficial to Owner for future additions or reevaluations of settings of overcurrent protective devices.

9. Include time-current coordination curves for each type and rating of overcurrent protective device included in switchboards. Submit on translucent log-log graft paper; include selectable ranges for each type of overcurrent protective device.

Retain first subparagraph below if mimic bus is specified.

10. Include diagram and details of proposed mimic bus.
11. Include schematic and wiring diagrams for power, signal, and control wiring.

Retain "Samples" Paragraph below if mimic bus is specified.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: Representative portion of mimic bus with specified material and finish, for color selection.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article. Both NECA 400 and NEMA PB 2.1 recommend that installers be "qualified," which is defined in NFPA 70.

- A. Qualification Data: For qualified [**Installer**] [**testing agency**].

Retain first paragraph below if required by seismic criteria applicable to Project. Coordinate with Division 26 Section "Vibration and Seismic Controls for Electrical Systems." See SEI/ASCE 7 for certification requirements for equipment and components.

Coordinate seismic requirements with DEN Project Manager.

- B. Seismic Qualification Certificates: Submit certification that switchboards, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For switchboards and components to include in

emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

1. Routine maintenance requirements for switchboards and all installed components.
2. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
3. Time-current coordination curves for each type and rating of overcurrent protective device included in switchboards. Submit on translucent log-log graft paper; include selectable ranges for each type of overcurrent protective device.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

Coordinate this article with Section 262813 "Fuses" for quantities of spare fuses and spare-fuse cabinet to be provided.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Potential Transformer Fuses: Equal to 10 percent of quantity installed for each size and type but no fewer than two (2) of each size and type.
 2. Control-Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two (2) of each size and type.
 3. Fuses and Fusible Devices for Fused Circuit Breakers: Equal to 10 percent of quantity installed for each size and type but no fewer than three (3) of each size and type.
 4. Fuses for Fused Switches: Equal to 10 percent of quantity installed for each size and type but no fewer than three (3) of each size and type.
 5. Fuses for Fused Power-Circuit Devices: Equal to 10 percent of quantity installed for each size and type but no fewer than three (3) of each size and type.
 6. Indicating Lights: Equal to 10 percent of quantity installed for each size and type but no less than one (1) of each size and type.

1.8 QUALITY ASSURANCE

- A. Installer Qualifications: An employer of workers qualified as defined in NEMA PB 2.1 and trained in electrical safety as required by NFPA 70E.

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide

services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Division 01 Section "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- B. Source Limitations: Obtain switchboards, overcurrent protective devices, components, and accessories from single source from single manufacturer.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Division 01 requirements.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchboards including clearances between switchboards and adjacent surfaces and other items. Comply with indicated maximum dimensions.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Comply with NEMA PB 2.
- F. Comply with NFPA 70.
- G. Comply with UL 891.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver switchboards in sections or lengths that can be moved past obstructions in delivery path.

Retain first paragraph below if site conditions require supplemental heating to prevent condensation. Select first option if switchboards do not have factory-installed space heaters. Select second option if switchboards have factory-installed space heaters specified in Part 2.

- B. Remove loose packing and flammable materials from inside switchboards and [**install temporary electric heating (250 W per section)**] [**connect factory-installed space heaters to temporary electrical service**] to prevent condensation.

See "Testing and Inspecting" Article in the Evaluations for guidance on which option to select in paragraph below.

- C. Handle and prepare switchboards for installation according to [**NECA 400**] [**NEMA PB 2.1**].

1.10 PROJECT CONDITIONS

Revise first Paragraph below to describe specific requirements for moving switchboards into place. Where appropriate, indicate alterations to existing facilities that may be required to accommodate an indicated delivery path. Coordinate with Drawings.

- A. Installation Pathway: Remove and replace access fencing, doors, lift-out panels, and structures to provide pathway for moving switchboards into place.

Retain first Paragraph below for switchboards installed in typical environmental conditions. For switchboards installed outdoors or in unusual environmental conditions, revise paragraph to indicate minimum and maximum ambient temperatures and expected humidity range. See "Switchboard Design" Article in the Evaluations.

- B. Environmental Limitations:

1. Do not deliver or install switchboards until spaces are enclosed and weathertight, wet work in spaces is complete and dry, work above switchboards is complete, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.
2. Rate equipment for continuous operation under the following conditions unless otherwise indicated:
 - a. Location: Indoors/outdoors.
 - b. Ambient Temperature: Not exceeding 120 deg F (49 deg C).
 - c. Altitude: 5500 feet (1677 m), not exceeding 6600 feet (2000 m).

Retain "Unusual Service Conditions" Paragraph below or revise to accommodate unusual service conditions that cannot be eliminated. See "Switchboard Design" in the Evaluations.

- C. Unusual Service Conditions: NEMA PB 2, usual service conditions, as follows:

1. Ambient temperatures within limits specified.
2. Altitude not exceeding 6600 feet (2000 m).

Retain "Interruption of Existing Electric Service" Paragraph below if interruption of existing electric service is required.

- D. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:

1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
2. Indicate method of providing temporary electric service.
3. Do not proceed with interruption of electric service without DEN Project Manager's written permission.
4. Comply with NFPA 70E.

1.11 COORDINATION

Revise first paragraph below for types of construction and encumbrances that affect switchboard installation.

- A. Coordinate layout and installation of switchboards and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping, encumbrances to workspace clearance requirements, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.12 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods with manufacturers listed in Part 2 articles.

1. Warranty Period: Minimum **[five (5)]** <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
3. Siemens Energy & Automation, Inc.
4. Square D; a brand of Schneider Electric.
5. **<Insert manufacturer>**
6. or approved equal.

Switchboards described in this article include service and distribution types most commonly applied.

Coordinate type of switchboard with types of overcurrent protective devices and with switchboard arrangement and available space. Consult manufacturer to determine layout requirements. See Evaluations for further discussion. Most switchboards are both front and rear aligned, with the possible exception of units with very large or unusual main cubicles. The Section Text defaults to front and rear alignment; coordinate with manufacturers for unusual conditions.

Retain one or more of first three paragraphs below. If retaining more than one, identify switchboard types on Drawings.

B. Front-Connected, Front-Accessible Switchboards:

1. Main Devices: **[Panel] [Fixed, individually]** mounted.
2. Branch Devices: Panel mounted.
3. Sections front and rear aligned.

C. Front- and Side-Accessible Switchboards:

1. Main Devices: Fixed, individually mounted.
2. Branch Devices: Panel mounted.
3. Sections front and rear aligned.

D. Front- and Rear-Accessible Switchboards:

1. Main Devices: **[Fixed, individually] [Drawout]** mounted.
2. Branch Devices: **[Panel] [Fixed, individually] [Panel and fixed, individually] [Fixed and individually compartmented] [Individually compartmented and drawout]** mounted.
3. Sections **[front and rear] [rear]** aligned.

Retain first two paragraphs below if rating data are not on Drawings.

- E. Nominal System Voltage: **[480Y/277 V] [208Y/120 V] <Insert system voltage>**.
- F. Main-Bus Continuous: **[5000] [4000] [3000] [2500] [2000] [1600] [1200] <Insert ampere rating>** A.

Retain first paragraph below for projects in seismic areas. If retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

- G. Seismic Requirements: Fabricate and test switchboards according to IEEE 344 to withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Switchboards rely on natural convection for dissipating heat; therefore, NEMA 250, Type 12 enclosures are not usually available.

H. Indoor Enclosures: Steel, NEMA 250, [Type 1] [Type 5].

Custom colors, especially for outdoor units, are normally available as an option. Coordinate with Owner to determine if a special color is required. Consider a white or very light color for the roofs of outdoor units for better reflectance.

I. Enclosure Finish for Indoor Units: Factory-applied finish in manufacturer's [standard gray] [custom color] finish over a rust-inhibiting primer on treated metal surface.

J. Outdoor Enclosures: [Type 3R] [Type 3R, with interior-lighted walk-in aisle].

1. Finish: Factory-applied finish in manufacturer's [standard] [custom] color; undersurfaces treated with corrosion-resistant undercoating.
2. Enclosure: [Flat] [Downward, rearward sloping] roof; [bolt-on rear covers] [rear hinged doors] for each section, with provisions for padlocking.
3. Doors: Personnel door at each end of aisle, minimum width of [30 inches (762 mm)] <Insert value>; opening outwards; with panic hardware and provisions for [padlocking] [cylinder lock].
4. Accessories: Fluorescent lighting fixtures, ceiling mounted; wired to a three-way light switch at each end of aisle; ground-fault circuit interrupter (GFCI) duplex receptacle; emergency battery pack lighting fixture installed on wall of aisle midway between personnel doors.
5. Walk-in Aisle Heating and Ventilating:

See Editing Instruction No. 3 in the Evaluations for temperature range included in NEMA PB 2 to define "usual service conditions." In first two subparagraphs below, optional interior temperatures are based on minimum and maximum ambient temperatures at which derating of fuses and circuit breakers should be considered. Insert higher or lower values if human comfort levels take precedence. Consult ASHRAE tables for recommended maximum and minimum outside design temperatures for locations in which switchboards will be installed.

- a. Factory-installed electric unit heater(s), wall or ceiling mounted, with integral thermostat and disconnect and with capacities to maintain switchboard interior temperature of [40 deg F (5 deg C)] <Insert temperature> with outside design temperature of [minus 30 deg F (minus 35 deg C)] <Insert temperature>.
- b. Factory-installed exhaust fan with capacities to maintain switchboard interior temperature of [100 deg F (38 deg C)] <Insert temperature> with outside design temperature of [120 deg F (49 deg C)] <Insert temperature>.
- c. Ventilating openings[complete with replaceable fiberglass air filters].
- d. Thermostat: Single stage; wired to control heat and exhaust fan.

Retain one of two subparagraphs below. Retain first subparagraph to require switchboard manufacturer to provide power through a control transformer. Retain second if power from a remote source is indicated on Drawings. Coordinate with Drawings.

6. Power for Space Heaters, Ventilation, Lighting, and Receptacle: Include a control-power transformer within the switchboard. Supply voltage shall be [120]

- [120/240] [120/208]-V ac.
7. Power for space heaters, ventilation, lighting, and receptacle provided by a remote source.

K. Barriers: Between adjacent switchboard sections.

Internal barriers and extra insulation are not an ANSI or a UL requirement, and they can interfere with ventilation required for heat dissipation. Insert internal barriers and extra insulation to isolate energized components, such as buses and vertical sections, if required to protect against damage from arcing ground faults; coordinate with manufacturers for restrictions, limitations, and bus-size increases. As another option, consider using low-voltage, metal-clad switchgear. See Evaluations for further discussion.

L. Insulation and isolation for [**main bus of main section and**] main and vertical buses of feeder sections.

Retain first paragraph below for switchboards installed outdoors. Heaters and controls may be required for indoor units in unconditioned spaces.

M. Cubical Space Heaters: Factory-installed electric space heaters of sufficient wattage in each vertical section to maintain enclosure temperature above expected dew point.

Where overcurrent devices are mounted on both sides of a central walk-in corridor, more than one thermostat may be required.

1. Space-Heater Control: [**Thermostats to maintain temperature of each section above expected dew point**] [**Manual switching of branch-circuit protective device**].
2. Space-Heater Power Source: [**Transformer, factory installed in switchboard**] [**120-V external branch circuit**].

N. Utility Metering Compartment: Fabricated, barrier compartment and section complying with utility company's requirements; hinged sealed door; buses provisioned for mounting utility company's current transformers and potential transformers or potential taps as required by utility company. If separate vertical section is required for utility metering, match and align with basic switchboard. Provide service entrance label and necessary applicable service entrance features.

Select option in first paragraph below if metering requires a voltage different from switchboard bus voltage.

O. Customer Metering Compartment: A separate customer metering compartment and section with front hinged door, for indicated metering, and current transformers for each meter. Current transformer secondary wiring shall be terminated on shorting-type terminal blocks. [**Include potential transformers having primary and secondary fuses with disconnecting means and secondary wiring terminated on terminal blocks.**]

Pull sections in first paragraph below may be required if incoming supply is beneath switchboard.

P. Bus Transition and Incoming Pull Sections: Matched and aligned with basic switchboard.

Retain first paragraph below for rear access.

- Q. Removable, Hinged Rear Doors and Compartment Covers: Secured by [**captive thumb screws**] [**standard bolts**], for access to rear interior of switchboard.
- R. Hinged Front Panels: Allow access to circuit breaker, metering, accessory, and blank compartments.

A pull box across the entire top of switchboard is usually only required for very large quantities of outgoing feeders and across the main incoming section for very large feeders with multiple large conductors per phase and neutral. Indicate the presence and extent of pull boxes on Drawings.

- S. Pull Box on Top of Switchboard:
 - 1. Adequate ventilation to maintain temperature in pull box within same limits as switchboard.

Retain first subparagraph below for top-mounted, circuit-breaker removal mechanism.

- 2. Set back from front to clear circuit-breaker removal mechanism.
 - 3. Removable covers shall form top, front, and sides. Top covers at rear shall be easily removable for drilling and cutting.
 - 4. Bottom shall be insulating, fire-resistive material with separate holes for cable drops into switchboard.
 - 5. Cable supports shall be arranged to facilitate cabling and adequate to support cables indicated, including those for future installation.
- T. Buses and Connections: Three phase, four wire unless otherwise indicated.

Retain subparagraph below for main-bus material.

- 1. Phase- and Neutral-Bus Material: Hard-drawn copper of 98 percent conductivity, [**silver-plated**,]with tin-plated copper feeder circuit-breaker line connections.

Retain first subparagraph below if drawout circuit breakers and rear-access sections are specified.

- 2. Load Terminals: Insulated, rigidly braced, runback bus extensions, of same material as through buses, equipped with [**mechanical**] [**compression**] connectors for outgoing circuit conductors. Provide load terminals for future circuit-breaker positions at full-ampere rating of circuit-breaker position.
 - 3. Ground Bus: [**1/4-by-2-inch-** (6-by-50-mm-)] [**1/4-by-1-inch-** (6-by-25-mm-)] [**Minimum-size required by UL 891,**] hard-drawn copper of 98 percent conductivity, equipped with [**mechanical**] [**compression**] connectors for feeder and branch-circuit ground conductors. For busway feeders, extend insulated equipment grounding cable to busway ground connection and support cable at intervals in vertical run.
 - 4. Main Phase Buses and Equipment Ground Buses: Uniform capacity for entire length of switchboard's main and distribution sections. Provide for future extensions from both ends.

Neutral buses can be reduced in size if a substantial portion of the loads are balanced three-phase types (e.g., motors and transformers). Neutral buses can be deleted if switchboards serve only three-phase balanced loads. For service-entrance rated switchboards, neutral buses need not extend beyond the

switchboard's main incoming section. Retain one of first two subparagraphs below or delete both for three-phase, three-wire systems.

5. Neutral Buses: 50 percent of the ampacity of phase buses unless otherwise indicated, equipped with **[mechanical] [compression]** connectors for outgoing circuit neutral cables. Brace bus extensions for busway feeder neutral bus.
6. Neutral Buses: 100 percent of the ampacity of phase buses unless otherwise indicated, equipped with **[mechanical] [compression]** connectors for outgoing circuit neutral cables. Brace bus extensions for busway feeder neutral bus.

Retain subparagraph below if optional barriers are specified.

7. Isolation Barrier Access Provisions: Permit checking of bus-bolt tightness.

Retain first paragraph below to require provisions for future expansion.

- U. Future Devices: Equip compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of circuit-breaker compartment.

Insulation on buses retains heat and reduces ampacity, which means larger bus bars are required. Retain first paragraph below if Project conditions require bus insulation; coordinate with manufacturers for restrictions, limitations, and bus-size increases. Uninsulated buses are standard.

- V. Bus-Bar Insulation: Factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating of 105 deg C.

Retain paragraph below for installations in humid tropical environments.

- W. Fungus Proofing: Permanent fungicidal treatment for overcurrent protective devices and other components including instruments and instrument transformers.

2.2 TRANSIENT VOLTAGE SUPPRESSION DEVICES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Siemens Energy & Automation, Inc.
 4. Square D; a brand of Schneider Electric.
 5. **<Insert manufacturer>**
 6. or approved equal.

Selection of options in first paragraph below is a matter of ease of maintenance and replacement; coordinate final choices with Owner's maintenance personnel. Wired-in type offers more safety with a slight reduction in protection; modular types offer the quickest maintenance, but may come at a slightly higher cost. See the Evaluations in Division 26 Section "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits" for guidance on revising this article.

- B. Surge Protection Device Description: IEEE C62.41-compliant, integrally mounted,

[wired-in] [plug-in] [bolt-on], solid-state, parallel-connected, **[modular (with field-replaceable modules)] [non-modular]** type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the switchboard short-circuit rating, and with the following features and accessories:

Retain accessories in 10 subparagraphs below to coordinate with options retained in paragraph above; verify availability and compatibility with manufacturer.

If specifying fuses for connecting TVSS devices to distribution system, verify ability of fuses to withstand surges consistent with ultimate surge current rating of device.

1. Fuses, rated at 200-kA interrupting capacity.
2. Fabrication using bolted compression lugs for internal wiring.

Retain first subparagraph below only if a fused switch or circuit breaker is not provided for the TVSS in the switchboard and the TVSS will not have a direct bus connection.

3. Integral disconnect switch.
4. Redundant suppression circuits.
5. Redundant replaceable modules.
6. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
7. LED indicator lights for power and protection status.
8. Audible alarm, with silencing switch, to indicate when protection has failed.
9. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
10. **[Four] [Six]**-digit, transient-event counter set to totalize transient surges.

Select first option in first paragraph below for high exposure and cost, second option for medium exposure and cost, and third option for low exposure and cost.

- C. Peak Single-Impulse Surge Current Rating: **[160 kA per mode/320 kA per phase] [120 kA per mode/240 kA per phase] [80 kA per mode/160 kA per phase]**.

Retain first paragraph below for switchboards located at or near Category C locations.

- D. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.

Retain one of three paragraphs below. Adjust clamping voltages to comply with Project conditions and verify compatibility of peak surge current rating and clamping voltage. Reference to UL 1449 is to its second edition.

- E. Protection modes and UL 1449 SVR for grounded wye circuits with **[480Y/277] [208Y/120] [600Y/347]**-V, three-phase, four-wire circuits shall be as follows:
1. Line to Neutral: **[800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347]**.
 2. Line to Ground: **[800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347]**.

3. Neutral to Ground: **[800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347]**.
- F. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:
1. Line to Neutral: 400 V, 800 V from high leg.
 2. Line to Ground: 400 V.
 3. Neutral to Ground: 400 V.
- G. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:
1. Line to Line: **[2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V]**.
 2. Line to Ground: **[1500 V for 480 V] [800 V for 240 V] [2500 V for 600 V]**.

2.3 DISCONNECTING AND OVERCURRENT PROTECTIVE DEVICES

Coordinate this article with Drawings. See the "Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for guidance on making selections.

- A. Molded-Case Circuit Breaker (MCCB): Comply with UL 489, with **[series-connected rating] [interrupting capacity]** to meet available fault currents.
1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
 2. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
 3. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:

Retain one or more of first four subparagraphs below; coordinate required adjustable settings with Division 26 Section "Overcurrent Protective Device Coordination Study." See "Electronic rms Trip versus MCCBs" Paragraph in "Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for additional guidance on specifying full-or standard-function features.

- a. Instantaneous trip.
 - b. Long- and short-time pickup levels.
 - c. Long- and short-time time adjustments.
 - d. Ground-fault pickup level, time delay, and I₂t response.
4. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
 5. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.

Retain first subparagraph below for GFCI circuit breakers for personnel ground-fault protection as required by NFPA 70; retain second subparagraph for GFEP circuit breakers (e.g., for self-limiting

heat-trace cables) as required by NFPA 70. GFCI and GFEP circuit breakers are only available fully rated up to interrupting ratings of 22 kA and are not suited to switchboard use. For switchboards subject to fault currents above 22 kA, series ratings must be used. Consider relocating these to downstream panelboards more suited to their application.

6. GFCI Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
7. Ground-Fault Equipment Protection (GFEP) Circuit Breakers: Class B ground-fault protection (30-mA trip).
8. Molded-Case Circuit-Breaker (MCCB) Features and Accessories:

Not all accessories and options listed in subparagraphs below are available for every rating and from every listed manufacturer. Verify availability and unique characteristics with manufacturers selected.

- a. Standard frame sizes, trip ratings, and number of poles.

See Editing Instruction No. 5 in the Evaluations for guidance on using mechanical vs. compression lugs.

- b. Lugs: **[Mechanical]** **[Compression]** style, suitable for number, size, trip ratings, and conductor material.
- c. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.

Select first option in first subparagraph below for solid-state trip units; select second option for thermal-magnetic trip units. If selecting second option, also retain "Shunt Trip" Subparagraph below.

- d. Ground-Fault Protection: **[Integrally mounted]** **[Remote-mounted]** relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
- e. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
- f. Communication Capability: **[Circuit-breaker-mounted]** **[Universal-mounted]** **[Integral]** **[Din-rail-mounted]** communication module with functions and features compatible with power monitoring and control system specified in Section 260913 "Electrical Power Monitoring and Control."
- g. Shunt Trip: 120-V trip coil energized from separate circuit, set to trip at **[55]** **[75]** percent of rated voltage.
- h. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
- i. Auxiliary Contacts: **[One SPDT switch]** **[Two SPDT switches]** with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
- j. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

- B. Insulated-Case Circuit Breaker (ICCB): **[80]** **[100]** percent rated, sealed, insulated-case power circuit breaker with interrupting capacity rating to meet available fault current.

1. **[Fixed]** **[Drawout]** circuit-breaker mounting.
2. Two-step, stored-energy closing.
3. **[Standard]** **[Full]**-function, microprocessor-based trip units with interchangeable rating plug, trip indicators, and the following field-adjustable settings:

Retain one or more of first four subparagraphs below; coordinate required adjustable settings with Division 26 Section "Overcurrent Protective Device Coordination Study." See "Electronic rms Trip versus MCCBs" Paragraph in "Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for additional features available for standard- and full-function trip units.

- a. Instantaneous trip.
 - b. Long- and short-time time adjustments.
 - c. Ground-fault pickup level, time delay, and I_{2t} response.
 - d. **<Insert settings>**.
4. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
 5. Remote trip indication and control.
 6. Communication Capability: Integral communication module with functions and features compatible with power monitoring and control system specified in Section 260913 "Electrical Power Monitoring and Control."
 7. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

Retain voltage in subparagraph below to match control-power supply.

8. Control Voltage: [**40-V dc**] [**125-V dc**] [**250-V dc**] [**120-V ac**].

Retain one of first two paragraphs below.

- C. Bolted-Pressure Contact Switch: Operating mechanism uses rotary-mechanical-bolting action to produce and maintain high clamping pressure on the switch blade after it engages the stationary contacts.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Boltswitch, Inc.
 - b. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - c. Pringle Electrical Manufacturing Company, Inc.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.
2. Main-Contact Interrupting Capability: Minimum of 12 times the switch current rating.
3. Operating Mechanism: Manual handle operation to close switch; stores energy in mechanism for opening and closing.

Retain one or both of first two subparagraphs below depending on switch applications in Project. First subparagraph is for switches with ground-fault protection and for remotely tripped switches; second is for manually tripped units. See Editing Instruction No. 4 in the Evaluations. Coordinate with Drawings and include notation that identifies electrically and manually tripped switches.

- a. Electrical Trip: Operation of lever or push-button trip switch, or trip signal from ground-fault relay or remote-control device, causes switch to open.
 - b. Mechanical Trip: Operation of mechanical lever, push button, or other device causes switch to open.
4. Auxiliary Switches: Factory installed, single pole, double throw, with leads connected to terminal block, and including one set more than quantity required for functional performance indicated.

Coordinate first subparagraph below with Drawings; include notation "suitable for use as service equipment" for switches that are the main control and means of disconnection for separately derived systems or for separate structures.

5. Service-Rated Switches: Labeled for use as service equipment.

Coordinate first subparagraph below with Drawings; indicate minimum fault-current rating of each switch.

6. Ground-Fault Relay: Comply with UL 1053; self-powered type with mechanical ground-fault indicator, test function, tripping relay with internal memory, and three-phase current transformer/sensor.

Revise first subparagraph below if relays capable of zone-selective interlocking are required.

- a. Configuration: [**Integrally mounted**] [**Remote-mounted**] relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.

Retain first three subparagraphs below to require optional features. Coordinate with Drawings.

- b. Internal Memory: Integrates the cumulative value of intermittent arcing ground-fault currents and uses the effect to initiate tripping.
 - c. No-Trip Relay Test: Permits ground-fault simulation test without tripping switch.
 - d. Test Control: Simulates ground fault to test relay and switch (or relay only if "no-trip" mode is selected).
7. Open-Fuse Trip Device: Arranged to trip switch open if a phase fuse opens.

- D. High-Pressure, Butt-Type Contact Switch: Operating mechanism uses butt-type contacts and a spring-charged mechanism to produce and maintain high-pressure contact when switch is closed.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first subparagraph and list of manufacturers below. See Division 01 Section "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - b. <Insert manufacturer>
 - c. or approved equal.
2. Main-Contact Interrupting Capability: Minimum of 12 times the switch current

- rating.
3. Operating Mechanism: Manual handle operation to close switch; stores energy in mechanism for opening and closing.

Retain one or both of first two subparagraphs below depending on switch applications in Project. First subparagraph is for switches with ground-fault protection and for remotely tripped switches; second is for manually tripped units. See Editing Instruction No. 4 in the Evaluations. Coordinate with Drawings and include notation that identifies electrically and manually tripped switches.

- a. Electrical Trip: Operation of lever or push-button trip switch, or trip signal from ground-fault relay or remote-control device, causes switch to open.
 - b. Mechanical Trip: Operation of mechanical lever, push button, or other device causes switch to open.
4. Auxiliary Switches: Factory installed, single pole, double throw, with leads connected to terminal block, and including one set more than quantity required for functional performance indicated.

Coordinate first subparagraph below with Drawings; include notation "suitable for use as service equipment" for switches that are the main control and means of disconnection for separately derived systems or for separate structures.

5. Service-Rated Switches: Labeled for use as service equipment.

Coordinate first subparagraph below with Drawings; indicate minimum fault-current rating of each switch.

6. Ground-Fault Relay: Comply with UL 1053; self-powered type with mechanical ground-fault indicator, test function, tripping relay with internal memory, and three-phase current transformer/sensor.

Revise first subparagraph below if relays capable of zone-selective interlocking are required.

- a. Configuration: [**Integrally mounted**] [**Remote-mounted**] relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.

Retain first three subparagraphs below to require optional features. Coordinate with Drawings.

- b. Internal Memory: Integrates the cumulative value of intermittent arcing ground-fault currents and uses the effect to initiate tripping.
 - c. No-Trip Relay Test: Permits ground-fault simulation test without tripping switch.
 - d. Test Control: Simulates ground fault to test relay and switch (or relay only if "no-trip" mode is selected).
7. Open-Fuse Trip Device: Arranged to trip switch open if a phase fuse opens.
- E. Fused Switch: NEMA KS 1, Type HD; clips to accommodate specified fuses; lockable handle.
 - F. Fuses are specified in Section 262813 "Fuses."

2.4 INSTRUMENTATION

Retain this article for Owner, not utility, metering.

A. Instrument Transformers: IEEE C57.13, NEMA EI 21.1, and the following:

Potential transformers (PTs) are not frequently needed, as most digital meters can be direct-bus connected up to 600 V. Consult manufacturers on need for PTs for instruments and meters selected. Indicate the primary-to-secondary ratio on Drawings.

1. Potential Transformers: IEEE C57.13; 120 V, 60 Hz, [**single**] [**tapped**] [**double**] secondary; disconnecting type with integral fuse mountings. Burden and accuracy shall be consistent with connected metering and relay devices.

Coordinate first subparagraph below with Drawings and indicate specific accuracy classes and burdens required for each application and the primary-to-secondary ratio.

2. Current Transformers: IEEE C57.13; 5 A, 60 Hz, secondary; [**wound**] [**bushing**] [**bar or window**] type; [**single**] [**double**] secondary winding and secondary shorting device. Burden and accuracy shall be consistent with connected metering and relay devices.

Manufacturers typically size control-power transformers, and normally only for equipment and devices integral to switchboards. Consider specifying additional spare capacity if required for operation of remote devices.

3. Control-Power Transformers: Dry type, mounted in separate compartments for units larger than 3 kVA.

Retain subparagraph below for certain ground-fault protection situations such as double-ended switchboards on four-wire, grounded neutral systems. Coordinate with Drawings.

4. Current Transformers for Neutral and Ground-Fault Current Sensing: Connect secondary wiring to ground overcurrent relays, via shorting terminals, to provide selective tripping of main and tie circuit breaker. Coordinate with feeder circuit-breaker, ground-fault protection.

Retain first paragraph below if digital metering is required. It offers substantially more capabilities than analog metering in much smaller packages; however, some facility managers still prefer analog devices with large, easy-to-read dials.

B. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:

1. Switch-selectable digital display of the following values with maximum accuracy tolerances as indicated:
 - a. Phase Currents, Each Phase: Plus or minus 1 percent.
 - b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - d. Megawatts: Plus or minus 2 percent.
 - e. Megavars: Plus or minus 2 percent.
 - f. Power Factor: Plus or minus 2 percent.
 - g. Frequency: Plus or minus 0.5 percent.
 - h. Accumulated Energy, Megawatt Hours: Plus or minus 2 percent;

accumulated values unaffected by power outages up to 72 hours.

Retain one or both of first two subparagraphs below. Retain first subparagraph for local recording of demand; retain second for remote recording of demand or if retaining "Impulse-Totalizing Demand Meter" Paragraph below.

- i. Megawatt Demand: Plus or minus 2 percent; demand interval programmable from five to 60 minutes.
 - j. Contact devices to operate remote impulse-totalizing demand meter.
2. Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.

Retain first four paragraphs below if analog metering functions are required in lieu of multifunction digital meters specified above.

Retain one of first two subparagraphs below. Retain first subparagraph for local recording of demand; retain second for remote recording of demand or if retaining "Impulse-Totalizing Demand Meter" Paragraph below.

Retain paragraph below if retaining contact devices to operate remote impulse-totalizing of demand in "Multifunction Digital-Metering Monitor" and "Watt-Hour Meters and Wattmeters" paragraphs above. Meter below offers an option for a centralized monitoring or customer metering system if monitoring total demand is required.

C. Impulse-Totalizing Demand Meter:

1. Comply with ANSI C12.1.
2. Suitable for use with switchboard watt-hour meter, including two-circuit totalizing relay.
3. Cyclometer.
4. Four-dial, totalizing kilowatt-hour register.
5. Positive chart drive mechanism.
6. Capillary pen holding a minimum of one month's ink supply.
7. Roll chart with minimum 31-day capacity; appropriate multiplier tag.
8. Capable of indicating and recording [5] [15] [30] <Insert time period>-minute integrated demand of totalized system.

2.5 CONTROL POWER

Retain one of first three paragraphs below.

- A. Control Circuits: 120-V ac, supplied through secondary disconnecting devices from control-power transformer.
- B. Control Circuits: 120-V ac, supplied from remote branch circuit.
- C. Control Circuits: <Insert control voltage>-V dc.

Retain three paragraphs below to require an automatic transfer of power using a main-tie-main or two-main scheme. Coordinate with selection of "Control Circuits" paragraphs above. See "Interlocked Main and Tie Circuit Breakers for Automatic and Manual Transfer of Power" Paragraph in "Disconnecting

and Overcurrent Protective Devices" Article in the Evaluations for discussion of other types of available transfer schemes, along with advantages and disadvantages of each type.

- D. Electrically Interlocked Main and Tie Circuit Breakers: Two control-power transformers in separate compartments, with interlocking relays, connected to the primary side of each control-power transformer at the line side of the associated main circuit breaker. 120-V secondaries connected through automatic transfer relays to ensure a fail-safe automatic transfer scheme.
- E. Control-Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.
- F. Control Wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

2.6 ACCESSORY COMPONENTS AND FEATURES

Retain first paragraph below for drawout circuit breakers.

- A. Accessory Set: Include tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.

Retain first paragraph below for circuit breakers with solid-state trip devices.

- B. Portable Test Set: For testing functions of solid-state trip devices without removing from switchboard. Include relay and meter test plugs suitable for testing switchboard meters and switchboard class relays.

Retain one or both of first two paragraphs below for installations with drawout circuit breakers. Coordinate requirements in first paragraph with manufacturers. Type of circuit-breaker lifting device to use depends on type and sizes of drawout circuit breakers or switches specified, on depth of switchboard and frontal protrusion of concrete base on which it sits, and on manufacturer.

- C. Portable Circuit-Breaker Lifting Device: Floor-supported, roller-based, elevating carriage arranged for movement of circuit breakers in and out of compartments for present and future circuit breakers.
- D. Overhead Circuit-Breaker Lifting Device: Mounted at top front of switchboard, with hoist and lifting yokes matching each drawout circuit breaker.

Retain paragraph below if fuse cabinet is not specified in Division 26 Section "Fuses."

- E. Spare-Fuse Cabinet: Suitably identified, wall-mounted, lockable, compartmented steel box or cabinet. Arrange for wall mounting.

2.7 IDENTIFICATION

Retain one of first three paragraphs below. Traditional mimic buses do not lend themselves to switchboard construction, especially for panel-mounted devices.

- A. Mimic Bus: Entire single-line switchboard bus work, as depicted on factory record drawing, on a photoengraved nameplate.
 - 1. Nameplate: At least **0.032-inch-** (0.813-mm-) thick anodized aluminum, located at eye level on front cover of the switchboard incoming service section.
- B. Mimic Bus: Entire single-line switchboard bus work, as depicted on factory record drawing, on an engraved laminated-plastic (Gravoply) nameplate.
 - 1. Nameplate: At least **0.0625-inch-** (1.588 mm-) thick laminated plastic (Gravoply), located at eye level on front cover of the switchboard incoming service section.
- C. Mimic Bus: Continuously integrated mimic bus factory applied to front of switchboard. Arrange in single-line diagram format, using symbols and letter designations consistent with final mimic-bus diagram.
- D. Coordinate mimic-bus segments with devices in switchboard sections to which they are applied. Produce a concise visual presentation of principal switchboard components and connections.

Revise first paragraph below to require other types of presentation media.

- E. Presentation Media: Painted graphics in color contrasting with background color to represent bus and components, complete with lettered designations.

Retain paragraph below for switchboards that incorporate one or more service disconnecting and overcurrent protective devices and that are used as the service entrance, outside feeder, or separately derived source means of disconnect and overcurrent protection.

- F. Service Equipment Label: NRTL labeled for use as service equipment for switchboards with one or more service disconnecting and overcurrent protective devices.

PART 3 - EXECUTION

3.1 EXAMINATION

Referenced NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- A. Receive, inspect, handle, and store switchboards according to **[NECA 400] [NEMA PB 2.1]**.
- B. Examine switchboards before installation. Reject switchboards that are moisture damaged or physically damaged.
- C. Examine elements and surfaces to receive switchboards for compliance with installation tolerances and other conditions affecting performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

Referenced NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- A. Install switchboards and accessories according to [NECA 400] [NEMA PB 2.1].
- B. Equipment Mounting: Install switchboards on concrete base, 4-inch (100-mm) nominal thickness. Comply with requirements for concrete base specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to switchboards.
- C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, straps and brackets, and temporary blocking of moving parts from switchboard units and components.

Retain first paragraph below if seismic controls are required for Project. Coordinate with Drawings.

- D. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."
- E. Operating Instructions: Frame and mount the printed basic operating instructions for switchboards, including control and key interlocking sequences and emergency procedures. Fabricate frame of finished wood or metal and cover instructions with clear acrylic plastic. Mount on front of switchboards.
- F. Install filler plates in unused spaces of panel-mounted sections.
- G. Install overcurrent protective devices, surge protection devices, and instrumentation.

Subparagraph below assumes that settings are indicated on Drawings or a coordination report is available for Contractor to use.

- 1. Set field-adjustable switches and circuit-breaker trip ranges.

Retain first paragraph below if spare-fuse cabinets are specified in "Accessory Components and Features" Article.

- H. Install spare-fuse cabinet.
- I. Comply with NECA 1.

3.3 CONNECTIONS

Coordinate this article with Drawings. Show locations and types of grounding connections available and which ones are used for grounding switchboards.

Coordinate busway and cable tray installations and specialty arrangements with schematics on Drawings and with requirements specified for busway and cable tray systems. Ensure that referenced Sections include required interfacing terminations necessary to attach to switchboards. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Comply with requirements for terminating feeder bus specified in Section 262500 "Enclosed Bus Assemblies." Drawings indicate general arrangement of bus, fittings, and specialties.
- B. Comply with requirements for terminating cable trays specified in Section 260536 "Cable Trays for Electrical Systems." Drawings indicate general arrangement of cable trays, fittings, and specialties.

3.4 IDENTIFICATION

- A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Switchboard Nameplates: Label each switchboard compartment with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- C. Device Nameplates: Label each disconnecting and overcurrent protective device and each meter and control device mounted in compartment doors with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

Retain paragraph below to identify who shall perform tests and inspections. Coordinate with "Field Quality-Control Reports" Paragraph in "Informational Submittals" Article.

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first two paragraphs below to describe tests and inspections to be performed.

B. Acceptance Testing Preparation:

1. Test insulation resistance for each switchboard bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

C. Tests and Inspections:

1. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

See Division 01 Section "Quality Requirements" for retesting and reinspecting requirements and Division 01 Section "Execution" for requirements for correcting the Work.

D. Switchboard will be considered defective if it does not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- E. Prepare test and inspection reports, including a certified report that identifies switchboards included and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.6 ADJUSTING

- A. Adjust moving parts and operable components to function smoothly, and lubricate as recommended by manufacturer.

Select first option in paragraph below if settings are included in the Contract Documents; select second option if indicated Section is included in the Contract Documents.

- B. Set field-adjustable circuit-breaker trip ranges [as indicated.] [as specified in Section 260573 "Overcurrent Protective Device Coordination Study."]

3.7 PROTECTION

- A. Temporary Heating: Apply temporary heat, to maintain temperature according to manufacturer's written instructions, until switchboard is ready to be energized and placed into service.

3.8 DEMONSTRATION

Select last option in paragraph below if retaining items in "Disconnecting and Overcurrent Protective Devices" Article above.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain switchboards,

overcurrent protective devices, instrumentation, and accessories[, **and to use and reprogram microprocessor-based trip, monitoring, and communication units**].

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262413

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SECTION 262416 - PANELBOARDS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Distribution panelboards.
 - 2. Lighting and appliance branch-circuit panelboards.
 - 3. Load centers.
 - 4. Electronic-grade panelboards.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. SVR: Suppressed voltage rating.
- B. TVSS: Transient voltage surge suppressor.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and SEI/ASCE 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Panelboards shall withstand the effects of earthquake motions determined according to **SEI/ASCE 7**.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **and the unit will be fully operational after the seismic event**]."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of panelboard, switching and overcurrent protective device, transient voltage suppression device, accessory, and component indicated. Include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, and finishes.
 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each panelboard and related equipment.
 1. Include dimensioned plans, elevations, sections, and details. Show tabulations of installed devices, equipment features, and ratings.
 2. Detail enclosure types and details for types other than NEMA 250, Type 1.
 3. Detail bus configuration, current, and voltage ratings.
 4. Short-circuit current rating of panelboards and overcurrent protective devices.

Retain first subparagraph below if series rating of overcurrent protective devices is used.

5. Include evidence of NRTL listing for series rating of installed devices.
6. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
7. Include wiring diagrams for power, signal, and control wiring.

Retain subparagraph below if final system short-circuit and coordination studies will be performed by designer or assigned to independent consultant. These curves are also beneficial to Owner for future additions or reevaluations of settings of overcurrent protective devices.

8. Include time-current coordination curves for each type and rating of overcurrent protective device included in panelboards. Submit on translucent log-log graph paper; include selectable ranges for each type of overcurrent protective device.

1.6 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified testing agency.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field Quality-Control Reports:
 1. Test procedures used.
 2. Test results that comply with requirements.
 3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

Retain option in paragraph below if retaining "Load Balancing" Paragraph in "Adjusting" Article.

- C. Panelboard Schedules: For installation in panelboards. [**Submit final versions after load balancing.**]

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For panelboards and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:
 1. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
 2. Time-current curves, including selectable ranges for each type of overcurrent protective device that allows adjustments.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

Revise this article to include extra materials that Owner may require, such as GFCI or GFEP circuit breakers or circuit breakers used for switching service, which may fail more frequently due to continuous use.

Coordinate with Division 26 Section "Fuses" for quantities of spare fuses and spare-fuse cabinet to be provided.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Keys: **[Two (2)] <Insert number>** spares for each type of panelboard cabinet lock.
 - 2. Circuit Breakers Including GFCI and Ground Fault Equipment Protection (GFEP) Types: **[Two (2)] <Insert number>** spares for each panelboard.
 - 3. Fuses for Fused Switches: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
 - 4. Fuses for Fused Power-Circuit Devices: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
 - 5. **<Insert extra materials>**.

1.9 QUALITY ASSURANCE

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Division 01 Section "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- B. Source Limitations: Obtain panelboards, overcurrent protective devices, components, and accessories from single source from single manufacturer.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Division 01 requirements.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for panelboards including clearances between panelboards and adjacent surfaces and other items. Comply with indicated maximum dimensions.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Comply with NEMA PB 1.
- F. Comply with NFPA 70.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Remove loose packing and flammable materials from inside panelboards; install temporary electric heating (250 W per panelboard) to prevent condensation.

See "Testing and Inspecting" Article in the Evaluations for guidance on which option to select in paragraph below.

- B. Handle and prepare panelboards for installation according to [NECA 407] [NEMA PB 1].

1.11 PROJECT CONDITIONS

Retain first paragraph below for panelboards installed in typical environmental conditions. For panelboards installed outdoors, in unconditioned spaces, or in unusual environmental conditions, revise paragraph to indicate maximum ambient temperature and expected humidity range. See Editing Instruction No. 2 in the Evaluations.

- A. Environmental Limitations:
1. Do not deliver or install panelboards until spaces are enclosed and weathertight, wet work in spaces is complete and dry, work above panelboards is complete, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.
 2. Rate equipment for continuous operation under the following conditions unless otherwise indicated:

In first subparagraph below, select first option for panelboards with fused switches; select second option for panelboards with circuit breakers.

- a. Ambient Temperature: Not exceeding minus 30 deg F (minus 35 deg C) to plus 120 deg F (plus 49 deg C).
- b. Altitude: 5500 feet (1677 m), not exceeding 6600 feet (2000 m).

Retain first paragraph below or revise to accommodate unusual service conditions that cannot be eliminated. See Editing Instructions No. 2 and No. 3 in the Evaluations.

- B. Service Conditions: NEMA PB 1, usual service conditions, as follows:
1. Ambient temperatures within limits specified.
 2. Altitude: 5500 feet, not exceeding 6600 feet (2000 m).

Retain paragraph below if interruption of existing electric service is required.

- C. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
1. Any power outages necessary to install or test electrical systems and/or

- equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
2. Do not proceed with interruption of electric service without DEN Project Manager's written permission.
 3. Comply with NFPA 70E.

1.12 COORDINATION

Revise first paragraph below for types of equipment that affect panelboard installation.

- A. Coordinate layout and installation of panelboards and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping, encumbrances to workspace clearance requirements, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

Retain paragraph below if freestanding panelboards are specified.

- B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

1.13 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: for Surge Suppression Devices Manufacturer's standard form in which manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods with manufacturers listed in Part 2 articles.

1. Warranty Period: Minimum [five (5)] <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.14 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR PANELBOARDS

Retain first paragraph below for projects in seismic areas. Coordinate with "Informational Submittals" Article for submittal of manufacturer's seismic qualification certification.

- A. Fabricate and test panelboards according to IEEE 344 to withstand seismic forces defined in Section "Vibration and Seismic Controls for Electrical Systems."
- B. Enclosures: **[Flush] [Surface] [Flush- and surface]**-mounted cabinets.
 - 1. Rated for environmental conditions at installed location.

See "Enclosures" Article in the Evaluations for discussion of enclosure types. Coordinate first five subparagraphs below with Drawings (by identifying the designated areas) or schedules (by including the required enclosure type). Availability of some enclosure types are limited by a panelboard's ampacity rating, included devices, or physical size; consult manufacturers for availability of, and limitations on, other than Type 1 enclosures.

- a. Indoor Dry and Clean Locations: NEMA 250, **[Type 1] <Insert type>**.
- b. Outdoor Locations: NEMA 250, **[Type 3R] <Insert type>**.
- c. **[Kitchen] [Wash-Down]** Areas: NEMA 250, **[Type 4X] <Insert type>**, **[stainless steel] <Insert material>**.
- d. Other Wet or Damp Indoor Locations: NEMA 250, **[Type 4] <Insert type>**.

Select first option in first subparagraph below for areas subject to lighter levels of contaminants and second option for areas subject to heavier levels.

- e. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: NEMA 250, **[Type 5] [Type 12]**.

Retain one of first two subparagraphs below.

- 2. Front: Secured to box with concealed trim clamps. For surface-mounted fronts, match box dimensions; for flush-mounted fronts, overlap box.
- 3. Hinged Front Cover: Entire front trim hinged to box and with standard door within hinged trim cover.

First two subparagraphs below are optional features. Coordinate with Drawings.

- 4. Skirt for Surface-Mounted Panelboards: Same gage and finish as panelboard front with flanges for attachment to panelboard, wall, and ceiling or floor.
- 5. Gutter Extension and Barrier: Same gage and finish as panelboard enclosure; integral with enclosure body. Arrange to isolate individual panel sections.

Coordinate first subparagraph below with "Enclosures" Paragraph above. Back boxes are also available painted. Revise if required to include special finishes to match, e.g., stainless steel, epoxy, and fiberglass-reinforced polyester.

- 6. Finishes:
 - a. Panels and Trim: **[Steel] [and] [galvanized steel]**, factory finished immediately after cleaning and pretreating with manufacturer's standard

two-coat, baked-on finish consisting of prime coat and thermosetting topcoat.

b. Back Boxes: [**Galvanized steel**] [**Same finish as panels and trim**].

7. Enclosures shall be at least 20 inches wide made from galvanized sheet steel in the sizes and NEMA types indicated, code gauge, minimum 16 gauge thickness

Retain first subparagraph below for use with lighting and appliance branch-circuit and distribution panelboards with doors. With the increasing use of computer-generated directories, metal frames are becoming an expensive option for most manufacturers.

8. Directory Card: Inside panelboard door, mounted in [**transparent card holder**] [**metal frame with transparent protective cover**].

9. <Insert optional features>.

- C. In all cases where the conductor to be connected to the busbar is 1/0 or larger cable, the connection shall be made with a 2-hole compression lug. Torque all lug, wire and bus terminations to the manufacturers recommendation using a micrometer type wrench.

Retain first paragraph below, and coordinate with Drawings and schedules, if Project requirements include identifying specific entry locations for incoming service or feeder raceways.

D. Incoming Mains Location: [**Top**] [**Bottom**] [**Top and bottom**].

E. Phase, Neutral, and Ground Buses:

In first subparagraph below, first option is standard with most manufacturers; second option costs more.

1. Material: Hard-drawn copper, 98 percent conductivity.

Five subparagraphs below are optional features. Ground and neutral buses in lighting and appliance panelboards are also referred to as "bars" in manufacturers' literature. Coordinate with Drawings.

2. Equipment Ground Bus: Adequate for feeder and branch-circuit equipment grounding conductors; bonded to box.

Isolated ground bus in first subparagraph below is sometimes physically located above and attached to the equipment ground bus with standoff insulators. Frequently and incorrectly, contractors connect equipment grounding conductors to this bus instead of to the equipment ground bus, which can be hazardous if separate equipment grounding and isolated ground conductors are not both included in the feeder serving the panelboard.

3. Isolated Ground Bus: Adequate for branch-circuit isolated ground conductors; insulated from box.
4. Extra-Capacity Neutral Bus: Neutral bus rated 200 percent of phase bus and UL listed as suitable for nonlinear loads, with a corresponding increase in the size of the grounded conductor back to the supply.
5. Split Bus: Vertical buses divided into individual vertical sections.
6. <Insert optional features>.

Include instructions in first paragraph below if special sizing or oversizing of lugs is required, if allowing optional use of aluminum for circuits sized for copper conductors, or when upsizing conductors for voltage drop.

F. Conductor Connectors: Suitable for use with conductor material and sizes.

1. Material: Hard-drawn copper, 98 percent conductivity.
2. Main and Neutral Lugs: **Mechanical** type.

See Editing Instruction No. 4 in the Evaluations for guidance on using compression versus mechanical lugs in first four subparagraphs below.

3. Ground Lugs and Bus-Configured Terminators: **Mechanical** type.

First three subparagraphs below are optional features.

4. Feed-Through Lugs: **Mechanical** type, suitable for use with conductor material. Locate at opposite end of bus from incoming lugs or main device.

In first subparagraph below, NEMA PB 1 allows subfeed lugs to be located on the load or line side of main devices or on main-lugs-only panelboards; however, coordinate with specific manufacturers as some have restrictions on which options are available.

5. Subfeed (Double) Lugs: **Mechanical** type suitable for use with conductor material. Locate at same end of bus as incoming lugs or main device.
6. Gutter-Tap Lugs: **Mechanical** type suitable for use with conductor material. Locate at same end of bus as incoming lugs or main device.
7. Extra-Capacity Neutral Lugs: Rated 200 percent of phase lugs mounted on extra-capacity neutral bus.
8. **<Insert optional features>**.

Retain first paragraph below for panelboards that incorporate one or more main service disconnecting and overcurrent protective devices and that are used as the service entrance, outside feeder, or separately derived source means of disconnect and overcurrent protection.

- G. Service Equipment Label: NRTL labeled for use as service equipment for panelboards or load centers with one or more main service disconnecting and overcurrent protective devices.

Retain first paragraph below if future provisions are required.

- H. Future Devices: Mounting brackets, bus connections, filler plates, and necessary appurtenances required for future installation of devices.

Retain one or both paragraphs below for series-rated system or system that has panelboards and circuit breakers rated for full value of short-circuit current available at location of equipment.

- I. Panelboard Short-Circuit Current Rating: Fully rated to interrupt symmetrical short-circuit current available at terminals.
- J. Breakers shall have built-in test points for testing long delay, and instantaneous functions of the breaker by means of a 120 volt operated test kit.
- K. General Requirements for Branch Circuit Panelboards:
1. Bolt-on type, heavy-duty, quick-make, quick-break, single- and multi-pole circuit breakers, of the types specified herein, shall be provided for each circuit with toggle handles that indicate when unit has tripped.
 2. Circuit breakers shall be thermal magnetic type with common type handle for all

multiple pole circuit breakers. Circuit breakers shall be minimum 100-ampere frame and up through 100-ampere trip sizes shall take up the same pole spacing. Circuit breakers shall be UL listed as Type SWD for lighting circuits.

- a. Circuit breaker handle locks shall be provided for all circuits that supply exit signs, emergency lights, energy management and control system (EMCS) panels and fire alarm panels.
 - b. Main circuit breaker, when shown, shall be vertical mounted top or bottom as required. Chassis mounted reverse fed main circuit breaker is not acceptable.
3. Circuit breakers shall have a minimum interrupting rating of 10,000 amperes symmetrical at 240 volts and 14,000 amperes symmetrical at 480 volts.

2.2 DISTRIBUTION PANELBOARDS

Distribution panelboards, as specified in this article, fall under requirements of "Power Panelboards" in NFPA 70.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:
1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Square D; a brand of Schneider Electric.
 4. or approved equal.
- B. Panelboards: NEMA PB 1, power and feeder distribution type.

Distribution panelboards, as standard, do not have doors; consult manufacturers for availability and types of doors. Retain first paragraph below if panelboards have doors.

- C. Doors: Secured with vault-type latch with tumbler lock; keyed alike.
1. For doors more than 36 inches (914 mm) high, provide two latches, keyed alike.

Select one of first two options in first paragraph below for panelboards with main overcurrent protective devices; select third option for panelboards with only main lugs for the incoming feeder. Consult manufacturers for limitations on ratings for each type of device selected.

- D. Mains: [**Circuit breaker**] [**Lugs only**].

Retain one of first three paragraphs below. Allowing only bolt-on circuit breakers will exclude Square D (Schneider Electric), which uses plug-in types with a positive-locking feature, as an approved manufacturer.

- E. Branch Overcurrent Protective Devices for Circuit-Breaker Frame Sizes 125 A and Smaller: [**Plug-in**] [**Bolt-on**] circuit breakers.

- F. Branch Overcurrent Protective Devices for Circuit-Breaker Frame Sizes Larger Than 125 A: Bolt-on circuit breakers; plug-in circuit breakers where individual positive-locking device requires mechanical release for removal.
- G. Branch Overcurrent Protective Devices: Fused switches.

Contactors can be incorporated to switch the entire panelboard or only a portion of the circuits. Coordinate with Drawings and schedules to indicate contactor connections, type, quantity of circuits controlled, current ratings, external control circuits, and number of poles. Consult manufacturers for their respective limitations on and availability of short-circuit ratings and electrically held contactors, which may not be available from all manufacturers.

- H. Contactors in Main Bus: NEMA ICS 2, Class A, **[electrically] [mechanically]** held, general-purpose controller, with same short-circuit interrupting rating as panelboard.

Retain one of two subparagraphs below. If control-power transformer is used, specify capacity and associated fuses on Drawings. If branch circuit is used, identify circuit on Drawings. Use of branch circuits also requires a warning sign identifying sources of remote circuits.

1. Internal Control-Power Source: Control-power transformer, with fused primary and secondary terminals, connected to main bus ahead of contactor connection.
2. External Control-Power Source: **[120-V branch circuit] [24-V control circuit] <Insert requirement>**.

2.3 LIGHTING AND APPLIANCE BRANCH-CIRCUIT PANELBOARDS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Square D; a brand of Schneider Electric.
 4. or approved equal.
- B. Panelboards: NEMA PB 1, lighting and appliance branch-circuit type.

Retain first paragraph below if mains are not indicated on Drawings.

- C. Mains: **[Circuit breaker] [or] [lugs only]**.
- D. Branch Overcurrent Protective Devices: Bolt-on circuit breakers, replaceable without disturbing adjacent units.

Contactors can be incorporated to switch the entire panelboard or only a portion of the circuits. Coordinate with Drawings and schedules to indicate contactor connections, type, quantity of circuits controlled, current ratings, external control circuits, and number of poles. Consult manufacturers for their respective limitations on and availability of short-circuit ratings and electrically held contactors, which may not be available from all manufacturers.

- E. Contactors in Main Bus: NEMA ICS 2, Class A, **[electrically] [mechanically]** held, general-purpose controller, with same short-circuit interrupting rating as panelboard.

Retain one of two subparagraphs below. If control-power transformer is used, specify capacity and associated fuses on Drawings. If branch circuit is used, identify circuit on Drawings. Use of branch circuits also requires a warning sign identifying sources of remote circuits.

1. Internal Control-Power Source: Control-power transformer, with fused primary and secondary terminals, connected to main bus ahead of contactor connection.
 2. External Control-Power Source: **[120-V branch circuit] [24-V control circuit] <Insert requirement>**.
- F. Doors: Concealed hinges; secured with flush latch with tumbler lock; keyed alike.
- G. Column-Type Panelboards: Narrow gutter extension, with cover, to overhead junction box equipped with ground and neutral terminal buses.

2.4 ELECTRONIC-GRADE PANELBOARDS

Electronic-grade panelboards are frequently assembled by integrators or contractors using prefabricated panelboards complying with UL 67 and with TVSS modules installed in them; however, this might negate UL 67 short-circuit current ratings of panelboards if they are not retested after installing TVSS modules. The Section Text requires that electronic-grade panelboards be labeled by an NRTL for compliance with UL 67 after the fabricator installs TVSS modules.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Square D; a brand of Schneider Electric.
 4. or approved equal.
- B. Panelboards: NEMA PB 1; with factory-installed, integral TVSS; labeled by an NRTL for compliance with UL 67 after installing TVSS.
- C. Doors: Secured with vault-type latch with tumbler lock; keyed alike.
- D. Main Overcurrent Protective Devices: Bolt-on thermal-magnetic circuit breakers.
- E. Branch Overcurrent Protective Devices: Bolt-on thermal-magnetic circuit breakers.
- F. Buses:
1. Copper phase and neutral buses; 200 percent capacity neutral bus and lugs.
 2. Copper equipment and isolated ground buses.

See the Evaluations in Division 26 Section "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits" for guidance on editing paragraph below. Selection of options is a matter of ease of

maintenance and replacement; coordinate final choices with Owner's maintenance personnel. Plug-in and modular types offer the quickest maintenance but may come at a slightly higher cost. Wired-in type offers more safety with a slight reduction in protection and are used for a TVSS installed in a segregated panel extension located above or below the main panel.

- G. Surge Protection Device: IEEE C62.41-compliant, integrally mounted, **[plug-in] [wired-in] [bolt-on]**, solid-state, parallel-connected, **[modular (with field-replaceable modules)]** type, with sine-wave tracking suppression and filtering modules, short-circuit current rating complying with UL 1449, second edition, and matching or exceeding the panelboard short-circuit rating, redundant suppression circuits, with individually fused metal-oxide varistors.

1. Accessories:

Retain accessories in first 10 subparagraphs below to coordinate with options retained in paragraph above; verify availability and compatibility with manufacturer.

If specifying fuses for connecting TVSS devices to distribution system, verify ability of fuses to withstand surges consistent with ultimate surge current rating of device.

- a. Fuses rated at 200-kA interrupting capacity.
- b. Fabrication using bolted compression lugs for internal wiring.

Retain first subparagraph below only if a fused switch or circuit breaker is not provided for the TVSS in the panelboard, and the TVSS will not have a direct bus connection.

- c. Integral disconnect switch.
- d. Redundant suppression circuits.
- e. Redundant replaceable modules.
- f. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
- g. LED indicator lights for power and protection status.
- h. Audible alarm, with silencing switch, to indicate when protection has failed.
- i. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
- j. **[Four] [Six]**-digit, transient-event counter set to totalize transient surges.

Select first option in first subparagraph below for high exposure and cost, second option for medium exposure and cost, and third option for low exposure and cost.

2. Peak Single-Impulse Surge Current Rating: **[160 kA per mode/320 kA per phase] [120 kA per mode/240 kA per phase] [80 kA per mode/160 kA per phase]**.
3. Minimum single-impulse current ratings, using 8-by-20-mic.sec. waveform described in IEEE C62.41.2.
 - a. Line to Neutral: **70,000A**.
 - b. Line to Ground: **[70,000] <Insert value> A**.
 - c. Neutral to Ground: **[50,000] <Insert value> A**.

Retain first subparagraph below for panelboards located at or near Category C locations.

4. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.

Retain one of four subparagraphs below. Adjust clamping voltages to comply with Project conditions and verify compatibility of peak surge current rating and clamping voltage. Reference to UL 1449 is to its second edition.

5. Protection modes and UL 1449 SVR for grounded wye circuits with [480Y/277] [208Y/120] [600Y/347]-V, three-phase, four-wire circuits shall be as follows:
 - a. Line to Neutral: [800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347].
 - b. Line to Ground: [800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347].
 - c. Neutral to Ground: [800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347].
6. Protection modes and UL 1449 SVR for 240/120-V, single-phase, three-wire circuits shall be as follows:
 - a. Line to Neutral: 400 V.
 - b. Line to Ground: 400 V.
 - c. Neutral to Ground: 400 V.
7. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:
 - a. Line to Neutral: 400 V, 800 V from high leg.
 - b. Line to Ground: 400 V.
 - c. Neutral to Ground: 400 V.
8. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:
 - a. Line to Line: [2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V].
 - b. Line to Ground: [1500 V for 480 V] [800 V for 240 V] [2500 V for 600 V].

2.5 DISCONNECTING AND OVERCURRENT PROTECTIVE DEVICES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Square D; a brand of Schneider Electric.
 4. or approved equal.

Coordinate two paragraphs below with Drawings. See the "Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for guidance on making selections.

- B. Molded-Case Circuit Breaker (MCCB): Comply with UL 489, with fully-rated **interrupting capacity** to meet available fault currents.
1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 600 A and below.
 2. Breakers with frame sizes above 600 amperes shall be solid state trip, complete with built-in current transformers, solid-state trip unit and flux transfer shunt trip. Breakers shall have trip rating plugs with ratings as indicated on the drawings. Rating plugs shall be interlocked so they are NOT interchangeable between frames and interlocked such that a breaker cannot be latched with the rating plug removed.
 3. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
 4. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:

Retain one or more of first four subparagraphs below and coordinate required adjustable settings with Division 26 Section "Overcurrent Protective Device Coordination Study." See "Electronic rms Trip versus MCCBs" Paragraph in "Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for additional guidance on specifying full- or standard-function features.

- a. Instantaneous trip.
 - b. Long- and short-time pickup levels.
 - c. Long- and short-time time adjustments.
 - d. Ground-fault pickup level, time delay, and I₂t response.
5. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.

Retain first subparagraph below for GFCI circuit breakers for personnel ground-fault protection as required by NFPA 70; retain second subparagraph for GFEP circuit breakers (e.g., for self-limiting, heat-trace cables) as required by NFPA 70. GFCI, GFEP, and AFCI circuit breakers are only available fully rated up to interrupting ratings of 22 kA. For panelboards subject to fault currents above 22 kA, series ratings must be used.

6. GFCI Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
7. Ground-Fault Equipment Protection (GFEP) Circuit Breakers: Class B ground-fault protection (30-mA trip).
8. Arc-Fault Circuit Interrupter (AFCI) Circuit Breakers: Comply with UL 1699; 120/240-V, single-pole configuration.
9. Molded-Case Circuit-Breaker (MCCB) Features and Accessories:

Not all accessories and options listed in subparagraphs below are available for every rating and from every listed manufacturer. Verify availability and unique characteristics with manufacturers selected.

- a. Standard frame sizes, trip ratings, and number of poles.

See Editing Instruction No. 4 in the Evaluations for guidance on using compression versus mechanical

lugs.

- b. Lugs: **Mechanical** style, suitable for number, size, trip ratings, and conductor materials.
- c. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.

Select first option in first subparagraph below for solid-state trip units; select second option for thermal-magnetic units. If selecting second option, also retain "Shunt Trip" Subparagraph below.

- d. Ground-Fault Protection: [**Integrally mounted**] [**Remote-mounted**] relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
- e. Communication Capability: [**Circuit-breaker-mounted**] [**Universal-mounted**] [**Integral**] [**Din-rail-mounted**] communication module with functions and features compatible with power monitoring and control system specified in Division 26 Section "Electrical Power Monitoring and Control."

For first subparagraph below, 120-V units trip at 55 percent or more of rated voltage; all other voltages trip at 75 percent or more of rated voltage.

- f. Shunt Trip: [**120**] [**24**] <Insert voltage>-V trip coil energized from separate circuit, set to trip at [**55**] [**75**] percent of rated voltage.
- g. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage [**without intentional**] [**with field-adjustable 0.1- to 0.6-second**] time delay.
- h. Auxiliary Contacts: [**One SPDT switch**] [**Two SPDT switches**] with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts and "b" contacts operate in reverse of circuit-breaker contacts.
- i. Alarm Switch: Single-pole, normally open contact that actuates only when circuit breaker trips.
- j. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
- k. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function with other upstream or downstream devices.
- l. Multipole units enclosed in a single housing or factory assembled to operate as a single unit.
- m. Handle Padlocking Device: Fixed attachment, for locking circuit-breaker handle in [**on**] [**off**] [**on or off**] position.

Device defined in subparagraph below is not, and should not be, used as a safety device; it is used for holding the circuit-breaker handle in designated position to avoid accidental interruption of important circuits such as circuits for fire-alarm control panel or emergency lighting.

- n. Handle Clamp: Loose attachment, for holding circuit-breaker handle in on position.

Some manufacturers offer shunt-trip operators for their fused switches; however, most do not recommend using this feature for providing ground-fault protection on switches rated 1000 A and above in panelboards; they recommend using MCCBs or switches specified in Division 26 Section "Switchboards." Consult manufacturers for availability and limitations if this feature is required.

- C. Fused Switch: NEMA KS 1, Type HD; clips to accommodate specified fuses; lockable handle.
1. Fuses, and Spare-Fuse Cabinet: Comply with requirements specified in Division 26 Section "Fuses."
 2. Fused Switch Features and Accessories: Standard ampere ratings and number of poles.

Accessories and options, in addition to the one in subparagraph below, may be available for some ratings and from some listed manufacturers. Consult manufacturers for availabilities and unique characteristics.

3. Auxiliary Contacts: **[One]** **[Two]** normally open and normally closed contact(s) that operate with switch handle operation.

2.6 PANELBOARD SUPPRESSORS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Division 01 Section "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Current Technology; a subsidiary of Danahar Corporation.
 2. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 3. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 4. Liebert Corporation.
 5. Square D; a brand of Schneider Electric.
 6. or approved equal.

Retain one of first two paragraphs below. Comply with manufacturer's written instructions for connecting TVSS devices to distribution system. See the Evaluations in Division 26 Section "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits" for guidance on editing this article.

- B. Surge Protection Device: IEEE C62.41-compliant, integrally mounted, solid-state, parallel-connected, non-modular type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the panelboard short-circuit rating, and with the following features and accessories:
1. Accessories:

Retain accessories in three subparagraphs below to suit Project.

- a. LED indicator lights for power and protection status.
- b. Audible alarm, with silencing switch, to indicate when protection has failed.
- c. One set of dry contacts rated at 5 A and 250-V ac, for remote monitoring of protection status.

Selection of options in first paragraph below is a matter of ease of maintenance and replacement; coordinate final choices with Owner's maintenance personnel. Plug-in and modular types offer the quickest maintenance but may come at a slightly higher cost. Wired-in type offers more safety with a slight reduction in protection and are used for a TVSS installed in a segregated panel extension located

above or below the main panel.

- C. Surge Protection Device: IEEE C62.41-compliant, integrally mounted, **[plug-in]** **[wired-in]** **[bolt-on]**, solid-state, parallel-connected, **[modular (with field-replaceable modules)]** **[non-modular]** type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the panelboard short-circuit rating, and with the following features and accessories:

1. Accessories:

Retain accessories in 10 subparagraphs below to coordinate with options retained in paragraph above; verify availability and compatibility with manufacturer.

If specifying fuses for connecting TVSS devices to distribution system, verify ability of fuses to withstand surges consistent with ultimate surge current rating of device.

- a. Fuses rated at 200-kA interrupting capacity.
- b. Fabrication using bolted compression lugs for internal wiring.

Retain first subparagraph below only if a fused switch or circuit breaker is not provided for the TVSS in the panelboard, and the TVSS will not have a direct bus connection.

- c. Integral disconnect switch.
- d. Redundant suppression circuits.
- e. Redundant replaceable modules.
- f. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
- g. LED indicator lights for power and protection status.
- h. Audible alarm, with silencing switch, to indicate when protection has failed.
- i. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
- j. **[Four]** **[Six]**-digit, transient-event counter set to totalize transient surges.

Select first option in first subparagraph below for high exposure and cost, second option for medium exposure and cost, and third option for low exposure and cost.

2. Peak Single-Impulse Surge Current Rating: **[160 kA per mode/320 kA per phase]** **[120 kA per mode/240 kA per phase]** **[80 kA per mode/160 kA per phase]**.
3. Minimum single-impulse current ratings, using 8-by-20-mic.sec. waveform described in IEEE C62.41.2.
 - a. Line to Neutral: **[70,000]** **<Insert value>** A.
 - b. Line to Ground: **[70,000]** **<Insert value>** A.
 - c. Neutral to Ground: **[50,000]** **<Insert value>** A.

Retain first subparagraph below for panelboards located at or near Category C locations.

4. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA),

8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.

Retain one of four subparagraphs below. Adjust clamping voltages to comply with Project conditions and verify compatibility of peak surge current rating and clamping voltage. Reference to UL 1449 is to its second edition.

5. Protection modes and UL 1449 SVR for grounded wye circuits with [480Y/277] [208Y/120] [600Y/347]-V, three-phase, four-wire circuits shall be as follows:
 - a. Line to Neutral: [800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347].
 - b. Line to Ground: [800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347].
 - c. Neutral to Ground: [800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347].

6. Protection modes and UL 1449 SVR for 240/120-V, single-phase, three-wire circuits shall be as follows:
 - a. Line to Neutral: 400 V.
 - b. Line to Ground: 400 V.
 - c. Neutral to Ground: 400 V.

7. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:
 - a. Line to Neutral: 400 V, 800 V from high leg.
 - b. Line to Ground: 400 V.
 - c. Neutral to Ground: 400 V.

8. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:
 - a. Line to Line: [2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V].
 - b. Line to Ground: [1500 V for 480 V] [800 V for 240 V] [2500 V for 600 V].

2.7 ACCESSORY COMPONENTS AND FEATURES

Retain this article for overcurrent protective devices that require items in paragraphs below; delete if these items are specified elsewhere, such as in Division 26 Section "Switchboards."

- A. Accessory Set: Include tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.

Retain paragraph below for circuit breakers with solid-state trip devices.

- B. Portable Test Set: For testing functions of solid-state trip devices without removing from panelboard. Include relay and meter test plugs suitable for testing panelboard meters and switchboard class relays.

PART 3 - EXECUTION

3.1 EXAMINATION

Referenced NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- A. Receive, inspect, handle, and store panelboards according to **[NECA 407] [NEMA PB 1.1]**.
- B. Examine panelboards before installation. Reject panelboards that are damaged or rusted or have been subjected to water saturation.
- C. Examine elements and surfaces to receive panelboards for compliance with installation tolerances and other conditions affecting performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

Referenced NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- A. Install panelboards and accessories according to **[NECA 407] [NEMA PB 1.1]**.

Retain first paragraph below for floor-mounted distribution panelboards. Even if floor mounted, all panelboard cabinets must still be securely attached to a vertical wall or surface.

- B. Equipment Mounting: Install panelboards on concrete bases, **4-inch (100-mm)** nominal thickness. Comply with requirements for concrete base specified in Section[s] **[03300 "Cast-in-Place Concrete"] [033053 "Miscellaneous Cast-in-Place Concrete"]**.
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on **18-inch (450-mm)** centers around full perimeter of base.
 - 2. For panelboards, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to panelboards.
 - 5. Attach panelboard to the vertical finished or structural surface behind the panelboard.

Retain first paragraph below for large floor-mounted distribution panelboards.

- C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from panelboards.

Retain first paragraph below if seismic controls are required for Project. Coordinate with Drawings.

- D. Comply with mounting and anchoring requirements specified in Section "Vibration and Seismic Controls for Electrical Systems."

Ensure that, whatever height is selected for top of trim in first paragraph below, the operating handle of top-most switch or circuit breaker, in on position, is not higher than 79 inches (2000 mm) above finished floor or grade.

- E. Mount top of trim [78 inches (1982 mm)] <Insert height> above finished floor unless matching height of existing equipment or approved otherwise.
- F. Mount panelboard cabinet plumb and rigid without distortion of box. Mount recessed panelboards with fronts uniformly flush with wall finish and mating with back box.
- G. Install overcurrent protective devices and controllers not already factory installed.

Subparagraph below assumes that settings are indicated on Drawings or a coordination report is available for Contractor to use.

1. Set field-adjustable, circuit-breaker trip ranges.
- H. Install filler plates in unused spaces.

Retain first paragraph below if ceilings are accessible or there are raised floors, or when panelboards are located in spaces that will be finished.

- I. Stub five 1-inch (27-GRC) empty conduits from panelboard into accessible ceiling space or space designated to be ceiling space in the future. Stub five 1-inch (27-GRC) empty conduits into raised floor space or below slab not on grade.

Retain option in first paragraph below if retaining "Load Balancing" Paragraph in "Adjusting" Article.

- J. Arrange conductors in gutters into groups and bundle and wrap with wire ties[**after completing load balancing**].
- K. Comply with NECA 1.

3.3 PANELBOARD SCHEDULE

- A. Panelboards shall be furnished and equipped as follows, except as otherwise specified:

Manufacturer:	120/208V:	277/480V:	600- 1200A:
Cutler Hammer	PRL-1	PRL-2	PRL-3 or 4
Square-D	NQOD	NEHB	I-LINE
GE	NLAB	NHB	CCB

Or approved equal by other manufacturer.

- B. Panelboards may contain not more than one subfeed breaker with ratings in excess of 100A, but less than 225A.

- C. Distribution panelboard shall be scheduled where more than one subfeed breaker rated in excess of 100A is required, and for any panelboard containing breakers with ratings of 225A or more.

3.4 IDENTIFICATION

- A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with Section "Identification for Electrical Systems."

Retain option in first paragraph below if retaining "Load Balancing" Paragraph in "Adjusting" Article.

- B. Create a directory to indicate installed circuit loads[**after balancing panelboard loads**]; incorporate Owner's final room designations. Clearly identify the load on each circuit, equipment serviced and location. Revise directory to reflect circuiting changes required to balance phase loads. In all instances where a contractor installs or disconnects a circuit in any panel, a newly typed panel schedule shall be furnished. The new or revised panel schedule shall have the date and Contractor's name typed at the top right hand corner. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are not acceptable.
- C. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section "Identification for Electrical Systems."

Retain paragraph below if nameplates are required for individual overcurrent devices in distribution panelboards.

- D. Device Nameplates: Label each branch circuit device in distribution panelboards with a nameplate complying with requirements for identification specified in Section "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

Retain paragraph below to identify who shall perform tests and inspections. If retaining option, retain "Field Quality-Control Reports" Paragraph in "Informational Submittals" Article.

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first two paragraphs below to describe tests and inspections to be performed.

B. Acceptance Testing Preparation:

1. Test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

C. Tests and Inspections:

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
3. Perform the following infrared scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than sixty (60) days after Final Acceptance, perform an infrared scan of each panelboard. Remove front panels so joints and connections are accessible to portable scanner.
 - b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each panelboard eleven (11) months after date of Substantial Completion.
 - c. Instruments and Equipment:
 - 1) Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

See Division 01 Section "Quality Requirements" for retesting and reinspecting requirements and Division 01 Section "Execution" for requirements for correcting the Work.

D. Panelboards will be considered defective if they do not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

E. Prepare test and inspection reports, including a certified report that identifies panelboards included and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

F. Submit torque values for all connections with a torque schedule and witness signature.

3.6 ADJUSTING

A. Adjust moving parts and operable component to function smoothly, and lubricate as recommended by manufacturer.

Select first option in first paragraph below if settings are included in the Contract Documents; select second option if indicated Section is included in the Contract Documents.

B. Set field-adjustable circuit-breaker trip ranges [**as indicated**] [**as specified in Section**

"Overcurrent Protective Device Coordination Study."]

Circuit changes made during load balancing may negate color-coding of phases and circuits. If load balancing proves undesirable or is to be performed by others, delete paragraph below.

- C. Load Balancing: After Substantial Completion, but not more than sixty (60) days after Final Acceptance, measure load balancing and make circuit changes.
 - 1. Measure as directed during period of normal system loading.
 - 2. Perform load-balancing circuit changes outside normal occupancy/working schedule of the facility and at time directed. Avoid disrupting critical 24-hour services such as fax machines and on-line data processing, computing, transmitting, and receiving equipment.
 - 3. After circuit changes, recheck loads during normal load period. Record all load readings before and after changes and submit test records.
 - 4. Tolerance: Difference exceeding 20 percent between phase loads, within a panelboard, is not acceptable. Rebalance and recheck as necessary to meet this minimum requirement.

3.7 PROTECTION

- A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262416

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SECTION 262416.16 - ELECTRONICALLY OPERATED CIRCUIT-BREAKER PANELBOARDS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes: Panelboards using electronically controlled, electrically operated circuit breakers.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. BAS: Building automation system.
- B. IP: Internet protocol.

- C. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- D. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
- E. PC: Personal computer; sometimes plural as "PCs."
- F. RS-485: A serial network protocol, similar to RS-232, complying with TIA-485-A.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for control modules, power distribution components, manual switches and plates, and conductors and cables.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For each electronically operated, circuit-breaker panelboard and related equipment.
 - 1. Include dimensioned plans, elevations, sections, and details. Show tabulations of installed devices, equipment features, and ratings.
 - 2. Detail enclosure types and details for types other than NEMA 250, Type 1.
 - 3. Detail bus configuration, current, and voltage ratings.
 - 4. Short-circuit current rating of panelboards and overcurrent protective devices.
 - 5. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.

Retain first subparagraph below if final system short-circuit and coordination studies will be performed by designer or assigned to independent consultant. These curves are also beneficial to Owner for future additions or reevaluations of overcurrent protective device settings.

- 6. Include time-current coordination curves for each type and rating of overcurrent protective device included in panelboards. Submit on translucent log-log graph paper; include selectable ranges for each type of overcurrent protective device.
- 7. Include diagrams for power, signal, and control wiring.

Retain "Block Diagram" Subparagraph below when control is digital, PC based, or IP based.

- 8. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data

gateways, concentrators, and other devices to be used. Describe characteristics of network and other data communication lines.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below if controllers are connected to devices or systems specified in other Sections.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Submit evidence that electronic controls are compatible with connected monitoring and control devices and systems specified in other Sections.
 - 1. Show interconnecting signal and control wiring and interfacing devices that prove compatibility of inputs and outputs.
 - 2. For networked controls, list network protocols and provide statements from manufacturers that input and output devices comply with interoperability requirements of the network protocol.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- B. Qualification Data: For testing agency.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548.16 "Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Seismic Qualification Certificates: For panelboards, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- D. Field quality-control reports.

Retain first paragraph below for PC- and IP-based control systems.

- E. Software licenses and upgrades required by and installed for operation and programming of digital and analog devices.
- F. Sample Warranty: For manufacturer's special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electronic controls to include in emergency, operation, and maintenance manuals.

Retain "Software and Firmware Operational Documentation" Paragraph below for PC- and IP-based control systems.

- B. Software and Firmware Operational Documentation:
1. Software operating and upgrade manuals.
 2. Program Software Backup: On magnetic media or compact disk, complete with data files.
 3. Device address list.
 4. Printout of software application and graphic screens.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Electrically Operated, Molded-Case Circuit Breakers: Equal to <Insert number> percent of amount installed [**for each size indicated**], but no fewer than <Insert number>.

1.8 QUALITY ASSURANCE

Retain "Testing Agency Qualifications" Paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also defines "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Handle and prepare panelboards for installation according to **[NECA 407] [NEMA PB 1.1]**.

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

1. Warranty Period: Minimum **[five (5)] <Insert number>** years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Products" Paragraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

- A. Products: Subject to compliance with requirements, provide one of the following:
1. Eaton Corporation, Cutler-Hammer Business Unit; Pow-R-Command Control Panelboards.
 2. General Electric Company, GE Consumer & Industrial - Electrical Distribution; A-Series Control Panels.
 3. Siemens Energy & Automation, Inc.; i-3 Control Technology.

4. Square D, a brand of Schneider Electric; PowerLink G3 Control Panelboards.
5. **<Insert manufacturer's name; product name or designation>**.
6. or approved equal.

- B. Source Limitations: Obtain electrically operated circuit breakers and power distribution components from single manufacturer.

2.2 SYSTEM DESCRIPTION

- A. Input signal from field-mounted or on-board signal source shall open or close one or more electrically operated circuit breakers in the electronically operated, circuit-breaker panelboards. Any combination of inputs shall be programmable to any combination outputs.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with 47 CFR, Subpart A and Subpart B, for Class A digital devices.

2.3 PERFORMANCE REQUIREMENTS

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

- A. Seismic Performance: Panelboards shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] **<Insert requirement>**.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [1.5] [1.0].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. **<Insert requirements for Component Amplification Factor and Component Response Modification Factor>.**

- B. Expansion Requirements: Capacity for future expansion of number of control functions by 25 percent of current capacity; to include equipment ratings, housing capacities, spare spaces for circuit breakers, terminals, number of conductors in control cables, and control software.

Retain "BAS Interface" Paragraph below for interface with the BAS. Coordinate with Section 230900 "Instrumentation and Control for HVAC."

- C. BAS Interface: Provide hardware and software to enable the BAS to monitor, control, display, and record data for use in processing reports.

Retain "Hardwired Points" or "Communication Interface" Subparagraph below. Retain first if interface with the BAS is through hardwired points and minimal interface is required. Retain second if extensive interface with the BAS is required and is beyond what hardwired points can provide. Requirement may exclude some manufacturers.

1. Hardwired Points:
 - a. Monitoring: On-off status, **<Insert monitoring point>**.
 - b. Control: On-off operation, **<Insert control point>**.
2. Communication Interface: Comply with [ASHRAE 135] **<Insert type of interface>** communication interface with the BAS shall enable the BAS operator to remotely control and monitor electronically operated circuit breakers from a BAS operator workstation. Control features and monitoring points displayed locally at panelboard controller shall be available through the BAS.

2.4 PANELBOARDS

- A. Electronically operated, circuit-breaker panelboards may contain remotely operated circuit breakers and standard branch circuit breakers specified in Section 262416 "Panelboards."
- B. Assemblies: Comply with UL 67 and NEMA PB 1.

Retain one of two "Surge Protective Device" paragraphs below.

- C. Surge Protective Device: Field mounted, complying with Section 264313 "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits."
- D. Surge Protective Device: Integrally mounted, complying with UL 1449 Type 1.
1. Comply with IEEE C62.41, Category C, 200-kA short-circuit current rating.
 2. Non-modular type with the following features and accessories:
 - a. Digital-display indicator lights for power and protection status.
 - b. **<Insert features and accessories>**.

- E. Enclosures: Comply with UL 50 and NEMA 250.

Retain "Future Devices" Paragraph below if future provisions are required.

- F. Future Devices: Mounting brackets, bus connections, filler plates, and necessary appurtenances required for future installation of devices.

Retain one of or both "Panelboard Short-Circuit Current Rating" paragraphs below for series-rated system or system that has panelboards and circuit breakers rated for full value of short-circuit current available at location of equipment. Typical short-circuit current rating of electrically operated circuit breakers is 10 kA. If higher values and series ratings are required, verify availability with manufacturers.

- G. Panelboard Short-Circuit Current Rating: Rated for series-connected system with integral or remote upstream overcurrent protective devices and labeled by an NRTL. Include size and type of allowable upstream and branch devices, listed and labeled for series-connected, short-circuit rating by an NRTL.
- H. Panelboard Short-Circuit Current Rating: Fully rated to interrupt [**10-kA**] symmetrical short-circuit current available at terminals.
- I. Panelboards shall have a UL-listed interrupting rating[**of 10 kA**], sufficient for the application, or a UL-listed series-connected rating for the maximum available fault current at that point in the system.

2.5 CIRCUIT BREAKERS

- A. Remotely operated branch circuit breakers shall provide branch circuit overcurrent protection.

In "Labeled with SWD and HID Ratings" Paragraph below, SWD rating is only available for 15- and 20-A, single-pole circuit breakers. Retain option if specifying other breaker sizes.

See Editing Instruction No. 2 in the Evaluations for discussion on short-circuit current ratings for equipment complying with UL 489.

- B. Labeled with SWD and HID Ratings: Comply with UL 489 for 15- and 20-A, single-pole branch devices.[**15- and 20-A circuit breakers, if scheduled, shall be a product of same manufacturer, and be of same class as the rated circuit breakers.**]

Retain "Switching Endurance Rating" Paragraph below if endurance in excess of UL 489 SWD test is required. Verify test method and available ratings with manufacturers.

- C. Switching Endurance Rating: Not less than [**50,000**] [**200,000**] <Insert number> full-load open/close/open remote operations.
- D. Remotely Operated Circuit Breakers: Manual override switch or handle position shall enable or disable the remote operation of the device and allow breaker handle to manually control the breaker's on-off status.

Retain "Main" option in article title below if retaining "Slave Panel Controllers" Article.

2.6 [MAIN]CONTROLLERS

- A. Description: Controllers shall contain the power supply and electronic control for operating and monitoring remotely operated branch circuit breakers.

See Editing Instruction No. 2 in the Evaluations for discussion on short-circuit current ratings for equipment complying with UL 916.

1. Comply with UL 916 (CSA C22.2, No. 205); with a microprocessor-based, solid-state, 365-day timing and control unit.
2. Power Supply: Powered from the panelboard, sized to provide control power for the operation of the remotely operated circuit breakers, controller, bus system, low-voltage inputs, and field-installed sensors.
3. Integral keypad and digital-display front panel for local setup, including the following:
 - a. Log and display remotely operated breaker on-time.
 - b. Provision to accept downloadable firmware so that the latest features may be added in the future without replacing the module.
4. Nonvolatile memory shall retain all setup configurations. After a power failure, the controller shall automatically reboot and return to normal system operation.

Retain "Ethernet Communications" Paragraph below if networking electronically operated, circuit-breaker panelboards. Coordinate with "Control Network" Article.

5. Ethernet Communications: Comply with [ASHRAE 135] <Insert network protocol> protocols.
 - a. Each input connected to the controller shall control any remotely operated breaker in any other networked electronically operated, circuit-breaker panelboard.
 - b. A schedule programmed at one controller shall be able to control any remotely operated breaker in any other networked panelboard.

In "Time Synchronization" Subparagraph below, the typical value ranges from one hour to 24 hours.

6. Time Synchronization: The timing unit shall be updated not less than every <Insert number> hour(s) with the network time server.
7. Web Server: Display information listed below over a standard Web-enabled server for displaying information over a standard Web browser.
 - a. A secure, password-protected login screen for modifying operational parameters, accessible to authorized users via Web page interface.
 - b. Separate Web page, showing status of each main and slave electronically operated, circuit-breaker panelboards with the arrangement of breakers on the page matching the physical appearance of the panel. Status shall include breaker nametags, pole configuration, location in panel, actual contact state (on-off/tripped/manual), and breaker on-time.
 - c. Panel summary showing the master and slave panels connected to the controller.

- d. Controller diagnostic information.
 - e. Show front panel mimic screens for setting up controller parameters, input types, zones, and operating schedules. These mimic screens shall also allow direct breaker control and zone overrides.
8. Alarm and E-mail Notification: Automatically initiate alarms based on preconfigured conditions listed below and routing alarm alerts as set at the control panel.
- a. General Alarms: Power loss, non-responding breakers, loss and restoration of sub-net communications, loss and restoration of serial port communications, loss and restoration of BAS commands.
 - b. Specific Alarms: Input status, zone status, breaker status on-time (0 to 99999 hours).
 - c. E-mail Notification: Automatically route e-mail messages to five individual e-mail addresses. Within the body text of the e-mail, include a link that will automatically redirect the user to the associated panels' status Web page.
- B. Timing Unit:
1. 365-day calendar, astronomical clock, and automatic adjustments for daylight savings and leap year.
 2. Clock configurable for 12-hour (A.M./P.M.) or 24-hour format.
 3. [16] <Insert number> independent schedules, each having [24] <Insert number> time periods.
 4. Schedule periods settable to the minute.
 5. Day of week, day of month, day of year with one-time or repeating capability.
 6. [32] <Insert number> special date periods.
- C. With [8] [16] <Insert number> inputs, each configurable to the following parameters:
1. Normally open, normally closed, two-wire maintained toggle, two-wire momentary toggle, two-wire momentary on, two-wire momentary off, or three-wire momentary operation.
 2. On and off-delay timers for local override operation, adjustable from five minutes to 12 hours. Local override shall be by field-installed, two-wire momentary toggle switch.

2.7 SLAVE PANEL CONTROLLERS

Retain this article if more than one panelboard is under unified control of the main controller.

- A. Slave panels shall contain the necessary busses and network hardware to allow connection of the sub-net wiring between panels, with programming at the main panel controller. Programmable timing unit, Web server, alarm and e-mail notification, and Ethernet connection to the control network is not required provided all of these functions are available for the slave panel from the main panel controller.

- B. Sub-net wiring connections shall allow connection of wiring to a terminal that can be removed from the panel without interrupting communications to other panels.
- C. Slave panels shall contain a nameplate label attached to the deadfront trim indicating the panel designation, panel network address, and panel designation of the associated master panel.

2.8 CONTROL NETWORK

Retain first option in "Panel Controllers" Paragraph below if networking more than one main controller. Retain second option if the network connects controllers associated with other BAS controllers.

- A. Panel Controllers: Networked with other [**electronically operated, circuit-breaker panel controllers**] [**BAS controllers**] in a peer-to-peer configuration using Ethernet [**10Base-T**] [**100Base-T**] network.

Retain "Compliance with ASHRAE 135" Paragraph below for DDC system for HVAC control network. Revise as required for other networks protocols.

See "Communication Networks" Article in the Evaluations for discussion of communication network options.

- B. Compliance with ASHRAE 135: Controllers shall support serial MS/TP and Ethernet IP communications, and shall be able to communicate directly via BAS RS-485 serial networks and Ethernet 10Base-T networks as a native device.

2.9 MANUAL SWITCHES AND PLATES

Coordinate use of manual switches in this article with override functions, with switch and wall-plate finish specified in Section 262726 "Wiring Devices."

- A. Keypads: Programmable, designed to control functions associated with the equipment of this Section. The units shall be able to control any system output device.
- B. Push-Button Switches: Modular, momentary-contact, low-voltage type.
 - 1. Match color specified in Section 262726 "Wiring Devices."

Two subparagraphs below are optional features.

- 2. Integral green [**digital-display**] pilot light to indicate when circuit is on.
 - 3. Internal white [**digital-display**] locator light to illuminate when circuit is off.
- C. Manual, Maintained Contact, Full- or Low-Voltage Switch: Comply with Section 262726 "Wiring Devices."
- D. Wall Plates: Single and multigang plates as specified in Section 262726 "Wiring Devices."

- E. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

2.10 CONDUCTORS AND CABLES

- A. Power Wiring to Supply Side of Class 2 Power Source: Not smaller than No. 12 AWG. Comply with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Class 2 and Class 3 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 18] [No. 22] [No. 24]** AWG. Comply with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Class 1 Control Cables: Multiconductor cable with copper conductors not smaller than **[No. 14] [No. 16] [No. 18]** AWG. Comply with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Digital and Multiplexed Signal Cables: Unshielded, twisted-pair cable with copper conductors, complying with TIA/EIA-568-B.2, **[Category 5e] [Category 6]** for horizontal copper cable. Comply with requirements in Section 271500 "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.1 EXAMINATION

NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- A. Receive, inspect, handle, and store panelboards according to **[NECA 407] [NEMA PB 1.1]**.
- B. Examine panelboards before installation. Reject panelboards that are damaged or rusted or have been subjected to water saturation.
- C. Examine elements and surfaces to receive panelboards for compliance with installation tolerances and other conditions affecting performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 WIRING INSTALLATION

- A. Comply with NECA 1.

Retain one of two "Wiring Method" paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings.

- B. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters[**and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used**]. Conceal raceway and cables except in unfinished spaces.

Retain first subparagraph below if retaining unenclosed wiring method option in "Wiring Method" Paragraph above.

1. Install plenum cable in environmental air spaces, including plenum ceilings.
2. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."

- C. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- D. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

3.3 PANELBOARD INSTALLATION

- A. Comply with NECA 1.

NECA and NEMA standards in first paragraph below include similar requirements. See "Testing and Inspecting" Article in the Evaluations.

- B. Install panelboards and accessories according to [**NECA 407**] [**NEMA PB 1.1**].

Retain first paragraph below if seismic controls are required for Project. Coordinate with Drawings.

- C. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

In "Mounting Height" Paragraph below, verify that operating handle of top-most switch or circuit breaker, in on position, is not higher than 79 inches (2000 mm) above finished floor or grade.

- D. Mounting Height: [**90 inches (2286 mm)**] <Insert dimension> to top of trim above finished floor unless otherwise indicated.
- E. Mount panelboard cabinet plumb and rigid without distortion of box. Mount recessed panelboards with fronts uniformly flush with wall finish and mating with back box.
- F. Install filler plates in unused spaces.

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with Section 260553 "Identification for Electrical Systems."
- C. Create a directory to indicate loads served by each circuit; incorporate Owner's final room designations. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are unacceptable.
- D. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate testing requirements with Section 262416 "Panelboards."

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
 - 3. Perform the following infrared scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each panelboard. Remove front panels so joints and connections are accessible to portable scanner.

- b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each panelboard 11 months after date of Substantial Completion.
- c. Instruments and Equipment:
 - 1) Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

C. Acceptance Testing Preparation:

- 1. Test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
- 2. Test continuity of each circuit.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. Panelboard will be considered defective if it does not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

E. Prepare test and inspection reports, including a certified report that identifies panelboards included and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Confirm correct communication wiring, initiate communications between panels, and program the control system according to approved time-of-day schedules and input override assignments.
 - 3. **<Insert startup steps if any>**.

3.7 ADJUSTING

- A. Occupancy Adjustments: When requested within [**twelve (12)**] **<Insert number>** months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] **<Insert number>** visits to Project during other-than-normal occupancy hours for this purpose.

3.8 SOFTWARE SERVICE AGREEMENT

Services in this article may not be allowed for publicly funded projects.

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for **[two (2)] <Insert number>** years.
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within **[two (2)] <Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: At least **[thirty (30)] <Insert number>** days to allow Owner to schedule and access the system and to upgrade computer equipment if necessary.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain control modules.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262416.16

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SECTION 262419 - MOTOR-CONTROL CENTERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED-NC Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1-2004, which requires the use of mechanical or electrical variable-speed drives on fan motors used in VAV system fans that are 15 hp and larger and on motors in variable-flow hydronic systems that are larger than 50 hp.

Energy savings resulting from the use of variable-frequency motor controllers on motors other than required by Prerequisite EA 2 can be combined with other energy-saving measures to meet the requirements of LEED-NC Credit EA 1.

LEED-NC Credit EA 5 requires the development of a Measurement & Verification (M&V) Plan to achieve this credit. Energy used by each VFC can be used in the simulation calibration process required by the International Performance Measurement & Verification Protocol (IPMVP), Volume III, Chapter 4, "Whole Building Calibrated Simulation" (Option D) to verify the building's compliance with this credit.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes MCCs for use with ac circuits rated 600 V and less and having the following factory-installed components:
 - 1. Incoming main lugs and OCPDs.
 - 2. Full-voltage magnetic controllers.

3. Reduced-voltage magnetic controllers.
4. Reduced-voltage, solid-state controllers.
5. Multispeed controllers.
6. VFCs.
7. Feeder-tap units.
8. TVSS.
9. Instrumentation.
10. Auxiliary devices.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. BAS: Building automation system.
- B. CE: Conformance Europeene (European Compliance).
- C. CPT: Control power transformer.
- D. EMI: Electromagnetic interference.
- E. GFCI: Ground fault circuit interrupting.
- F. IGBT: Insulated-gate bipolar transistor.
- G. LAN: Local area network.
- H. LED: Light-emitting diode.
- I. MCC: Motor-control center.
- J. MCCB: Molded-case circuit breaker.
- K. MCP: Motor-circuit protector.
- L. NC: Normally closed.
- M. NO: Normally open.
- N. OCPD: Overcurrent protective device.
- O. PCC: Point of common coupling.
- P. PID: Control action, proportional plus integral plus derivative.
- Q. PT: Potential transformer.
- R. PWM: Pulse-width modulated.
- S. RFI: Radio-frequency interference.

- T. SCR: Silicon-controlled rectifier.
- U. TDD: Total demand (harmonic current) distortion.
- V. THD(V): Total harmonic voltage demand.
- W. TVSS: Transient voltage surge suppressor.
- X. VFC: Variable-frequency controller.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Installer Qualifications: Installers shall specialize in installation of medium voltage equipment with a minimum of 5 years of experience
- B. Seismic Performance: MCCs shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

- 1. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.
- C. Field Conditions: The drawings are diagrammatic and indicate the general arrangement of electrical work. Locations are approximate and shall be subject to minor modifications as dictated by field conditions and as directed by DEN Project Manager.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of controller and each type of MCC. Include shipping and operating weights, features, performance, electrical ratings, operating characteristics, and furnished specialties and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

LEED-NC Credit EA 5 requires continuous metering equipment for monitoring building energy-consumption performance over time. VFCs providing input to a BAS on energy usage can support this requirement. Coordinate with requirements in "VFC Controls and Indication" Article.

1. Product Data for Credit EA 5: For continuous metering equipment for energy consumption.

See Editing Instructions No. 2 and No. 3 in the Evaluations for discussion of Shop Drawing types defined in UL 845 that are available from manufacturers, including "standard," "approval," "production," and "custom" drawings. If retaining "Shop Drawings" Paragraph below, coordinate with manufacturers for availability of information and include additional information to suit Project. There can be a considerable cost premium for specifying optional drawings, especially if custom. Coordinate below with "Characteristics and Ratings" Article and see "Classification of MCCs" Article in the Evaluations for guidance on which subparagraphs to retain, based on MCC class and type specified.

Retain "Production" option below if optional drawings, representing the MCCs as released for production and shipping, are required from manufacturer. Manufacturers' production drawings are usually not intended for Action Submittals; if requested, they normally are for informational purposes only. If production drawings are required for review, retain "production" option and delete "Production Drawings" Paragraph.

- C. Shop Drawings: For each MCC, manufacturer's **[approval]** **[custom]** **[and]** **[production]** drawings as defined in UL 845. In addition to requirements specified in UL 845, including drawing index, dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.
 1. Show tabulations of installed devices, equipment features, and ratings. Include the following:
 - a. Each installed unit's type and details.
 - b. Factory-installed devices.
 - c. Enclosure types and details.
 - d. Nameplate legends.
 - e. Short-circuit current (withstand) rating of complete MCC, and for bus structure and each unit.
 - f. Features, characteristics, ratings, and factory settings of each installed controller and feeder device, and installed devices.
 - g. Specified optional features and accessories.
 - h. **<Insert required information>**.
 2. Schematic **[and Connection]** Wiring Diagrams: For power, signal, and control wiring for each installed controller. Provide complete one-line diagram and complete three-line diagram.
 3. Wiring diagrams shall reflect the physical location of components. Destination labeling shall be used.
 4. Relaying and control schematic diagram.
 5. Size and number of bus bars per phase, neutral and ground.
 6. Time-current curves of all equipment and components.
 7. Conduit entry and exit locations and requirements.
 8. Assembly ratings including:

- a. Short-circuit rating.
 - b. Voltage.
 - c. Continuous current.
 - d. Basic impulse level for equipment over 600 volts.
9. Major component ratings including:
- a. Voltage.
 - b. Continuous current.
 - c. Interrupting ratings.
10. Cable terminal sizes.
11. Component list.
12. Nameplate legends.
13. Vertical and horizontal bus capacities.
14. Features, characteristics, ratings, and factory settings of each installed unit.
15. Where applicable, the following additional information shall be submitted to the DEN Project Manager:
- a. Busway connections.
 - b. Connection details between close-coupled assemblies.
 - c. Composite floor plan of close-coupled assemblies.
 - d. Interlock scheme drawing and sequence of operations.
16. **<Insert required information>**.

Retain "Harmonic Analysis Study and Report" Paragraph below if VFCs are included in MCCs and an analysis is required from MCC manufacturer. Ensure that the information necessary for manufacturer to perform the analysis is included in the Construction Documents, including specified TDD and THD(V) limits. See "Harmonic Distortion" Article in the Evaluations and the Drawing Coordination Checklist for additional information.

- D. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze **[possible]** **[designated]** operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) **[at each VFC]** **[at the defined PCC]** to specified levels.

1.6 INFORMATIONAL SUBMITTALS

Manufacturers' "standard" drawings, as defined in UL 845 and NEMA ICS 18, are not intended for Action Submittals; if submitted, they normally are for informational purposes only. If "approval" drawings are required in "Shop Drawings" Paragraph, delete "Standard Drawings" Paragraph below. See Editing Instruction No. 2 in the Evaluations for explanation of these drawings.

- A. Standard Drawings: For each MCC, as defined in UL 845.

Retain "Production Drawings" Paragraph below if optional drawings, representing the MCCs as released for production and shipping, are required from manufacturer. Manufacturers' "production" drawings, as defined in UL 845 and NEMA ICS 18, are not intended for Action Submittals; if requested, they normally

are for informational purposes only. If production drawings are required for review, retain "production" option in "Shop Drawings" Paragraph and delete below. See Editing Instruction No. 3 in the Evaluations for explanation of these drawings.

- B. Production Drawings: For each MCC, as defined in UL 845.

Retain "Coordination Drawings" Paragraph below. See "Installation Considerations" Article in the Evaluations for additional guidance on when to retain paragraph.

Coordinate requirements for coordination drawings with DEN Project Manager.

- C. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around MCCs where pipe and ducts are prohibited. Show MCC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Sections specifying mechanical vibration, supports, electrical supports, and seismic controls. See ASCE/SEI 7 for certification requirements for equipment and components.

- D. Seismic Qualification Certificates: For MCCs, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- E. Qualification Data: For qualified testing agency.

Retain "Product Certificates" Paragraph below for product certificates from manufacturers.

- F. Product Certificates: For each MCC, from manufacturer.
- G. Source quality-control reports.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- H. Field quality-control reports.

Projects with multiple sizes and types of controllers might include different types of overload relays. Retain one or both of first two paragraphs below to suit type(s) of motor overload protection. See Evaluations for discussion.

- I. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.
- J. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor running overload protection suit actual motors to be protected.
- K. Manufacturer's System Start-Up Plan.
- L. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For MCCs, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

See Editing Instructions No. 2 and No. 3 in the Evaluations for discussion of Shop Drawing types defined in UL 845 available from manufacturers, and which are included as part of operation and maintenance submittals. However, field modifications and wiring identification are typically not included in Record Drawings, but can be incorporated at additional costs. Retain "Manufacturer's Record Drawings" Subparagraph below if drawings of the MCCs, as manufactured and shipped, and including field modifications, are required.

- 1. Manufacturer's Record Drawings: As defined in UL 845. In addition to requirements specified in UL 845, include field modifications [**and field-assigned wiring identification**] incorporated during construction by manufacturer, Contractor, or both. Provide paper copy and electronic copy in format as approved by DEN Project Manager.

Coordinate subparagraphs below with features. Retain first subparagraph if circuit breakers are specified in combination controllers; retain second if field-adjustable overload relays are specified; retain third if reduced-voltage, solid-state controllers are specified; retain fourth if VFCs are specified; retain fifth if specifying optional control features.

- 2. Manufacturer's written instructions for testing and adjusting circuit breaker and MCP trip settings.
- 3. Manufacturer's written instructions for setting field-adjustable overload relays.
- 4. Manufacturer's written instructions for testing, adjusting, and reprogramming reduced-voltage, solid-state controllers.
- 5. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
- 6. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
- 7. Certified production test reports.
- 8. Installation information including equipment anchorage provisions.
- 9. Seismic certification.
- 10. Recommended renewal parts list.

11. Submit torque values for all connections with a torque schedule and witness signature.
- B. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.
- C. The Manufacturer shall provide three (3) certified copies of factory test reports to DEN Project Manager.

Verify requirements for as-built plans with DEN Project Manager.

- D. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

Revise this article to include extra materials that Owner may require, which may fail more frequently due to continual use. Coordinate extra materials with features retained in Part 2.

Coordinate quantity of fuses with Section 262813 "Fuses" for required space in spare-fuse cabinet.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents. Deliver maintenance materials as directed by DEN Project Manager.
 1. Power Fuses: Equal to **[ten (10)] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[three (3)] <Insert number>** of each size and type.
 2. Control Power Fuses: Equal to **[ten (ten (10))] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[two (2)] <Insert number>** of each size and type.
 3. Indicating Lights: **[Two (2)] <Insert number>** of each type and color installed.
 4. Auxiliary Contacts: Furnish **[one (1)] <Insert number>** spare(s) for each size and type of magnetic controller installed.
 5. Power Contacts: Furnish **[three (3)] <Insert number>** spares for each size and type of magnetic contactor installed.
 6. **<Insert extra materials>**.
- B. Include spare parts data listing; source and current prices of replacement parts and supplies; and recommended maintenance procedures and intervals.

1.9 QUALITY ASSURANCE

Retain "Testing Agency Qualifications" Paragraph below if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- B. Source Limitations: Obtain MCCs and controllers of a single type from single source from single manufacturer.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with NFPA 70.

Retain "IEEE Compliance" Paragraph below for projects in seismic areas. If retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

- E. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- F. The Manufacturer of this equipment shall have been pre-qualified by Owner.
- G. When requested by the DEN Project Manager, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.

1.10 DELIVERY, STORAGE, AND HANDLING

Retain first paragraph below if there are obstacles to movement of normal shipping lengths of MCCs. Coordinate with Drawings.

- A. Deliver MCCs in 60-inch maximum width shipping splits of lengths that can be moved past obstructions in delivery paths, individually wrapped for protection and mounted on shipping skids.
- B. Handle MCCs according to the following:
 - 1. NEMA ICS 2.3, "Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers Rated Not More Than 600 Volts."
 - 2. NECA 402, "Recommended Practice for Installing and Maintaining Motor Control Centers."
- C. Equipment shall be handled and stored in accordance with Manufacturer's instructions.

One (1) copy of these instructions shall be included with the equipment at time of shipment.

- D. Store in a clean, dry space. Maintain factory wrapping or provide an additional heavy canvas or heavy plastic cover to protect units from dirt, water, construction debris, and traffic. Keep the unit above ambient temperature until energized.
- E. Handle in accordance with manufacturer's written instructions. Lift only with lugs provided for the purpose. Handle carefully to avoid damage to motor control center components, enclosure, and finish.

Retain first option in paragraph below for controllers that are not required to have factory-installed space heaters; otherwise, retain second option.

- F. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside MCCs. Equipment being stored prior to installation shall be stored so as to maintain the equipment in a clean and dry condition. If stored outdoors indoor gear shall be covered and heated, and outdoor gear shall be heated. Install temporary electric heating, with at least 250 W per vertical section, or connect factory-installed space heaters to temporary electrical service.

1.11 PROJECT CONDITIONS

Revise "Environmental Limitations" Paragraph below to specify unusual environmental or service conditions. For equipment installed outdoors, indicate maximum and minimum ambient temperature and expected humidity range. For additional ambient compensation requirements for fuses, MCCBs, and overload relays, see Editing Instructions No. 5, No. 6, and No. 8 in the Evaluations.

- A. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
 - 1. Ambient Temperature Range: **Minus 30 deg F** (minus 35 deg C) to **120 deg F** (49 deg C), with an average value exceeding **95 deg F** (35 deg C) over a 24-hour period.
 - 2. Ambient Storage Temperature: **Minus 30 deg F** (minus 35 deg C) and not exceeding **140 deg F** (60 deg C).
 - 3. Humidity: Less than 95 percent (noncondensing).
 - 4. Altitude: **5,500 feet** (1677 m) above sea level..
 - 5. **<Insert unusual service condition>**.

Retain "Interruption of Existing Electrical Service or Distribution Systems" Paragraph below if interruption of existing electrical services or distribution systems is required.

- B. Interruption of Existing Electrical Service or Distribution Systems: Do not interrupt electrical service to, or distribution systems within, a facility occupied by Owner or others unless permitted under the following conditions, and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport

- Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
2. Indicate method of providing temporary electrical service.
 3. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.
 4. Comply with NFPA 70E.

Dimensions of MCCs, especially those with VFCs and other devices, or various options, can vary considerably in size between manufacturers. Retain "Product Selection for Restricted Space" Paragraph below with "Basis-of-Design Product" Paragraph in "Manufactured Units" Article if installation space for MCCs is limited; show maximum dimensions on Drawings. See "Installation Considerations" and "Large Equipment" articles in the Evaluations for additional guidance.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for MCCs, including clearances between MCCs and adjacent surfaces and other items.
- D. Field Measurements: Verify existing dimensions by field measurements. Verify clearances and locate obstructions within manufacturing and installation tolerances of enclosed bus assemblies.

1.12 COORDINATION

Retain first paragraph below if required for MCCs.

- A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.

Revise both paragraphs below to refer to other Sections, such as conveying equipment systems, if control coordination is required.

- B. Coordinate features of MCCs, installed units, and accessory devices with remote pilot devices and control circuits to which they connect.
- C. Coordinate features, accessories, and functions of each MCC, each controller, and each installed unit with ratings and characteristics of supply circuits, motors, required control sequences, and duty cycle of motors and loads.

1.13 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace [TVSS] [VFCs] <Insert devices> that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods with manufacturers listed in Part 2 articles.

1. Warranty Period: Minimum [five (5)] <Insert number> years from date of

Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

B. CONSTRUCTION WASTE MANAGEMENT

1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

- A. Motor Control Centers shall be as designed or approved equal, and shall have been tested in a high power laboratory to prove adequate mechanical and electrical capabilities. All major components shall have been individually design tested and guaranteed by the manufacturer. Wiring shall be as per specified NEMA standards.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain "Manufacturers" Paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. ABB; Control Products.
 2. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 3. General Electric Company; GE Industrial Systems.
 4. Rockwell Automation, Inc.; Allen-Bradley Brand.
 5. Siemens Energy & Automation, Inc.; Power Distribution.
 6. Square D; a brand of Schneider Electric.
 7. <Insert manufacturer>
 8. or approved equal.

MCCs in this article include service and distribution types most commonly applied. Coordinate types of MCCs with types of controllers and OCPDs and with MCC arrangements and available spaces. Consult manufacturer to determine layout requirements. See Evaluations. Most MCCs are both front and rear aligned, with the possible exception of units with extremely large or unusual main and fixed branch cubicles. The Section Text defaults to front and rear alignment, with front-only access; coordinate with manufacturers for unusual conditions.

- C. General Requirements for MCCs: Comply with NEMA ICS 18 and [UL 845] <Insert standard>.
- D. The type of enclosure shall be in accordance with NEMA Standards for Type 1A with gasketed doors. All enclosing sheet steel, wireways and unit doors shall be gasketed.

- E. The Motor Control Center shall be 600-volt class suitable for operation on a three phase, 60 Hertz system. The system operating voltage shall be 480 volts, 3-phase, 4-wire unless otherwise indicated on the drawings.
- F. Provide a shunt trip device for the main circuit breaker in the motor control center. The shunt trip shall operate on 120v A.C. Power for the shunt trip shall be provided by the control power for the transformer and capacitor trip device specified under the incoming line metering section of the specification. Undervoltage and single-phase protection for the motor control center shall be provided when the microprocessor metering module output contact energizes the shunt trip of the main circuit breaker.

2.2 FUNCTIONAL FEATURES

In addition to equipment and devices included in the Section Text, UL 845 and various listed manufacturers also allow in MCCs such items as automatic transfer switches, distribution transformers, lighting and appliance and distribution panelboards, combination lighting contactors, etc. Although not included in the Section Text, these items can be added if required. Coordinate with retained unit types and Drawings.

- A. Description: Modular arrangement of main units, controller units, control devices, feeder-tap units, instruments, metering, auxiliary devices, and other items mounted in vertical sections of MCC.

Coordinate "Controller Units" Paragraph below with Drawings.

- B. Controller Units: Combination controller units.
 - 1. Install units up to and including Size 3 on drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.
 - 2. Equip units in Type B and Type C MCCs with pull-apart terminal strips for external control connections.

Coordinate "Feeder-Tap Units" Paragraph below with Drawings.

- C. Feeder-Tap Units: Through 225-A rating shall have drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.

Coordinate "Future Units" Paragraph below with Drawings. Indicate, in schedule, sizes of future controllers to be accommodated.

- D. Future Units: Compartments fully bused and equipped with guide rails or equivalent, ready for insertion of drawout units.

Coordinate "Spare Units" Paragraph below with Drawings.

- E. Spare Units: Installed in compartments indicated "spare."

2.3 INCOMING MAINS

Not all manufacturers offer all options in this article. Coordinate with manufacturers for available options. Coordinate selection of the disconnecting means and OCPD with short-circuit current ratings required for Project. See the "Main- and Feeder-Tap Disconnecting and Overcurrent Protective Devices" Article and Editing Instructions No. 5, No. 6, and No. 9 in the Evaluations for guidance on making selections.

Retain "Incoming Mains Location" Paragraph below, and coordinate with Drawings and schedules, if Project requirements include identifying specific entry locations for incoming service or feeder raceways.

A. Incoming Mains Location: **[Top]** **[and]** **[bottom]**.

Include instructions in "Main Lugs Only" Paragraph below if special sizing or oversizing of lugs is required, if allowing optional use of aluminum for circuits sized for copper conductors, or when upsizing conductors for voltage drop.

B. Main Lugs Only: Conductor connectors suitable for use with conductor material and sizes.

1. Material: Hard-drawn copper, 98 percent conductivity.
2. Main and Neutral Lugs: **[Compression]** **[Mechanical]** type.

C. MCCB: Comply with UL 489, with interrupting capacity to meet available fault currents.

1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
2. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
3. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:

Retain one or more of first four subparagraphs below; coordinate required adjustable settings with Section 260573 "Overcurrent Protective Device Coordination Study." See "Electronic rms Trip versus MCCBs and ICCBs" Paragraph in "Main- and Feeder-Tap Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for additional guidance on specifying full- or standard-function features.

- a. Instantaneous trip.
 - b. Long- and short-time pickup levels.
 - c. Long- and short-time time adjustments.
 - d. Ground-fault pickup level, time delay, and I^2t response.
4. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
 5. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.
 6. MCCB Features and Accessories:

Not all accessories and options listed in subparagraphs below are available for every rating and from every listed manufacturer. Verify, with manufacturers, availability and unique characteristics.

- a. Standard frame sizes, trip ratings, and number of poles.

See Editing Instruction No. 14 in the Evaluations for guidance on using mechanical versus compression lugs.

- b. Lugs: **[Mechanical]** **[Compression]** style, suitable for number, size, trip ratings, and conductor material.
- c. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.

Retain first option in "Ground-Fault Protection" Subparagraph below for solid-state trip units; retain second option for thermal-magnetic trip units. If retaining second option, also retain "Shunt Trip" Subparagraph below.

- d. Ground-Fault Protection: **[Integrally mounted]** **[Remote-mounted]** relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
- e. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
- f. Communication Capability: **[Circuit-breaker-mounted]** **[Universal-mounted]** **[Integral]** **[Din-rail-mounted]** communication module with functions and features compatible with power monitoring and control system specified in Section 260913 "Electrical Power Monitoring and Control."
- g. Shunt Trip: 120-V trip coil energized from separate circuit, set to trip at **[55]** **[75]** percent of rated voltage.
- h. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
- i. Auxiliary Contacts: **[One SPDT switch]** **[Two SPDT switches]** with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
- j. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

- D. Insulated-Case Circuit Breaker: **[80]** **[100]** percent rated, sealed, insulated-case power circuit breaker with interrupting capacity rating to meet available fault current.

1. **[Fixed]** **[Drawout]** circuit-breaker mounting.
2. Two-step, stored-energy closing.
3. **[Standard]** **[Full]**-function, microprocessor-based trip units with interchangeable rating plug, trip indicators, and the following field-adjustable settings:

Retain one or more of first four subparagraphs below; coordinate required adjustable settings with Section 260573 "Overcurrent Protective Device Coordination Study." See "Electronic rms Trip versus MCCBs and ICCBs" Paragraph in "Main- and Feeder-Tap Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for additional features available for standard- and full-function trip units.

- a. Instantaneous trip.
- b. Long- and short-time time adjustments.
- c. Ground-fault pickup level, time delay, and I²t response.
- d. **<Insert settings>**.

4. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
5. Remote trip indication and control.
6. Communication Capability: Integral communication module with functions and features compatible with power monitoring and control system specified in Section 260913 "Electrical Power Monitoring and Control."
7. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

Retain voltage in "Control Voltage" Subparagraph below to match control power supply.

8. Control Voltage: [40-V dc] [125-V dc] [250-V dc] [120-V ac].

2.4 COMBINATION CONTROLLERS

A. Full-Voltage Controllers:

Show controller pole quantities, NEMA size and type, and accessories for each controller on Drawings. See "Full-Voltage Controllers" Article in the Evaluations for selection considerations. See Editing Instructions No. 4 and No. 10 in the Evaluations.

Not all features, accessories, and options in this article are available for every rating, with every type enclosure, and from every listed manufacturer. Verify, with manufacturers, availability and unique characteristics. Show on Drawings those features and accessories that apply to each controller.

1. General Requirements for Full-Voltage Enclosed Controllers: Comply with NEMA ICS 2, general purpose, Class A.

Three-pole, integral horsepower magnetic controllers are suitable for use with three-phase ac motors up to 1600 hp, and from NEMA ICS 2, Size 00 to Size 9; however, not all listed manufacturers offer enclosed controllers up to Size 9. Two- and four-pole models are also available in varying minimum and maximum horsepower ratings and NEMA sizes. See "Magnetic Controllers" Article in the Evaluations for additional guidance on their use.

2. Magnetic Controllers: Full voltage, across the line, electrically held.
 - a. Configuration: [Nonreversing] [and] [reversing] <Insert configuration>.

B. Reduced-Voltage Magnetic Controllers:

Show controller pole quantities, NEMA size and type, and accessories for each controller on Drawings. See "Reduced-Voltage Magnetic Controllers" Article in the Evaluations for selection considerations. See Editing Instructions No. 4 and No. 10 in the Evaluations. Reduced-voltage magnetic controllers are available in either open- or closed-transition modes; however, the Section Text includes only closed-transition mode. Open-transition mode may be added to suit Project.

1. General Requirements for Reduced-Voltage Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A; closed transition; adjustable time delay on transition.
2. Reduced-Voltage Magnetic Controllers: Reduced voltage, electrically held.
 - a. Configuration:

- b. Wye-Delta Controller: Four contactors, with a three-phase starting resistor/reactor bank.
- c. Part-Winding Controller: Separate START and RUN contactors, field-selectable for one-half or two-thirds winding start mode, with either six- or nine-lead motors; with separate overload relays for starting and running sequences.
- d. Autotransformer Reduced-Voltage Controller: Medium-duty service, with integral overtemperature protection; taps for starting at 50, 65, and 80 percent of line voltage; two START and one RUN contactors.

C. Reduced-Voltage, Solid-State Controllers:

Show controller pole quantities, NEMA size and type, and accessories for each controller on Drawings. See "Reduced-Voltage Controllers," "Reduced-Voltage, Solid-State Controllers," and "Solid-State Controllers" articles in the Evaluations for selection considerations. See Editing Instructions No. 4 and No. 11 in the Evaluations.

Standard and optional features vary considerably among manufacturers of solid-state controllers. Also, features and options depend on motor characteristics and operating criteria of driven equipment.

1. General Requirements for Reduced-Voltage, Solid-State Controllers: Comply with UL 508.

Three-pole, reduced-voltage, solid-state controllers are available for use with three-phase ac motors 3 to 600 hp, and in voltages from 208- to 575-V ac; however, not all listed manufacturers may offer enclosed controllers in all these ratings and voltage ranges.

2. Reduced-Voltage, Solid-State Controllers: An integrated unit with power SCRs, heat sink, microprocessor logic board, door-mounted digital display and keypad, bypass contactor, and overload relay; suitable for use with NEMA MG 1, Design B, polyphase, medium-induction motors.
 - a. Configuration: [**Standard duty**] [**Severe duty**]; [**nonreversible**] [**reversible**].
 - b. Starting Mode: [**Voltage ramping**] [**Current limit**] [**Torque control**] [**Torque control with voltage boost**]; [**field selectable**].
 - c. Stopping Mode: [**Coast to stop**] [**Adjustable torque deceleration**] [**Adjustable braking**]; [**field selectable**].

Most manufacturers provide shorting contactors to bypass the SCRs at full speed, instead of the controller operating continually through the SCRs. Bypass contactors are usually of less than full-voltage rating, and many are IEC-rated controllers. They are not sized or intended for starting the motor across the line. Some manufacturers, however, offer the alternative of full-voltage bypass contactors for severe-duty applications, to completely bypass the SCRs on failure (allowing use of the controller as a full-voltage controller).

- d. Shorting (Bypass) Contactor: Operates automatically when full voltage is applied to motor, and bypasses the SCRs. Solid-state controller protective features shall remain active when the shorting contactor is in the bypass mode.
- e. Shorting[**and Input Isolation**] Contactor Coils: Pressure-encapsulated type; manufacturer's standard operating voltage, matching control power or line voltage, depending on contactor size and line-voltage rating.[**Provide coil transient suppressors.**]

- f. Logic Board: Identical for all ampere ratings and voltage classes, with environmental protective coating.
- g. Adjustable acceleration-rate control using voltage or current ramp, and adjustable starting torque control with up to **[400]** **<Insert number>** percent current limitation for 20 seconds.
- h. SCR bridge shall consist of at least two SCRs per phase, providing stable and smooth acceleration **[with]** **[without]** external feedback from the motor or driven equipment.
- i. Keypad, front accessible; for programming the controller parameters, functions, and features; shall be manufacturer's standard and include not less than the following functions:
 - 1) Adjusting motor full-load amperes, as a percentage of the controller's rating.
 - 2) Adjusting current limitation on starting, as a percentage of the motor full-load current rating.
 - 3) Adjusting linear acceleration and deceleration ramps, in seconds.
 - 4) Initial torque, as a percentage of the nominal motor torque.
 - 5) Adjusting torque limit, as a percentage of the nominal motor torque.
 - 6) Adjusting maximum start time, in seconds.
 - 7) Adjusting voltage boost, as a percentage of the nominal supply voltage.
 - 8) Selecting stopping mode, and adjusting parameters.
 - 9) Selecting motor thermal-overload protection class between 5 and 30.
 - 10) Activating and de-activating protection modes.
 - 11) Selecting or activating communications modes.
 - 12) **<Insert function>**.
- j. Digital display, front accessible; for showing motor, controller, and fault status; shall be manufacturer's standard and include not less than the following:
 - 1) Controller Condition: Ready, starting, running, stopping.
 - 2) Motor Condition: Amperes, voltage, power factor, power, and thermal state.
 - 3) Fault Conditions: Controller thermal fault, motor overload alarm and trip, motor underload, overcurrent, shorted SCRs, line or phase loss, phase reversal, and line frequency over or under normal.
 - 4) **<Insert items>**.
- k. Controller Diagnostics and Protection:
 - 1) Microprocessor-based thermal protection system for monitoring SCR and motor thermal characteristics, and providing controller overtemperature and motor overload alarm and trip; settings selectable via the keypad.
 - 2) Protection from line-side reverse phasing; line-side and motor-side phase loss; motor jam, stall, and underload conditions; and line frequency over or under normal.

Retain one of first two subparagraphs below to provide motor protection on a controller fault.

- 3) Input isolation contactor that opens when the controller diagnostics detect a faulted solid-state component, or when the motor is stopped.

Retain first subparagraph below only if specifying combination controllers.

- 4) Shunt trip that opens the disconnecting means when the controller diagnostics detect a faulted solid-state component.
- 5) **<Insert items>**.

I. Remote Output Features:

- 1) All outputs prewired to terminal blocks.
- 2) Form C status contacts that change state when controller is running.
- 3) Form C alarm contacts that change state when a fault condition occurs.
- 4) **<Insert items>**.

m. Optional Features:

- 1) Analog output for field-selectable assignment of motor operating characteristics; **[0 to 10-V dc] [4 to 20-mA dc]**.
- 2) Additional field-assignable Form C contacts for alarm outputs.
- 3) Surge suppressors in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
- 4) Full-voltage bypass contactor operating **[automatically] [manually, with NORMAL/BYPASS selector switch]**. Power contacts shall be totally enclosed, double break, and silver-cadmium oxide; and assembled to allow inspection and replacement without disturbing line or load wiring.

D. Multispeed Magnetic Controllers:

Show controller pole quantities, NEMA size and type, and accessories for each controller on Drawings. See "Multispeed Controllers" Article in the Evaluations for selection considerations. See Editing Instructions No. 4 and No. 11 in the Evaluations. The Section Text includes two-speed controllers only; however, most manufacturers catalog controllers offering more than two speeds. Multispeed controllers supporting more than two speeds may be added to suit Project.

1. General Requirements for Multispeed Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A.
2. Multispeed Magnetic Controllers: Two speed, full voltage, across the line, electrically held. Compelling relay to ensure that motor will start only at low speed.
 - a. Configuration: **[Nonreversing] [Reversing]; [consequent pole] [two winding]**.

Retain one or both of first two subparagraphs below. If retaining both, indicate on Drawings where each type is required. Compelling and accelerating relays cannot be specified together for the same controller.

Compelling, accelerating, and decelerating relays can be used for all multispeed controllers; antiplugging relays are used only for reversing multispeed controllers.

- b. Compelling relays shall ensure that motor starts only at low speed.
- c. Accelerating timer relays shall ensure properly timed acceleration through speeds lower than that selected.
- d. Decelerating timer relays shall ensure automatically timed deceleration through each speed.
- e. Antiplugging timer relays shall ensure a time delay when transferring from FORWARD to REVERSE and back.

E. Disconnecting Means and OCPDs:

Disconnecting means and OCPDs must be closely coordinated with calculated short-circuit current values at the controller locations because they are directly related to short-circuit withstand ratings of their combination controllers. Although fusible switches (with appropriate fuses) can provide Type 2 controller protection from very high short-circuit currents, not all circuit breakers or MCPs can. See Editing Instructions No. 9 and No. 10 in the Evaluations for explanation of protection types and when they should be considered. The Section Text does not include nonfusible disconnecting means because they are usually not an option with MCCs.

1. Fusible Disconnecting Means:

- a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate [Class J] [Class L] <Insert class> fuses.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain "Auxiliary Contacts" Subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.

MCP disconnecting means must be used in combination with integral overload relays.

2. MCP Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and NO or NC contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
- d. [NC] [NO] alarm contact that operates only when MCP has tripped.

First subparagraph below is an optional, added-cost feature.

- e. Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

3. MCCB Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
- b. Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- c. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and NO or NC contact requirements on Drawings.

- d. Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
- e. **[NC] [NO]** alarm contact that operates only when MCCB has tripped.

4. Molded-Case Switch Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with in-line fuse block for Class J or L power fuses (depending on ampere rating), providing an interrupting capacity to comply with available fault currents; MCCB with fixed, high-set instantaneous trip only.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and NO or NC contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with molded-case switch handle.
- d. **[NC] [NO]** alarm contact that operates only when molded-case switch has tripped.

F. Overload Relays:

Manufacturers typically integrate overload functions into solid-state controllers and use separate thermal or solid-state overload relays only if full-voltage bypass controllers are specified. Retain one or more of first three subparagraphs below if specifying full-voltage bypass contactors. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 7 and "Overload Protection" Article in the Evaluations for additional guidance.

1. Melting-Alloy Overload Relays:

- a. Inverse-time-current characteristic.
- b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
- c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

2. Bimetallic Overload Relays:

- a. Inverse-time-current characteristic.
- b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
- c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below only if applicable. See Editing Instruction No. 8 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- d. Ambient compensated.
 - e. Automatic resetting.
3. Solid-State Overload Relays:
- a. Switch or dial selectable for motor running overload protection.
 - b. Sensors in each phase.
 - c. **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added-cost features.

- d. Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
- e. Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

4. **[NC] [NO]** isolated overload alarm contact.
5. External overload reset push button.

G. Control Power:

1. Control Circuits: **[24] [120] <Insert value>-V ac**; obtained from **[integral CPT, with primary and secondary fuses] <Insert source of control power>**, with **[CPT] [control power source]** of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

Retain "CPT Spare Capacity" Subparagraph below if retaining "CPT" option in "Control Circuits" Subparagraph above and spare CPT capacity is required. Spare capacity is usually available in 100-VA increments. Consult manufacturers for maximum spare capacity and available CPT sizes for different NEMA and enclosure sizes because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

- a. CPT Spare Capacity: **[50] [100] [200] <Insert value> VA**.

2.5 VFCS

Show VFC pole quantities, size and type, and accessories for each controller on Drawings. See "Specifying VFCs" Article and Editing Instruction No. 13 in the Evaluations for selection considerations.

Standard and optional features vary considerably among VFC manufacturers. Not all features, accessories, and options in this article are available for every rating, with every type enclosure, and from every listed manufacturer. Also, features and options depend on motor characteristics and operating criteria of driven equipment. Verify, with manufacturer, availability and unique characteristics. Show on Drawings those features and accessories that apply to each VFC.

- A. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and **[UL 508C]** <Insert standard>.

Retain first option in "Application" Paragraph below for constant-torque loads such as positive-displacement pumps and reciprocating and screw compressors; retain second option for variable-torque loads such as centrifugal blowers, compressors, fans, and pumps. The Section Text does not include VFCs for constant-horsepower loads because they are seldom used in commercial (e.g., plumbing and HVAC) applications; however, they can be added to suit Project.

- B. Application: **[Constant torque]** [and] **[variable torque]** <Insert application>.

Low-voltage VFCs are available for use with three-phase ac motors from 1/2 to 500 hp (depending on voltage rating), and in single- or three-phase input voltages from 200- to 575-V ac; however, not all listed manufacturers may offer VFCs in all these ratings and voltage ranges. Using single-phase voltages for VFCs controlling three-phase motors may require substantial derating of the VFCs; consult manufacturers for limitations and derating requirements. See "Controllers" and "VFCS" articles in the Evaluations for additional information on how VFCs are used as controllers.

- C. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

Retain one or both of first two subparagraphs below as required to support motors and driven equipment specified in other Divisions. See the "Multispeed and Variable-Speed Considerations" Article in the Evaluations in Section 230513 "Common Motor Requirements for HVAC Equipment," for guidance on motor requirements and applications using VFCs..

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

Retain subparagraph below if specifying units for use on single-phase systems for three-phase motors.

4. Listed and labeled for single-phase use by an NRTL acceptable to authorities having jurisdiction.

- D. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

Retain first option in "Output Rating" Paragraph below for variable-torque drives; retain second option for constant-torque drives.

- E. Output Rating: Three-phase; 10 to [60 Hz, with voltage proportional to frequency throughout voltage range] [66 Hz, with torque constant as speed changes]; maximum voltage equals input voltage.
- F. Unit Operating Requirements:

Increases in technology are allowing manufacture of VFCs with greater tolerance to system anomalies and better operating performance; most listed manufacturers are offering VFCs that tolerate the greater optional variances, or offer the higher levels of performance included in subparagraphs below. Consult manufacturers if Project system conditions fall outside the selected parameters in first three subparagraphs below, because corrective actions or additional modifications may be required before VFCs can be applied. In "Input AC Voltage Tolerance" Subparagraph below, voltage tolerance is more a factor of voltage limitations for industrial control devices (e.g., magnetic contactors) in an enclosed VFC and not the VFC's power converter, which can usually tolerate greater voltage variations.

- 1. Input AC Voltage Tolerance: Plus 10 and minus [10] [15] percent of VFC input voltage rating.
- 2. Input AC Voltage Unbalance: Not exceeding [3] [5] percent.
- 3. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.
- 4. Minimum Efficiency: [96] [97] <Insert number> percent at 60 Hz, full load.
- 5. Minimum Displacement Primary-Side Power Factor: [96] [98] <Insert number> percent under any load or speed condition.

Retain first option in "Overload Capability" Subparagraph below for variable-torque VFCs; retain second option for constant-torque VFCs.

- 6. Overload Capability: [1.1] [1.5] times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
- 7. Starting Torque: Minimum of 100 percent of rated torque from 3 to 60 Hz.
- 8. Speed Regulation: Plus or minus [5] [10] percent.

Carrier frequencies much above 2.5 kHz are seldom desired for motors more than 200 hp due to the increased possibility of overheating the motor windings. For large horsepower motors being used with VFCs, consult motor manufacturers for recommended limitations on carrier frequencies to mitigate motor winding overtemperatures.

- 9. Output Carrier Frequency: Selectable; 0.5 to [15] <Insert value> kHz.
- 10. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

- G. Inverter Logic: Microprocessor based, [16] [32] bit, isolated from all power circuits.
- H. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.

Retain one of two "Signal" subparagraphs below with "Isolated Control Interface" Paragraph above. Coordinate retained subparagraph with selections made in "Control Signal Interfaces" Paragraph in "VFC Controls and Indication" Article.

- 1. Signal: Electrical.
- 2. Signal: Pneumatic.

I. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: **[0.1 to 999.9]** <Insert range> seconds.
4. Deceleration: **[0.1 to 999.9]** <Insert range> seconds.
5. Current Limit: 30 to a minimum of 150 percent of maximum rating.
6. **<Insert adjustment and parameters>**.

J. Self-Protection and Reliability Features:

Coordinate Project-specific, self-protection and reliability features with manufacturers, because standard and optional features vary considerably among manufacturers.

1. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
2. Loss of Input Signal Protection: Selectable response strategy including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
3. Under- and overvoltage trips.
4. Inverter overcurrent trips.
5. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
6. Critical frequency rejection, with **[three (3)]** <Insert number> selectable, adjustable deadbands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
8. Loss-of-phase protection.
9. Reverse-phase protection.
10. Short-circuit protection.
11. Motor overtemperature fault.
12. **<Insert additional protection or reliability feature>**.

"Automatic Reset/Restart" and "Power-Interruption Protection" paragraphs below are mutually exclusive in the same VFC. Retain both if required for separate VFCs; indicate on Drawings where each type is required.

K. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.

L. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.

Retain "Bidirectional Autospeed Search" Paragraph below if retaining "Automatic Reset/Restart" Paragraph above, if retaining automatic and manual "Bypass Mode" Paragraph in "VFC Bypass Systems" Article, or both.

- M. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
- N. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
- O. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

Not all manufacturers offer all options in "Integral Input Disconnecting Means and OCPD" Paragraph below. Coordinate with manufacturers for available options. Coordinate selection of the disconnecting means and OCPD with short-circuit current (withstand) ratings required for Project. See "Application of Switches and Circuit Breakers" Article and Editing Instructions No. 4, No. 5, and No. 8 in the Evaluations for selection considerations.

- P. Integral Input Disconnecting Means and OCPD: **[NEMA AB 1, instantaneous-trip circuit breaker] [NEMA AB 1, molded-case switch, with power fuse block and current-limiting fuses] [NEMA AB 1, thermal-magnetic circuit breaker] [NEMA KS 1, nonfusible switch, with power fuse block and current-limiting fuses] [NEMA KS 1, fusible switch]** with pad-lockable, door-mounted handle mechanism.

Retain first "Disconnect Rating" Subparagraph below for VFCs without bypass systems; retain second for VFCs with bypass systems.

- 1. Disconnect Rating: Not less than 115 percent of VFC input current rating.
- 2. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.

Retain "Auxiliary Contacts" Subparagraph below if retaining fusible or nonfusible switches in "Integral Input Disconnecting Means and OCPD" Paragraph above and external control power is used; or, use for remote indication of disconnecting means position.

- 3. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.

Retain one or both of two subparagraphs below if retaining any circuit-breaker-type disconnecting means in "Integral Input Disconnecting Means and OCPD" Paragraph. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and NO or NC contact requirements on Drawings.

- 4. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
- 5. **[NC] [NO]** alarm contact that operates only when circuit breaker has tripped.

2.6 VFC CONTROLS AND INDICATION

Coordinate local control and indication requirements with Owner or end users. Most of the indications included in "Status Lights" Paragraph below can be and are accomplished by listed manufacturers through digital displays in their panel-mounted operator stations. However, many operators still prefer the ability to "pass and glance" to determine the status of operating machinery or equipment.

A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.
7. **<Insert condition>**.

B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.
 - a. Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.

C. Historical Logging Information and Displays:

Retain first subparagraph below if time and date stamping is not accomplished through the BAS. This is an added cost option with some listed manufacturers.

1. Running log of total power versus time.
2. Total run time.
3. Fault log, maintaining last [**four (4)**] **<Insert number>** faults with time and date stamp for each.
4. **<Insert information or display>**.

D. Indicating Devices: Digital display[**and additional readout devices as required,**] mounted flush in VFC door and connected to display VFC parameters, including, but not limited to:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).
11. **<Insert parameter>**.

Coordinate three interface paragraphs below with Section 230900 "Instrumentation and Control for HVAC." Retain paragraphs to suit Project. If retaining more than one paragraph, indicate here or on Drawings where each interface type is required.

E. Control Signal Interfaces:

1. Electric Input Signal Interface:

In first subparagraph below, some manufacturers offer an operator-selectable "x"- to "y"-mA dc signal input.

- a. A minimum of **[two]** <Insert number> programmable analog inputs: **[0- to 10-V dc] [4- to 20-mA dc] [Operator-selectable "x"- to "y"-mA dc]** <Insert signal parameters>.
- b. A minimum of **[six]** <Insert number> multifunction programmable digital inputs.

Retain "Pneumatic Input Signal Interface" Subparagraph below only if Project includes pneumatic controls. Several listed manufacturers now treat this feature as an added-cost option because it is so infrequently used anymore.

2. Pneumatic Input Signal Interface: **3 to 15 psig** (20 to 104 kPa).
3. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:
 - a. 0- to 10-V dc.
 - b. 4- to 20-mA dc.
 - c. Potentiometer using up/down digital inputs.
 - d. Fixed frequencies using digital inputs.
 - e. <Insert signal input>.
4. Output Signal Interface: A minimum of **[one (1)]** <Insert number> programmable analog output signal(s) (**[0- to 10-V dc] [4- to 20-mA dc] [operator-selectable "x"- to "y"-mA dc]** <Insert signal parameters>), which can be configured for any of the following:
 - a. Output frequency (Hz).
 - b. Output current (load).
 - c. DC-link voltage (V dc).
 - d. Motor torque (percent).
 - e. Motor speed (rpm).
 - f. Set point frequency (Hz).
 - g. <Insert indication>.
5. Remote Indication Interface: A minimum of **[two (2)]** <Insert number> programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
 - a. Motor running.
 - b. Set point speed reached.
 - c. Fault and warning indication (overtemperature or overcurrent).

- d. PID high- or low-speed limits reached.
- e. <Insert indication>.

Retain "PID Control Interface" Paragraph below if VFC controls interface directly with local controls and not through a BAS.

- F. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.

- 1. Number of Loops: [**One (1)**] [**Two (2)**] <Insert number>.

Retain "BAS Interface" Paragraph below if VFC controls interface with the BAS. Retain option if BAS is used to monitor and record energy usage for verification of LEED-NC Credit EA 5.

- G. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms[**and energy usage**]. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.

- 1. Network Communications Ports: Ethernet and [**RS-422/485**] <Insert port type>.
 - 2. Embedded BAS Protocols for Network Communications: [**ASHRAE 135 BACnet**] [**Echelon LonWorks**] [**Ethernet TCP/IP**] [**Johnson Metasys N2**] [**Modbus/Memobus**] [**Siemens System 600 APOGEE**] <Insert protocol type>; protocols accessible via the communications ports.

2.7 VFC LINE CONDITIONING AND FILTERING

If input voltage or current distortion due to harmonic generation in VFCs is a concern, consult manufacturers for options available to mitigate harmonic distortion. Options may include dc bus link reactors, isolation transformers, active and passive harmonic filters, and 12- or 18-pulse phase-shifting input transformers. Retain first or second "Input Line Conditioning" Paragraph below if retaining "Harmonic Analysis Study and Report" Paragraph in "Action Submittals" Article, if a specific method of mitigation is not important, and if manufacturer is delegated responsibility to incorporate whatever mitigating means are necessary to comply with specified limitations. Otherwise, retain third "Input Line Conditioning" Paragraph below and insert specific requirements. See "Harmonic Distortion" Article in the Evaluations for additional guidance.

- A. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD at input terminals of VFCs to less than [**5**] [**8**] <Insert number> percent and THD(V) to [**3**] [**5**] <Insert number> percent.
- B. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD and THD(V) at the defined PCC per [**IEEE 519**] <Insert standard>.
- C. Input Line Conditioning: <Insert requirements>.

Normally, if the separation between motor and VFC is less than 100 feet (30 m), the motor is designed for use with VFC (see "Motor Application Considerations" Article in the Evaluations), low carrier frequencies are specified, or all three, then output filtering may not be an issue. However, if distances are over 100

feet (30 m) and high carrier frequencies are being used, controller output voltage can exceed motor pulse-withstand capability. Consult motor and VFC manufacturers to determine need for, and options available for, conditioning output voltage. Options may include line inductors, dV/dT filters, output reactors, and motor termination filters. See "Motor and VFC Compatibility" Article in the Evaluations for additional guidance.

D. VFC Output Filtering: <Insert requirements>.

If EMI/RFI generation in VFCs is a concern, consult manufacturers for options available to mitigate it. Specifying compliance with applicable standards and following proper installation methods will usually address EMI/RFI issues. Retain first "EMI/RFI Filtering" Paragraph below if a specific method of mitigation is not important and manufacturer is delegated responsibility to incorporate whatever mitigating means are necessary to comply with specified limitations. Otherwise, retain second "EMI/RFI Filtering" Paragraph. See "Electromagnetic Compatibility" Article in the Evaluations for additional guidance.

E. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for [Category C2] <Insert category>.

F. EMI/RFI Filtering: <Insert requirements>.

2.8 VFC BYPASS SYSTEMS

Retain this article only if VFCs will require bypass systems. Applying bypass systems to VFCs requires additional consideration of system parameters and code requirements. Additionally, listed manufacturers offer different forms of bypass strategies and different operating characteristics. See "Bypass Systems" Article in the Evaluations for guidance; and coordinate with manufacturers for available selections.

A. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes, and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

Retain one of two "Bypass Mode" paragraphs below, or both if required for separate VFCs, and indicate on Drawings where each type is required. First paragraph is for bypass control where the motor must be at zero speed before the bypass function is performed; second paragraph allows for bypass control whether the motor is at rest or is running. If retaining second paragraph, also retain "Bidirectional Autospeed Search" Paragraph in "VFCS" Article.

B. Bypass Mode: Manual operation only; requires local operator selection at VFC. Transfer between power converter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.

C. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.

Retain one of two "Bypass Controller" paragraphs below. First paragraph is frequently called a "two-contactor-style" bypass - it typically does not allow power converter maintenance while the VFC is operating in bypass, because the power converter input remains energized, unless used with an input isolating switch. Second paragraph is for a "three-contactor-style" bypass - it allows power converter maintenance while the motor continues to operate at full speed in bypass, because the power converter is

de-energized as well as being isolated from input and output power circuits. Either option can be operated in manual or manual/automatic mode.

- D. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller[; **with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode**].

In "Bypass Contactor" Subparagraph below, IEC-rated contactors are most often used for the bypass contactor in HVAC applications and for smaller motors, and they are usually smaller and less costly than equivalent NEMA-rated contactors. NEMA-rated contactors are most often used in industrial applications and for larger motors, where they must carry high motor inrush and full-load running currents. IEC-rated contactors are most often used in all applications for the isolating contactors, because they are only used to isolate the power converter and normally do not carry any current. Consult manufacturers for the types used for each.

1. Bypass Contactor: Load-break, [IEC] [NEMA]-rated contactor.
2. Output Isolating Contactor: Non-load-break, [IEC] [NEMA]-rated contactor.

Retain "Isolating Switch" Subparagraph below if retaining option in "Bypass Controller" Paragraph above.

3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

There is some concern among various listed manufacturers that the input isolating contactor of the three-contactor bypass, without an isolating switch and a barrier between the power converter and the bypass, may not comply with NFPA 70 requirements for safe isolation of the power converter during energized maintenance, because the contactor is not a positive, lockable disconnecting means, and lack of a barrier can lead to accidental contact with live parts in the bypass. Consult authorities having jurisdiction if this is a concern.

- E. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller[; **with input isolating switch and barrier**] arranged to isolate the power converter input and output and permit safe testing[**and troubleshooting**] of the power converter, both energized and de-energized, while motor is operating in bypass mode.

1. Bypass Contactor: Load-break, [IEC] [NEMA]-rated contactor.
2. Input and Output Isolating Contactors: Non-load-break, [IEC] [NEMA]-rated contactors.

Retain "Isolating Switch" Subparagraph below if retaining first option in last "Bypass Controller" Paragraph above.

3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

First option in "Bypass Contactor Configuration" Paragraph below is for full-voltage starting; second option is for reduced-voltage starting. For large horsepower motors, consider using a reduced-voltage bypass controller instead of a full-voltage controller. See "Full-Voltage Controllers" and "Reduced-Voltage

Controllers" articles in the Evaluations for additional guidance. Some listed manufacturers also offer reduced-voltage, solid-state controllers as a bypass option - consult manufacturers if this is a preference.

F. Bypass Contactor Configuration: **[Full-voltage (across-the-line)] [Reduced-voltage (autotransformer)] <Insert type>** type.

1. NORMAL/BYPASS selector switch.

Retain first subparagraph below only if retaining combined automatic and manual bypass mode in last "Bypass Mode" Paragraph above.

2. HAND/OFF/AUTO selector switch.
3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.
4. Contactor Coils: Pressure-encapsulated type **[with coil transient suppressors]**.
 - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
 - b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: **[120] <Insert value>-V ac**; obtained from **[integral CPT, with primary and secondary fuses] <Insert source of control power>**, with **[CPT] [control power source]** of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.

Retain "CPT Spare Capacity" Subparagraph below if retaining "CPT" option in "Control Circuits" Subparagraph above and spare CPT capacity is required. Spare capacity is normally available in 100-VA increments. Consult manufacturers for maximum spare capacity and available CPT sizes for different NEMA and enclosure sizes because adding spare capacity and an oversized CPT may require using an enlarged cubicle.

6. CPT Spare Capacity: **[50] [100] [200] <Insert value> VA**.

G. Overload Relays: NEMA ICS 2.

Manufacturers typically integrate overload functions into the microprocessors of VFCs and use separate thermal or solid-state overload relays only if specifying a bypass system. Retain one or more of three subparagraphs below if specifying a bypass system. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 6 and "Overload Protection" Article in the Evaluations for additional guidance.

1. Melting-Alloy Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
 - c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
2. Bimetallic Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.

- c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below if applicable. See Editing Instruction No. 7 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- d. Ambient compensated.
- e. Automatic resetting.

3. Solid-State Overload Relays:

- a. Switch or dial selectable for motor-running overload protection.
- b. Sensors in each phase.
- c. **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added-cost features.

- d. Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
- e. Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

- f. **[NC] [NO]** isolated overload alarm contact.
- g. External overload reset push button.

2.9 OPTIONAL VFC FEATURES

Optional feature types and quantities vary considerably among VFC manufacturers. Consult manufacturers for availability and limitations. Features vary according to VFC and motor characteristics and driven-equipment operating criteria. Retain applicable features in this article; insert others to suit Project. Indicate requirements for and quantities of optional features on Drawings if not included here. These features are normally added-cost items. See "Optional VFC Features" Article in the Evaluations for additional guidance.

Retain "Multiple-Motor Capability" Paragraph below if Project requires multiple motors controlled from a single VFC and controller redundancy is unnecessary.

- A. **Multiple-Motor Capability:** VFC suitable for variable-speed service to multiple motors. Overload protection shuts down VFC and motors served by it, and generates fault indications, when overload protection activates.

Retain one or more of three subparagraphs below if required for separate VFCs; indicate on Drawings where each type is required. Other multimotor options are available from some listed manufacturers; consult manufacturers if other combinations are required.

- 1. Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.

2. Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.

Retaining subparagraph below requires retaining and properly revising "VFC Bypass Systems" Article to support this configuration. Consult manufacturers for more information.

3. Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.
- B. Damper control circuit with end of travel feedback capability.
- C. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
- D. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
- E. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from **[the firefighter's control station] [smoke-control fan controller] <Insert location>**, this password-protected input:
1. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).

Retain one of first two subparagraphs below. First subparagraph is for VFCs without a bypass system; second subparagraph is for VFCs with a bypass system, and the bypass will be used for this function. In first subparagraph, coordinate preset speed with pressure rating of the ventilation system. Consider requiring final speed setting to be determined during commissioning, testing, and balancing of the ventilation system. Ensure that ducted systems are designed to tolerate the higher pressures generated by the full or preset speed settings.

2. Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
3. Forces VFC to transfer to Bypass Mode and operate motor at full speed.
4. Causes display of Override Mode on the VFC display.
5. Reset VFC to normal operation on removal of override signal **[automatically] [manually]**.

If retaining "Remote Indicating Circuit Terminals" Paragraph below, consider adding Specifications for remote indicating devices.

- F. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
- G. Remote digital operator kit.
- H. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer **[and a notebook computer]**.
- I. **<Insert optional feature>**.

2.10 FEEDER-TAP UNITS

Not all manufacturers offer all options in this article. Coordinate with manufacturers for available selections. Coordinate selection of the disconnecting means and OCPD with short-circuit current ratings required for Project. See "Main- and Feeder-Tap Disconnecting and Overcurrent Protective Devices" Article and Editing Instructions No. 5, No. 6, and No. 9 in the Evaluations for guidance on making selections.

- A. MCCB: Comply with UL 489, with [**series-connected rating**] [**interrupting capacity**] to meet available fault currents.
1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
 2. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
 3. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:

Retain one or more of first four subparagraphs below; coordinate required adjustable settings with Section 260573 "Overcurrent Protective Device Coordination Study." See "Electronic rms Trip versus MCCBs and ICCBs" Paragraph in "Main- and Feeder-Tap Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for additional guidance on specifying full- or standard-function features.

- a. Instantaneous trip.
 - b. Long- and short-time pickup levels.
 - c. Long- and short-time time adjustments.
 - d. Ground-fault pickup level, time delay, and I^2t response.
4. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
 5. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.
 6. MCCB Features and Accessories:

Not all accessories and options listed in subparagraphs below are available for every rating and from every listed manufacturer. Verify, with manufacturers, availability and unique characteristics.

- a. Standard frame sizes, trip ratings, and number of poles.

See Editing Instruction No. 14 in the Evaluations for guidance on using mechanical vs. compression lugs.

- b. Lugs: [**Mechanical**] [**Compression**] style, suitable for number, size, trip ratings, and conductor material.
- c. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.

Retain first option in "Ground-Fault Protection" Subparagraph below for solid-state trip units; retain second option for thermal-magnetic trip units. If retaining second option, also retain "Shunt Trip" Subparagraph below.

- d. Ground-Fault Protection: **[Integrally mounted] [Remote-mounted]** relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
 - e. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
 - f. Communication Capability: **[Circuit-breaker-mounted] [Universal-mounted] [Integral] [Din-rail-mounted]** communication module with functions and features compatible with power monitoring and control system specified in Section 260913 "Electrical Power Monitoring and Control."
 - g. Shunt Trip: 120-V trip coil energized from separate circuit, set to trip at **[55] [75]** percent of rated voltage.
 - h. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
 - i. Auxiliary Contacts: **[One SPDT switch] [Two SPDT switches]** with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
 - j. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
- B. Fusible Switch: NEMA KS 1, Type HD, clips to accommodate specified fuses with lockable handle.
- C. Fuses are specified in Section 262813 "Fuses."

2.11 TRANSIENT VOLTAGE SUPPRESSION DEVICES

The Section Text addresses only internally mounted TVSS devices, without a separate list of manufacturers, because most listed MCC manufacturers will limit internally mounted TVSS selections to manufacturers with which their MCCs have been tested and listed by NRTLs. For externally mounted TVSS devices, see Section 264313 "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits."

Retaining options in "Surge Protection Device Description" Paragraph below is a matter of ease of maintenance and replacement; coordinate final choices with Owner's maintenance personnel. Wired-in type offers more safety with a slight reduction in protection; modular types offer the quickest maintenance, but may come at a slightly higher cost. See the Evaluations in Section 264313 "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits" for guidance on revising this article.

- A. Surge Protection Device Description: IEEE C62.41-compliant, integrally mounted, **[wired-in] [plug-in] [bolt-on]**, solid-state, parallel-connected, **[modular (with field-replaceable modules)] [non-modular]** type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the MCC short-circuit rating, and with the following features and accessories:

Retain accessories in 10 subparagraphs below to coordinate with options retained in "Surge Protection Device Description" Paragraph above; verify availability and compatibility with manufacturer.

If specifying fuses for connecting TVSS devices to distribution system, verify ability of fuses to withstand surges consistent with ultimate surge current rating of device.

1. Fuses, rated at 200-kA interrupting capacity.
2. Fabrication using bolted compression lugs for internal wiring.

Retain first subparagraph below only if a fused switch or circuit breaker is not provided for the TVSS in the MCC and the TVSS will not have a direct bus connection.

3. Integral disconnect switch.
4. Redundant suppression circuits.
5. Redundant replaceable modules.
6. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
7. LED indicator lights for power and protection status.
8. Audible alarm, with silencing switch, to indicate when protection has failed.
9. Form-C contacts rated at 5 A and 250-V ac, one NO and one NC, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
10. **[Four] [Six]**-digit, transient-event counter set to totalize transient surges.

Retain first option in "Peak Single-Impulse Surge Current Rating" Paragraph below for high exposure and cost, second option for medium exposure and cost, and third option for low exposure and cost.

- B. Peak Single-Impulse Surge Current Rating: **[160 kA per mode/320 kA per phase] [120 kA per mode/240 kA per phase] [80 kA per mode/160 kA per phase]**.

Retain "Withstand Capabilities" Paragraph below for MCCs located at or near Category C locations.

- C. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.

Retain one of three paragraphs below. Adjust clamping voltages to comply with Project conditions and verify compatibility of peak surge current rating and clamping voltage. Reference to UL 1449 is to its second edition.

- D. Protection modes and UL 1449 SVR for grounded wye circuits with **[480Y/277] [208Y/120] [600Y/347]**-V, three-phase, four-wire circuits shall be as follows:
1. Line to Neutral: **[800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347]**.
 2. Line to Ground: **[800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347]**.
 3. Neutral to Ground: **[800 V for 480Y/277] [400 V for 208Y/120] [1200 V for 600Y/347]**.
- E. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:
1. Line to Neutral: 400 V, 800 V from high leg.
 2. Line to Ground: 400 V.
 3. Neutral to Ground: 400 V.

- F. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:
1. Line to Line: **[2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V]**.
 2. Line to Ground: **[1500 V for 480 V] [800 V for 240 V] [2500 V for 600 V]**.

2.12 INSTRUMENTATION

Retain this article for Owner, not utility, metering.

- A. Instrument Transformers: IEEE C57.13, NEMA EI 21.1, and the following:

PTs are not frequently needed, as most digital meters can be direct-bus connected up to 600 V. Consult manufacturers on need for PTs for instruments and meters. Indicate the primary-to-secondary ratio on Drawings.

1. PTs: IEEE C57.13; 120 V, 60 Hz, **[single] [tapped] [double]** secondary; disconnecting type with integral fuse mountings. Burden and accuracy shall be consistent with connected metering and relay devices.

Coordinate "Current Transformers" Subparagraph below with Drawings and indicate specific accuracy classes and burdens required for each application and the primary-to-secondary ratio.

2. Current Transformers: IEEE C57.13; 5 A, 60 Hz, secondary; **[wound] [bushing] [bar or window]** type; **[single] [double]** secondary winding and secondary shorting device. Burden and accuracy shall be consistent with connected metering and relay devices.

Manufacturers typically size CPTs and normally only for equipment and devices integral to MCCs. Consider specifying additional spare capacity if required for operation of remote devices.

3. CPTs: Dry type, mounted in separate compartments for units larger than 3 kVA.

Retain "Current Transformers for Neutral and Ground-Fault Current Sensing" Subparagraph below for certain ground-fault protection situations such as double-ended MCCs on four-wire, grounded neutral systems. Coordinate with Drawings.

4. Current Transformers for Neutral and Ground-Fault Current Sensing: Connect secondary wiring to ground overcurrent relays, via shorting terminals, to provide selective tripping of main and tie circuit breaker. Coordinate with feeder circuit-breaker, ground-fault protection.

Retain "Multifunction Digital-Metering Monitor" Paragraph below if digital metering is required. Digital metering offers substantially more capabilities than analog metering in much smaller packages; however, some facility managers still prefer analog devices with large, easy-to-read dials.

- B. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
1. Listed or recognized by a nationally recognized testing laboratory.
 2. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 3. Switch-selectable digital display of the following values with the indicated maximum accuracy tolerances:

- a. Phase Currents, Each Phase: Plus or minus 1 percent.
- b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
- c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
- d. Three-Phase Real Power (Megawatts): Plus or minus 2 percent.
- e. Three-Phase Reactive Power (Megavars): Plus or minus 2 percent.
- f. Power Factor: Plus or minus 2 percent.
- g. Frequency: Plus or minus 0.5 percent.
- h. Accumulated Energy, Megawatt Hours: Plus or minus 2 percent; accumulated values unaffected by power outages up to 72 hours.

Retain one or both of first two subparagraphs below. Retain first subparagraph for local recording of demand; retain second for remote recording of demand or if retaining "Impulse-Totalizing Demand Meter" Paragraph.

- i. Megawatt Demand: Plus or minus 2 percent; demand interval programmable from five to 60 minutes.
 - j. Contact devices to operate remote impulse-totalizing demand meter.
4. Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.

Retain first four paragraphs below if analog metering functions are required in lieu of multifunction digital meters specified above.

- C. Ammeters, Voltmeters, and Power-Factor Meters: ANSI C39.1.
1. Meters: 4-inch (100-mm) diameter or 6 inches (150 mm) square, flush or semiflush, with antiparallax 250-degree scale and external zero adjustment.
 2. Voltmeters: Cover an expanded-scale range of nominal voltage plus 10 percent.
- D. Instrument Switches: Rotary type with off position.
1. Voltmeter Switches: Permit reading of all phase-to-phase voltages and phase-to-neutral voltages where a neutral is included.
 2. Ammeter Switches: Permit reading of current in each phase and maintain current-transformer secondaries in a closed-circuit condition at all times.
- E. Feeder Ammeters: 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale. Meter and transfer device with off position, located on overcurrent device door for feeder circuits, unless otherwise indicated.
- F. Watt-Hour Meters and Wattmeters:
1. Comply with ANSI C12.1.
 2. Three-phase induction type with two stators, each with current and potential coil, rated 5 A, 120 V, 60 Hz.
 3. Suitable for connection to three- and four-wire circuits.
 4. Potential indicating lamps.
 5. Adjustments for light and full load, phase balance, and power factor.
 6. Four-dial clock register.

Retain one of first two subparagraphs below. Retain first subparagraph for local recording of demand; retain second for remote recording of demand or if retaining "Impulse-Totalizing Demand Meter" Paragraph.

7. Integral demand indicator.
8. Contact devices to operate remote impulse-totalizing demand meter.
9. Ratchets to prevent reverse rotation.
10. Removable meter with drawout test plug.
11. Semiflush mounted case with matching cover.
12. Appropriate multiplier tag.

Retain "Impulse-Totalizing Demand Meter" Paragraph below if retaining contact devices to operate remote impulse-totalizing of demand in "Multifunction Digital-Metering Monitor" and "Watt-Hour Meters and Wattmeters" paragraphs above. Meter below offers an option for a centralized monitoring or customer metering system if monitoring total demand is required.

G. Impulse-Totalizing Demand Meter:

1. Comply with ANSI C12.1.
2. Suitable for use with MCC watt-hour meter, including two-circuit totalizing relay.
3. Cyclometer.
4. Four-dial, totalizing kilowatt-hour register.
5. Positive chart drive mechanism.
6. Capillary pen holding a minimum of one month's ink supply.
7. Roll chart with minimum 31-day capacity; appropriate multiplier tag.
8. Capable of indicating and recording [**five**] [**15**] [**30**] **<Insert time period>**-minute integrated demand of totalized system.

2.13 MCC CONTROL POWER

Retain one of three "Control Circuits" paragraphs below if MCCs require control power for metering and central-control units not associated with combination controllers or VFCs.

- A. Control Circuits: 120-V ac, supplied through secondary disconnecting devices from CPT.
- B. Control Circuits: 120-V ac, supplied from remote branch circuit.
- C. Control Circuits: **<Insert value>**-V dc.

Retain three paragraphs below to require an automatic transfer of power using a main-tie-main or two-main scheme. Coordinate with selection of "Control Circuits" paragraphs. See "Interlocked Main and Tie Circuit Breakers for Automatic and Manual Transfer of Power" Paragraph in "Main- and Feeder-Tap Disconnecting and Overcurrent Protective Devices" Article in the Evaluations for discussion of other types of available transfer schemes, along with advantages and disadvantages of each type.

- D. Electrically Interlocked Main and Tie Circuit Breakers: Two CPTs in separate compartments, with interlocking relays, connected to the primary side of each CPT at the line side of the associated main circuit breaker. 120-V secondaries connected through automatic transfer relays to ensure a fail-safe automatic transfer scheme.

- E. Control Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.
- F. Control Wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

2.14 ENCLOSURES

See "Enclosures" Article in the Evaluations for discussion of enclosure types. Coordinate paragraphs below with Drawings by identifying the designated areas on plans or by including the required enclosure types. Enclosure materials and finishes may be added to the Section Text. Availability of some enclosure types is limited by type and rating of MCCs; special accommodations and accessories (e.g., powered/filtered ventilation) may be required for some enclosure types, especially those with solid-state controllers and VFCs. Consult manufacturers for availability of and limitations on enclosures other than NEMA 250, Type 1. MCCs are not usually available in explosion-proof enclosures.

- A. Indoor Enclosures: Freestanding steel cabinets unless otherwise indicated. NEMA 250, **[Type 1] [Type 1A] [Type 2] [Type 12]** unless otherwise indicated to comply with environmental conditions at installed location.

Retain "Space Heaters" Paragraph below if required for MCCs installed in unconditioned indoor spaces.

- B. Space Heaters: Factory-installed electric space heaters of sufficient wattage in each vertical section to maintain enclosure temperature above expected dew point.
 - 1. Space-Heater Control: **[Thermostats to maintain temperature of each section above expected dew point] [Manual switching of branch-circuit protective device]**.
 - 2. Space-Heater Power Source: **[Transformer, factory installed in MCC] [120-V external branch circuit]**.

Custom colors, especially for outdoor units, are normally available as an option. Coordinate with DEN Project Manager to determine if a special color is required. Consider a white or very light color for the roofs of outdoor units for better reflectance.

- C. Enclosure Finish for Indoor Units: Factory-applied finish in manufacturer's **[standard gray] [custom color]** finish over a rust-inhibiting primer on treated metal surface.
- D. Outdoor Enclosures: **[Type 3R, non-walk-in aisle] [Type 3R, with interior-lighted walk-in aisle]**.
 - 1. Finish: Factory-applied finish in manufacturer's **[standard] [custom]** color; undersurfaces treated with corrosion-resistant undercoating.
 - 2. Enclosure: **[Flat] [Downward, rearward sloping]** roof; **[bolt-on rear covers] [rear hinged doors]** for each section, with provisions for padlocking.
 - 3. Doors: Personnel door at each end of aisle, minimum width of **[30 inches (762 mm)] <Insert dimension>**; opening outwards; with panic hardware and provisions for **[padlocking] [cylinder lock]**.

4. Accessories: Fluorescent lighting fixtures, ceiling mounted; wired to a three-way light switch at each end of aisle; GFCI duplex receptacle; emergency battery pack lighting fixture installed on wall of aisle midway between personnel doors.
5. Walk-in Aisle Heating and Ventilating:

See Editing Instruction No. 12 in the Evaluations for temperature range included in UL 845 to define "usual service conditions." In first two subparagraphs below, optional interior temperatures are based on minimum and maximum ambient temperatures at which derating of fuses and circuit breakers should be considered. Insert higher or lower values if human comfort levels take precedence. Consult ASHRAE tables for recommended maximum and minimum outside design temperatures for locations in which MCCs will be installed.

- a. Factory-installed electric unit heater(s), wall or ceiling mounted, with integral thermostat and disconnect and with capacities to maintain switchboard interior temperature of [40 deg F (5 deg C)] <Insert temperature> with outside design temperature of [104 deg F (40 deg C)] <Insert temperature>.
- b. Factory-installed exhaust fan with capacities to maintain switchboard interior temperature of [100 deg F (38 deg C)] <Insert temperature> with outside design temperature of [23 deg F (minus 5 deg C)] <Insert temperature>.
- c. Ventilating openings[**complete with replaceable fiberglass air filters**].
- d. Thermostat: Single stage; wired to control heat and exhaust fan.

Retain one of two subparagraphs below. Retain first subparagraph to require MCC manufacturers to provide power through a control transformer. Retain second if power from a remote source is indicated on Drawings. Coordinate with Drawings.

6. Power for Space Heaters, Ventilation, Lighting, and Receptacle: Include a CPT within the switchboard. Supply voltage shall be [120] [120/240] [120/208]-V ac.
 7. Power for space heaters, ventilation, lighting, and receptacle provided by a remote source.
- E. Compartments: Modular; individual [**lift-off**] doors with concealed hinges and quick-captive screw fasteners. Interlocks on units requiring disconnecting means in off position before door can be opened or closed, except by operating a permissive release device.
- F. Interchangeability: Compartments constructed to allow for removal of units without opening adjacent doors, disconnecting adjacent compartments, or disturbing operation of other units in MCC; same size compartments to permit interchangeability and ready rearrangement of units, such as replacing three single units with a unit requiring three spaces, without cutting or welding.
- G. Wiring Spaces:
1. Vertical wireways in each vertical section for vertical wiring to each unit compartment; supports to hold wiring in place.
 2. Horizontal wireways in [**bottom**] [**top**] [**bottom and top**] of each vertical section for horizontal wiring between vertical sections; supports to hold wiring in place.

- H. Each unit shall have 1.0 x 2.5 inch hot stamped nameplate. The lettering shall be black, 3/16 inch high in a white background and shall include unit number, load name and number. Provide a typed directory showing the MCC unit and the name and number of the load served on the main section. See section 16195 for additional information.

2.15 AUXILIARY DEVICES

Retain applicable accessories below. Indicate requirements for and quantities of accessories on Drawings. See "Accessories" Article in the Evaluations for additional guidance; consult manufacturers for availability of and limitations on other accessories.

- A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.
1. Push Buttons, Pilot Lights, and Selector Switches: [**Heavy**] [**Standard**]-duty, [**oiltight**] type.
 - a. Push Buttons: [**Covered**] [**Lockable**] [**Recessed**] [**Shielded**] [**Shrouded**] [**Unguarded**] types; [**maintained**] [**momentary**] contact unless otherwise indicated.
 - b. Pilot Lights: [**Incandescent**] [**LED**] [**Neon**] [**Resistor**] [**Transformer**] types; <Insert color(s)>; **push to test**.
 - c. Selector Switches: [**Rotary**] <Insert description> type.
 2. Elapsed-Time Meters: Heavy duty with digital readout in hours[; **nonresettable**] [; **resettable**].

Retain "Meters" Subparagraph below if metering (for amperes, voltage, frequency, watts, power factor, etc.) is required for controllers. Indicate on Drawings where and which types of metering and selector switches are required. Normally, metering is limited to enclosure Types 1 and 12; consult manufacturers on availability of meters in other types of enclosures. Some listed manufacturers offer digital metering through the communications output of the solid-state overload relays; consult manufacturers for availability.

3. Meters: Panel type, 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale and plus or minus 2 percent accuracy with selector switches having an off position.
- B. [**NC**] [**NO**] [**Reversible NC/NO**] contactor auxiliary contact(s).
- C. Control Relays: Auxiliary and adjustable [**pneumatic**] [**solid-state**] time-delay relays.

Features in "Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays" Paragraph below are available in individual relays or combined into a single multipurpose relay. Consult manufacturers for availability. Consider specifying phase-failure relays for single-phasing protection in fusible-switch combination controllers if solid-state overload relays are not specified.

- D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

- E. Space heaters, with NC auxiliary contacts, to mitigate condensation in enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- F. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
- G. Cover gaskets for Type 1 enclosures.
- H. Terminals for connecting power factor correction capacitors to the **[line]** **[load]** side of overload relays.
- I. Spare control-wiring terminal blocks**;** **unwired** **;** **wired**.

Retain "Spare-Fuse Cabinet" Paragraph below if using fuses for power or control circuits.

- J. Spare-Fuse Cabinet: Identified **[and compartmented steel box]** **[cabinet with hinged lockable door]**.
- K. **<Insert auxiliary device>**.

2.16 CHARACTERISTICS AND RATINGS

NEMA ICS 18 recommends that the information in this article, as a minimum, be provided for manufacturers to adequately and correctly design and furnish an MCC.

Retain one of two "Wiring" paragraphs below to denote MCC wiring "class." Retain first option to accept manufacturer's standard design parameters; retain second option when retaining optional custom drawings in "Shop Drawings" Paragraph in "Action Submittals" Article. Retain one "Type" option to denote MCC wiring type. See "Classification of MCCs" Article in the Evaluations for a discussion of alternatives.

- A. Wiring: NEMA ICS 18, **[Class I]** **[Class I-S]**, **[Type A]** **[Type B, for starters above Size 3]** **[Type B-D, for starter Size 3 and below]** **[Type B-T, for starter Size 3 and below]** **[Type C]**.
- B. Wiring: NEMA ICS 18, **[Class II]** **[Class II-S]**, **[Type B, for starters above Size 3]** **[Type B-D, for starter Size 3 and below]** **[Type B-T, for starter Size 3 and below]** **[Type C]**.

Retain "Control and Load Wiring" Paragraph below for Type B in either "Wiring" Paragraph.

- C. Control and Load Wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

Retain one of three "Nominal System Voltage" paragraphs below to denote MCC voltage rating. Retain first option in first or second paragraph when MCC has no phase-to-neutral connections and is not used as service equipment; retain second option when MCC has phase-to-neutral connections or is used as service equipment, or both.

- D. Nominal System Voltage: **[480 V, three phase, three wire] [480Y/277 V, three phase, four wire]**.
- E. Nominal System Voltage: **[208 V, three phase, three wire] [208/120 V, three phase, four wire]**.
- F. Nominal System Voltage: **<Insert voltage and phasing>**.

An MCC's short-circuit current rating and the ratings of its included units are based on a variety of conditions. See Editing Instruction No. 4 in the Evaluations for guidance on revising first two paragraphs below. Retain "Short-Circuit Current Rating for Each Unit" Paragraph below for MCCs without main overcurrent devices or used in series with upstream current-limiting overcurrent devices; retain "Short-Circuit Current Rating of MCC" Paragraph for MCCs with integral current-limiting main overcurrent devices. Although NEMA ICS 18 and UL 845 list short-circuit current ratings from 5 to 100 kA, listed manufacturers seldom, if ever, offer MCCs or units rated below 22 kA. Not all available ratings are included in these two paragraphs; consult manufacturers for available options.

- G. Short-Circuit Current Rating for Each Unit: **[Combination series rated] [Fully rated]; [22] [42] [65] [100] <Insert value> kA.**
- H. Short-Circuit Current Rating of MCC: **[Combination series rated] [Fully rated]** with its main overcurrent device; **[22] [42] [65] [100] <Insert value> kA.**
- I. Environmental Ratings:

MCCs are available that are suitable for use under environmental conditions different than those indicated in four subparagraphs below, which are based on "normal service conditions" specified in UL 845. However, derating, special modifications, or both, may be required, especially if installing VFCs or other solid-state controllers. Coordinate with "Project Conditions" Article, and consult manufacturers for required modifications, derating, or both, to accommodate unusual service conditions.

1. Ambient Temperature Rating: Not less than **0 deg F** (minus 18 deg C) and not exceeding **104 deg F** (40 deg C), with an average value not exceeding **95 deg F** (35 deg C) over a 24-hour period.
2. Ambient Storage Temperature Rating: Not less than minus **4 deg F** (minus 20 deg C) and not exceeding **140 deg F** (60 deg C)
3. Humidity Rating: Less than 95 percent (noncondensing).
4. Altitude Rating: Not exceeding **6600 feet** (2000 m), or **3300 feet** (1000 m) if MCC includes solid-state devices.

Options in "Main-Bus Continuous Rating" Paragraph below are "preferred" ratings from UL 845, with 600 A being the lowest permissible rating.

- J. Main-Bus Continuous Rating: **[600] [800] [1000] [1200] [1600] [2000] <Insert value> A.**

Normally, MCC manufacturers will size vertical buses based on the ratings of the branch devices and controllers in each vertical section and to comply with UL 845, which also specifies a minimum rating of 300 A. Retain options in "Vertical-Bus **[Minimum]** Continuous Rating" Paragraph below only if there is a specific Project requirement to override manufacturers' standard vertical bus ratings, such as for future additions to vertical sections or Owner requirements for a minimum bus size, regardless of actual connected device ratings.

- K. Vertical-Bus **[Minimum]** Continuous Rating: **[300] [600] [1200]** <Insert value> A.

UL 845 lists bus short-circuit current ratings (also called "bus bracing" in manufacturers' literature) from 22 to 200 kA, but the upper limit in NEMA ICS 18 is 100 kA. These values can exceed the individual unit ratings if the MCC rating is based on a series rating. Retain first option in "Horizontal and Vertical Bus Bracing (Short-Circuit Current Rating)" Paragraph below unless a bus rating greater than the MCC short-circuit current rating is required.

- L. Horizontal and Vertical Bus Bracing (Short-Circuit Current Rating): **[Match MCC short-circuit current rating]** <Insert ampere rating>.

In "Main Horizontal and Equipment Ground Buses" Paragraph below, indicate location of future extensions on Drawings if not retaining first option.

- M. Main Horizontal and Equipment Ground Buses: Uniform capacity for entire length of MCC's main and vertical sections. Provide for future extensions[**from both ends**].[**Brace bus extensions for busway feeder bus.**]
- N. Vertical Phase and Equipment Ground Buses: Uniform capacity for entire usable height of vertical sections, except for sections incorporating single units.
- O. Phase-[**and Neutral-**]Bus Material: Hard-drawn copper of 98 percent conductivity, [**silver**] [**tin**] plated.

Neutral buses, when required, can be reduced in size if a substantial portion of the loads are balanced three-phase types (e.g., motors and transformers). See "Neutral buses" Paragraph in "Accessory Components and Features" Article in the Evaluations. Retain one of two "Neutral Buses" paragraphs below or delete both for three-phase, three-wire systems.

- P. Neutral Buses: 50 percent of the ampacity of phase buses unless otherwise indicated, equipped with [**mechanical**] [**compression**] connectors for outgoing circuit neutral cables.[**Brace bus extensions for busway feeder neutral bus.**]
- Q. Neutral Buses: 100 percent of the ampacity of phase buses unless otherwise indicated, equipped with [**mechanical**] [**compression**] connectors for outgoing circuit neutral cables.[**Brace bus extensions for busway feeder neutral bus.**]
- R. Ground Bus: **[Minimum size required by UL 845]** <Insert size>, hard-drawn copper of 98 percent conductivity, equipped with [**mechanical**] [**compression**] connectors for feeder and branch-circuit equipment grounding conductors.[**For busway feeders, extend insulated equipment grounding cable to busway ground connection and support cable at intervals in vertical run.**]
- S. Front-Connected, Front-Accessible MCCs:
1. Main Devices: **[Drawout]** **[Fixed]** mounted.
 2. Controller Units: **[Drawout]** **[and]** **[fixed]** mounted.
 3. Feeder-Tap Units: **[Drawout]** **[and]** **[fixed]** mounted.
 4. Sections front and rear aligned.

Retain "Utility Metering Compartment" Paragraph below if MCCs are used for service equipment and utility metering is performed at the MCCs. Utilities require separate isolated compartments for their metering.

- T. Utility Metering Compartment: Fabricated, barrier compartment and section complying with utility company's requirements; hinged sealed door; buses provisioned for mounting utility company's current transformers and potential transformers or potential taps as required by utility company. If separate vertical section is required for utility metering, match and align with basic MCC. Provide service entrance label and necessary applicable service entrance features.

Retain "Owner Metering Compartment" Paragraph below if a separate compartment is required. Retain option if metering requires a voltage different from MCC bus voltage.

- U. Owner Metering Compartment: A separate customer metering compartment and section with front hinged door, metering, and current transformers for each meter. Current transformer secondary wiring shall be terminated on shorting-type terminal blocks. **[Include potential transformers having primary and secondary fuses with disconnecting means and secondary wiring terminated on terminal blocks.]**

Pull sections in "Bus Transition and Incoming Pull Sections" Paragraph below may be required if incoming supply is beneath MCC.

- V. Bus Transition and Incoming Pull Sections: Matched and aligned with basic MCC.

A pull box across the entire top of MCC is usually only required for very many outgoing feeders and across the main incoming section for very large feeders with multiple large conductors per phase and neutral (if used). Indicate the presence and extent of pull boxes on Drawings.

- W. Pull Box on Top of an MCC:

1. Adequate ventilation to maintain temperature in pull box within same limits as MCC.

Retain first subparagraph below for top-mounted, circuit-breaker removal mechanism.

2. Set back from front to clear circuit-breaker removal mechanism.
3. Removable covers forming top, front, and sides. Top covers at rear easily removable for drilling and cutting.
4. Insulated bottom of fire-resistive material with separate holes for cable drops into MCC.
5. Cable supports arranged to facilitate cabling and adequate to support cables, including those for future installation.

Retain subparagraph below if optional barriers are specified.

6. Isolation Barrier Access Provisions: Permit checking of bus-bolt tightness.

Retain "Future Devices" Paragraph below to require provisions for future expansion.

- X. Future Devices: Equip compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of unit.

- Y. Bus-Bar Insulation: Factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating of 105 deg C.

Retain "Fungus Proofing" Paragraph below for installations in humid tropical environments.

- Z. Fungus Proofing: Permanent fungicidal treatment for OCPDs and other components including instruments and instrument transformers.

2.17 SOURCE QUALITY CONTROL

- A. MCC Testing: Inspect and test MCCs according to requirements in **[NEMA ICS 18]** <Insert standard>.

NEMA ICS 61800-2 includes acceptance testing by manufacturer of VFCs completely assembled and wired, before shipment from the factory.

- B. VFC Testing: Test and inspect VFCs according to requirements in **[NEMA ICS 61800-2]** <Insert standard>.
 1. Test each VFC while connected to **[its specified motor]** **[a motor that is comparable to that for which the VFC is rated]**.
 2. Verification of Performance: Rate VFCs according to operation of functions and features specified.

- C. The following standard factory tests shall be performed on the contactor element provided under this section. All tests shall be in accordance with the latest version of ANSI standards:

1. Alignment test with master cell to verify all interfaces and interchangeability.
2. Contactors operated over the range of minimum to maximum control voltage.
3. Factory setting of contact gap.
4. One-minute dielectric test per ANSI standards.
5. Final inspections and quality checks.

- D. The following production test shall be performed on each contactor housing:

1. Alignment test with actual equipment to verify interfaces.
2. One-minute dielectric test per ANSI standards on primary and secondary circuits.
3. Operation of wiring, relays and other devices verified by an operational sequence test.
4. Final inspection and quality check.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. MCCs will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

- G. The Manufacturer shall provide three (3) certified copies of factory test reports to DEN Project Manager.
- H. Verification of Performance: DEN Project Manager shall be the responsible party in determining if the equipment is satisfactory to be shipped to the site.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and surfaces to receive MCCs, with Installer present, for compliance with requirements for installation tolerances, **<Insert Project-specific conditions,>** and other conditions affecting performance of the Work.
- B. Examine enclosed controllers before installation. Reject enclosed controllers that are wet, moisture damaged, or mold damaged.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 HARMONIC ANALYSIS STUDY

- A. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze **[possible] [designated]** operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at the defined PCC to specified levels.
- B. Prepare a harmonic analysis study report complying with IEEE 399 and NETA Acceptance Testing Specification.

3.3 INSTALLATION

- A. Coordinate layout and installation of MCCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
- B. Site Verification of Conditions:
 - 1. Contractor shall make all necessary field measurements to verify that equipment shall fit in allocated space in full compliance with minimum required clearances specified in local codes and standards.
 - 2. Examine installation area to assure there is enough clearance to install equipment.
 - 3. Check concrete pads for uniformity and level surface.
 - 4. Verify that equipment is ready to install.
 - 5. Verify that required utilities are available, in proper location and ready for use.
 - 6. Beginning of installation means installer accepts conditions.

7. Tighten bus-assembly joints with torque wrench or similar tool recommended by bus assembly manufacturer. Tighten joints again after bus assemblies have been energized for 30 days.
 8. Connect bus assemblies and components to wiring system and to ground as indicated and instructed by manufacturer.
 9. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those in specified standards.
 10. Submit torque values for all connections with a torque schedule and witness signature.
- C. Contractor shall install all equipment per the Manufacturer's recommendations and contract drawings.
- D. Coordinate power factor correction assembly terminations to equipment enclosures to ensure proper phasing, connection, and closure.

Retain "Floor-Mounting Controllers" Paragraph below for equipment supported on concrete bases attached to concrete slabs. If installing MCCs on concrete bases, ensure that main and compartment disconnect operating handles will not be higher than 79 inches (2000 mm) above finished floor.

- E. Floor-Mounting Controllers: Install MCCs on 4-inch (100-mm) nominal thickness concrete base. Comply with requirements for concrete base specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 4. Install anchor bolts to elevations required for proper attachment to supported equipment.

Retain "Seismic Bracing" Paragraph below if seismic controls are Project requirement. Coordinate with Drawings and Sections specifying vibration and seismic controls.

- F. Seismic Bracing: Comply with requirements specified in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- G. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

Coordinate first five paragraphs below with product descriptions.

- H. Install fuses in each fusible switch.
- I. Install fuses in control circuits if not factory installed. Comply with requirements in Section 262813 "Fuses."

- J. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.
- K. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
- L. Install power factor correction capacitors. Connect to the **[line]** **[load]** side of overload relays. If connected to the load side of overload relays, adjust overload heater sizes to accommodate the reduced motor full-load currents.
- M. Torque all connections per manufacturer recommendations. Submit torque values for all connections with a torque schedule and witness signature.
- N. Comply with NECA 1.

3.4 IDENTIFICATION

- A. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification of MCC, MCC components, and control wiring.
 - 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 - 2. Label MCC and each cubicle with engraved nameplate.
 - 3. Label each enclosure-mounted control and pilot device.

Retain subparagraph below if retaining "Schematic[**and Connection**] Wiring Diagrams" Subparagraph and "Manufacturer's Record Drawings" Subparagraph, and its option for field-installed wiring identification, in "Action Submittals" Article.

- 4. Mark up a set of manufacturer's connection wiring diagrams with field-assigned wiring identifications and return to manufacturer for inclusion in Record Drawings.

Retain "Operating Instructions" Paragraph below if required. Show specific information to be included in framed instructions on Drawings.

- B. Operating Instructions: Frame printed operating instructions for MCCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of MCCs.

3.5 CONTROL WIRING INSTALLATION

Retain this article if remote control or remote status indication is required. Coordinate options retained with wiring type(s) retained in Part 2.

- A. Install wiring between **[enclosed controllers]** **[master terminal boards]** and remote devices[**and facility's BAS**] [**and facility's central-control system**]. Comply with requirements in Section 260523 "Control-Voltage Electrical Power Cables."
- B. Bundle, train, and support wiring in enclosures.

- C. Connect selector switches and other automatic-control selection devices where applicable.
 - 1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switch is in manual-control position.
 - 2. Connect selector switches within enclosed controller circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.6 CONNECTIONS

Coordinate conduit installations and specialty arrangements with schematics on Drawings and with requirements specified. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Comply with requirements for installation of conduit in Section 260533 "Raceways and Boxes for Electrical Systems." Drawings indicate general arrangement of conduit, fittings, and specialties.
- B. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 FIELD QUALITY CONTROL

See Editing Instruction No. 15 in the Evaluations for guidance on the level of field quality control that would be appropriate for Project. Retain one of first two paragraphs below to identify who shall perform tests and inspections. Retain and edit "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first two paragraphs below to describe tests and inspections to be performed.

- C. Acceptance Testing Preparation:
 - 1. Test insulation resistance for each enclosed controller, component, connecting supply, feeder, and control circuit.
 - 2. Test continuity of each circuit.

D. Tests and Inspections:

1. Inspect controllers, wiring, components, connections, and equipment installation. [**Test and adjust controllers, components, and equipment.**]
2. Test insulation resistance for each enclosed controller element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at controller locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify DEN Project Manager before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

NETA Acceptance Testing Specification allows three methods to test and inspect bolted electrical connections for high resistance; the infrared (thermographic) method is the most thorough and costly. Retain "Initial Infrared Scanning" Subparagraph below if this method is preferred.

8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multipole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
 - b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multipole enclosed controller 11 months after date of Substantial Completion.
 - c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

Retain subparagraph below if retaining "Manufacturer's Record Drawings" Subparagraph in "Closeout Submittals" Article to include field modifications incorporated during construction.

10. Mark up a set of manufacturer's drawings with all field modifications incorporated during construction and return to manufacturer for inclusion in Record Drawings.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. Enclosed controllers will be considered defective if they do not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- F. Prepare test and inspection reports, including a certified report that identifies enclosed controllers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.8 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor with performing startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. **<Insert startup steps if any>**.

3.9 ADJUSTING

Retain applicable paragraphs below to correspond to selections made in Part 2.

- A. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
- B. Adjust overload relay heaters or settings if power factor correction capacitors are connected to the load side of the overload relays.
- C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify DEN Project Manager before increasing settings.
- D. Set the taps on reduced-voltage autotransformer controllers at **[50] [65] [80]** percent.
- E. Set field-adjustable switches and program microprocessors for required start and stop sequences in reduced-voltage, solid-state controllers.
- F. Program microprocessors in VFCs for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

Retain option in paragraph below unless settings are included on Drawings.

- G. Set field-adjustable circuit-breaker trip ranges[**as specified in Section 260573 "Overcurrent Protective Device Coordination Study."**]

3.10 PROTECTION

Retain this article if retaining "Delivery, Storage, and Handling" Article and if retaining space heaters in "Auxiliary Devices" Article.

- A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until enclosed controllers are ready to be energized and placed into service.
- B. Replace controllers whose interiors have been exposed to water or other liquids prior to Substantial Completion.
- C. Provide final protection to ensure that moisture does not enter bus assembly.

3.11 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.12 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist with training of Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers[, **and to use and reprogram microprocessor-based, reduced-voltage, solid-state controllers**].
- B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.
- C. Train Owner's maintenance personnel on procedures and schedules for starting up and shutting down, troubleshooting, servicing, and maintaining equipment and schedules.
- D. Review data in maintenance manuals.

3.13 COMMISSIONING

- A. Infrared Scanning: Two (2) months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.
- B. Use an infrared scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
- C. Perform two follow-up infrared scans of bus assembly, one at four (4) months and the other at eleven (11) months after Substantial Completion.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262419

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SECTION 262500 - ENCLOSED BUS ASSEMBLIES

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FORM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Section includes the following:
 - 1. Feeder-bus assemblies.
 - 2. Plug-in bus assemblies.
 - 3. Bus plug-in devices.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviation that remains after this Section has been edited.

- A. SPD: Surge Protective Devices.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

A. Shop Drawings: For each type of bus assembly and plug-in device.

1. Show fabrication and installation details for enclosed bus assemblies. Include plans, elevations, and sections of components. Designate components and accessories, including clamps, brackets, hanger rods, connectors, straight lengths, and fittings.

Retain first subparagraph below if Project requires fire-stop or weather barriers.

2. Show fittings, materials, fabrication, and installation methods for listed fire-stop barriers and weather barriers.
3. Indicate required clearances, method of field assembly, and location and size of each field connection.
4. Detail connections to switchgear, switchboards, transformers, and panelboards.
5. Wiring Diagrams: Power[**and signal**] [**and control**] [, **signal, and control**] wiring.

Retain subparagraph and associated subparagraphs below if products are required to withstand specific design loads and DEN Project Manager either has delegated design responsibility to Contractor or wants to review structural data as another way to verify products' compliance with performance requirements. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

6. Seismic-Restraint Details: Signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting seismic restraints.
 - b. Detail fabrication, including anchorages and attachments to structure and to supported equipment.

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph and subparagraphs below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- ##### A. Coordination Drawings: Floor plans and sections, drawn to scale. Include scaled bus-assembly layouts and relationships between components and adjacent structural, mechanical, and electrical elements. Show the following:

Revise subparagraphs below to suit Project.

1. Vertical and horizontal enclosed bus-assembly runs, offsets, and transitions.
2. Clearances for access above and to the side of enclosed bus assemblies.
3. Vertical elevation of enclosed bus assemblies above the floor or bottom of structure.
4. Support locations, type of support, and weight on each support.

- B. Location of adjacent construction elements including light fixtures, HVAC and plumbing equipment, fire sprinklers and piping, signal and control devices, and other equipment.

Coordinate paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- C. Qualification Data: For [professional engineer] [and] [testing agency].
- D. Product Certificates: For each type of enclosed bus assembly, signed by product manufacturer.

Retain paragraph below if Contractor is responsible for field quality-control testing.

- E. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For enclosed bus assemblies to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Revise subparagraph below to suit Project.

1. Plug-in Units: [10] <Insert number> percent of amount installed[for each size indicated], but no fewer than <Insert number> unit(s).
2. [Two (2)] <Insert number> hookstick operators for plug-in units.

1.8 QUALITY ASSURANCE

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, retain one of first two paragraphs below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain first paragraph and subparagraph below if Contractor selects testing agency.

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

1. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.
- B. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
- C. Source Limitations: Obtain enclosed bus assemblies and plug-in devices through one source from a single manufacturer.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Comply with NEMA BU 1, "Busways."
- F. Comply with NFPA 70.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, store, and handle enclosed bus assemblies according to NEMA BU 1.1, "General Instructions for Proper Handling, Installation, Operation and Maintenance of Busway Rated 600 Volts or Less."

1.10 PROJECT CONDITIONS

- A. Derate enclosed bus assemblies for continuous operation at indicated ampere ratings for ambient temperature not exceeding [122 deg F (50 deg C)] [140 deg F (60 deg C)] **<Insert ambient temperature>**.

1.11 COORDINATION

Revise paragraph below to delete or add types of construction that penetrate or are supported by ceilings.

- A. Coordinate layout and installation of enclosed bus assemblies and suspension system with other construction that penetrates ceilings or floors or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

Retain paragraph below if required for concrete curbs around vertical floor penetrations.

- B. Coordinate size and location of concrete curbs around openings for vertical bus. Concrete, reinforcement, and formwork requirements are specified with concrete.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain one of two paragraphs and list of manufacturers in this Article. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Calvert Company (The).
 2. Eaton Electrical Inc.; Cutler-Hammer Products.
 3. Electric Busway Corp.
 4. General Electric Company; Electrical Distribution & Control Division.
 5. Siemens Energy & Automation, Inc.
 6. Square D; Schneider Electric.
 7. **<Insert manufacturer's name.>**
 8. or approved equal.

2.2 ENCLOSED BUS ASSEMBLIES

- A. Feeder-Bus Assemblies: NEMA BU 1, low-impedance bus assemblies in nonventilated housing; single-bolt joints; ratings as indicated.

Retain subparagraph below for projects in seismic areas. Coordinate with "Informational Submittals" Article for submittal of manufacturer's seismic qualification certification.

1. Seismic Fabrication Requirements: Fabricate mounting provisions and attachments for feeder-bus assemblies with reinforcement strong enough to withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems" when mounting provisions and attachments are anchored to building structure

Select from options in first subparagraph below and revise to suit Project. Consider 200 percent neutral on 4-wire systems if a significant portion of load is nonlinear (e.g., computers, fluorescent or high-intensity-discharge lighting, variable-frequency drives, etc.) and harmonic cancellation on the neutral conductor is unlikely. If busways with different voltages and neutral capacities are required, delete subparagraph and include a schedule on Drawings. See sample schedule in the Evaluations.

2. Voltage: [120/208] [240] [480] [277/480] V; 3 phase; [100] [200] [percent neutral capacity].

3. Temperature Rise: 55 deg C above 40 deg C ambient maximum for continuous rated current.
4. Bus Materials: Current-carrying copper conductors, fully insulated with Class 130C insulation except at joints; plated surface at joints.
5. Ground:

Retain one or more of three subparagraphs below.

- a. 50 percent capacity integral with housing.
- b. 50 percent capacity internal bus bars of material matching bus material.
- c. 50 percent capacity isolated, internal bus bar of material matching bus material.

If subways with different ground or enclosure types are required, delete "Ground" Subparagraph and associated subparagraphs above or "Enclosure" Subparagraph below, or both, and include a schedule on Drawings. See sample schedule in the Evaluations.

6. Enclosure: [**Steel with manufacturer's standard finish**] [**Aluminum with manufacturer's standard finish**] [**Weatherproof, steel or aluminum with manufacturer's standard finish, sealed seams, drains, and removable closures**].
 7. Fittings and Accessories: Manufacturer's standard.
 8. Mounting: Arranged flat, edgewise, or vertically without derating.
- B. Plug-in Bus Assemblies: NEMA BU 1, low-impedance bus assemblies in nonventilated housing; single-bolt joints; ratings as indicated.

Retain subparagraph below for projects in seismic areas. Coordinate with "Informational Submittals" Article for submittal of manufacturer's seismic qualification certification.

1. Seismic Fabrication Requirements: Fabricate mounting provisions and attachments for switchboards with reinforcement strong enough to withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems" when mounting provisions and attachments are anchored to building structure.

Select from options in first subparagraph below and revise to suit Project. Consider 200 percent neutral on 4-wire systems if a significant portion of load is nonlinear (e.g., computers, fluorescent or high-intensity-discharge lighting, variable-frequency drives, etc.) and harmonic cancellation on the neutral conductor is unlikely. If busways with different voltages and neutral capacities are required, delete subparagraph and include a schedule on Drawings. See sample schedule in the Evaluations.

2. Voltage: [**120/208**] [**240**] [**480**] [**277/480**] V; 3 phase; [**100**] [**200**] [**percent neutral capacity**].
3. Temperature Rise: 55 deg C above 40 deg C ambient maximum for continuous rated current.
4. Bus Materials: Current-carrying copper conductors, fully insulated with Class 130C insulation except at stabs and joints; plated surface at stabs and joints.
5. Ground:

Retain one or more of three subparagraphs below.

- a. 50 percent capacity integral with housing.
- b. 50 percent capacity internal bus bar of material matching bus material.
- c. 50 percent capacity isolated, internal bus bar of material matching bus material.

If subways with different ground or enclosure types are required, delete "Ground" Subparagraph and associated subparagraphs above or "Enclosure" Subparagraph below, or both, and include a schedule on Drawings. See sample schedule in the Evaluations.

6. Enclosure: [**Steel, with manufacturer's standard finish, plug-in openings 24 inches (610 mm) o.c., and hinged covers over unused openings**] [**Aluminum, with manufacturer's standard finish, plug-in openings 24 inches (610 mm) o.c., and hinged covers over unused openings**].
7. Fittings and Accessories: Manufacturer's standard.
8. Mounting: Arranged flat, edgewise, or vertically without derating.

2.3 PLUG-IN DEVICES

Chain-operable handles are available for plug-in devices.

For fusible-switch plug-in devices, R-type rejection fuse clips and J-type fuse clips are available in sizes from 30 to 600 A, rated 600 V. L-type, bolt-on fuse clips are available in 800 to 1600 A, 600-V fusible switches. Coordinate options selected in paragraph below with Section 262813 "Fuses."

- A. Fusible Switches: NEMA KS 1, heavy duty; with [**R-type rejection**] [**J-type**] [**L-type**] fuse clips to accommodate specified fuses; hookstick-operated handle, lockable with two padlocks, and interlocked with cover in closed position. See Section 262813 "Fuses" for fuses and fuse installation requirements.

Indicate in schedule or diagrams on Drawings the frame size, trip rating, number of poles, interrupting-capacity rating, and auxiliary devices.

- B. Molded-Case Circuit Breakers: NEMA AB 1; hookstick-operated handle, lockable with two padlocks, and interlocked with cover in closed position.
- C. TVSS: NEMA 250, Type 1 enclosure with NEMA KS 1, fusible, disconnect switch and external handle to isolate TVSS from busway. TVSS product and installation requirements are specified in Section 264313 "Transient-Voltage Protection for Low-Voltage Electrical Power Circuits."
- D. Motor Controllers: NEMA ICS 2, Class A, full voltage, nonreversing, across the line, unless otherwise indicated.
 1. Control Circuit: 120 V; obtained from [**integral control power transformer**] **<Insert source of control power>** with a control power [**transformer**] [**source**] of enough capacity to operate connected pilot, indicating and control devices, plus 100 percent spare capacity.
 2. Combination Controller: Factory-assembled combination controller and disconnect switch with or without overcurrent protection as indicated.

Retain one of first three subparagraphs below if required.

- a. Fusible Disconnecting Means: NEMA KS 1, heavy-duty, fusible switch with **[R-type rejection] [J-type]** fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 947-4-1, as certified by a nationally recognized testing laboratory (NRTL) acceptable to authorities having jurisdiction. See Section 262813 "Fuses" for fuses and fuse installation requirements.
 - b. Nonfusible Disconnecting Means: NEMA KS 1, heavy-duty, nonfusible switch.
 - c. Circuit-Breaker Disconnecting Means: NEMA AB 1, motor-circuit protector with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
3. Overload Relay: Ambient-compensated type with inverse-time-current characteristic and NEMA ICS 2, **[Class 10] [Class 20] [Class 30]** tripping characteristic. Overload relays shall have heaters or sensors in each phase matched to nameplate full-load current of specific motor to which they connect and with appropriate adjustment for duty cycle.

Retain subparagraph above or below.

4. Adjustable Overload Relay: Dipswitch selected for motor running overload protection with NEMA ICS 2, **[Class 10] [Class 20] [Class 30]** tripping characteristic, and selected to protect motor against voltage and current unbalance and single phasing. Adjustable overload relays shall have Class II ground-fault protection with start and run delays to prevent nuisance trip on starting.

Coordinate paragraph and subparagraphs below with Drawings.

- E. Multispeed Motor Controllers: Match controller to motor type, application, and number of speeds; include the following accessories:
1. Compelling relay ensures motor starts only at low speed.
 2. Accelerating relay ensures properly timed acceleration through speeds lower than that selected.
 3. Decelerating relay ensures automatically timed deceleration through each speed.

Retain paragraph below if required.

- F. Accessories: Hookstick operator, adjustable to maximum extension of **[14 feet (4.3 m)]** **<Insert dimension>**.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Support bus assemblies independent of supports for other elements such as equipment enclosures at connections to panelboards and switchboards, pipes, conduits, ceilings, and ducts.
1. Design each fastener and support to carry load indicated by seismic requirements and to comply with seismic-restraint details according to Section 260548.16 "Seismic Controls for Electrical Systems."

Retain subparagraph above if requirements for seismic control are included in Part 1. Retain four subparagraphs below if seismic restraint is not required. Revise to suit Project.

2. Design each fastener and support to carry 200 lb (90 kg) or 4 times the weight of bus assembly, whichever is greater.
 3. Support bus assembly to prevent twisting from eccentric loading.
 4. Support bus assembly with not less than 3/8-inch (10-mm) steel rods. Install side bracing to prevent swaying or movement of bus assembly. Modify supports after completion to eliminate strains and stresses on bus bars and housings.
 5. Fasten supports securely to building structure according to Section 260529 "Hangers and Supports for Electrical Systems."
- B. Install expansion fittings at locations where bus assemblies cross building expansion joints. Install at other locations so distance between expansion fittings does not exceed manufacturer's recommended distance between fittings.
- C. Construct rated fire-stop assemblies where bus assemblies penetrate fire-rated elements such as walls, floors, and ceilings. Seal around penetrations according to Section 078413 "Penetration Firestopping."
- D. Install weatherseal fittings and flanges where bus assemblies penetrate exterior elements such as walls or roofs. Seal around openings to make weathertight. See Section 079200 "Joint Sealants" for materials and application.

Coordinate floor penetrations with Structural Drawings.

- E. Install a concrete curb at least 4 inches (100 mm) high around bus-assembly floor penetrations.
- F. Coordinate bus-assembly terminations to equipment enclosures to ensure proper phasing, connection, and closure.
- G. Tighten bus-assembly joints with torque wrench or similar tool recommended by bus-assembly manufacturer. Tighten joints again after bus assemblies have been energized for 30 days.
- H. Install bus-assembly, plug-in units. Support connecting conduit independent of plug-in unit.

- I. Connect bus assemblies and components to wiring system and to ground as indicated and instructed by manufacturer.
 1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.

3.2 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

Retain paragraph below to require a factory-authorized service representative to perform inspections, tests, and adjustments.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

Retain paragraph and subparagraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections and prepare test reports.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph and subparagraph below to describe tests and inspections to be performed by any of the entities in three paragraphs above.

- C. Tests and Inspections:

Tests referenced in subparagraph below are from NETA Acceptance Testing Specification and include inspection procedures to verify proper installation. They also include tests and measurements of insulation resistance and turns ratios. Cost of extensive testing may not be warranted for some projects. Revise subparagraph to suit Project.

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

- D. Remove and replace units that do not pass tests and inspections and retest as specified above.
- E. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.
 - 1. Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
 - 2. Perform two (2) follow-up infrared scans of bus assembly, one at four (4) months and the other at eleven (11) months after Substantial Completion.
 - 3. Prepare a certified report identifying bus assembly checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.
- F. Test Labeling: On completion of satisfactory testing of each unit, attach a dated and signed "Satisfactory Test" label to tested component.

3.4 ADJUSTING

- A. Set field-adjustable, circuit-breaker trip ranges[**and overload relay trip settings**] as indicated.

3.5 CLEANING

- A. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

3.6 PROTECTION

- A. Provide final protection to ensure that moisture does not enter bus assembly.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION **262500**

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SECTION 262600 - POWER DISTRIBUTION UNITS

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes freestanding, prepackaged power distribution units for transforming, conditioning, and distributing electrical power.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for Project.

- A. SPD: Surge protection device.
- B. UPS: Uninterrupted power supply.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For power distribution units. Include system description, ratings, capacities, and performance characteristics.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Include dimensioned plans, sections, and elevations. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
- C. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For [manufacturer] [testing agency].
- B. Product Certificates: For each type of power distribution unit, signed by product manufacturer.

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Coordinate seismic requirements with DEN Project Manager.

- C. Manufacturer Seismic Qualification Certification: Submit certification that power distribution units, accessories, and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

Coordinate seismic requirements with DEN Project Manager.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
- 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and

- locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Source quality-control reports.

1. For each factory test of power distribution units.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

E. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For power distribution units to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, retain first paragraph below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain first paragraph and subparagraph below if Contractor selects testing agency.

- A. Source Limitations: Obtain power distribution unit and associated components specified in this Section from a single manufacturer with responsibility for entire power distribution unit installation.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Comply with NFPA 70.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver equipment in fully enclosed vehicles after specified environmental conditions have been permanently established in spaces where equipment is to be placed.

- B. Store equipment in spaces with environments controlled within manufacturer's ambient temperature and humidity tolerances for non-operating equipment.

1.9 COORDINATION

Retain first paragraph below for power distribution units mounted on concrete bases. Retain second paragraph if power distribution units are located in computer rooms with access flooring systems. Because of their weight, power distribution units are usually mounted on support systems that penetrate the access flooring system and are independent of it.

- A. Coordinate size and location of concrete bases with actual power distribution unit provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.
- B. Coordinate layout and installation of power distribution units with access flooring for proper support and seismic restraint of units.

Revise paragraph and subparagraphs below to specify coordination with other parties involved in finalizing electronic equipment arrangement and installation.

- C. Coordinate layout and installation of power distribution units with Owner's equipment.
 - 1. Meet jointly with electronic equipment representatives and Owner's representatives to exchange information and agree on details of equipment arrangements and installation interfaces.
 - 2. Record agreements reached in meetings and distribute record to other participants.
 - 3. Adjust arrangements and locations of power distribution units to accommodate and optimize arrangement and space requirements of equipment.

1.10 PROJECT CONDITIONS

- A. Environmental Conditions: Units shall be capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability.

Revise requirements in subparagraphs below to suit conditions at equipment installation location; include unusual service conditions.

- 1. Storage Temperature Range: Minus 67 to plus 185 deg F (Minus 55 to plus 85 deg C).
- 2. Operating Temperature Range: 32 to 104 deg F (0 to 40 deg C).
- 3. Relative Humidity Range: 0 to 95 percent, noncondensing.
- 4. Altitude: Sea level to [5500 feet (1677 m)] <Insert dimension> above sea level.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers in this Article. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Eaton Corporation.
 2. Liebert; a brand of Emerson Electric Co.
 3. Myers Power Products, Inc.
 4. PDI; a brand of Smiths Power.
 5. Square D; by Schneider Electric.
 6. United Power Corporation.
 7. **<Insert manufacturer's name>.**
 8. or approved equal.

2.2 MANUFACTURED UNITS

Casters in the "Description" Paragraph below are usually limited to units with a rating of 250 A or less. Verify with manufacturers and consider the effect of casters on the supporting floor before retaining requirement for casters.

- A. Description: Integrated and coordinated assembly of power-line-conditioning and distribution components packaged in a single cabinet or modular assembly of cabinets[**each with full-swivel casters mounted to bottom frame**]. Include the following components:
1. Input-power, circuit-breaker section.
 2. Isolation transformer.
 3. SPD system.
 4. Output panelboard(s).
 5. Alarm, monitoring, and control system.

Retain first paragraph below for projects in seismic areas.

- B. Provide units that are constructed to withstand seismic forces specified in Section 260548 "Vibration and Seismic Controls for Electrical Systems."

- C. Unit Capacity Rating: Unit shall carry indicated rms kilovolt-ampere load continuously without exceeding rated insulation temperature for the following input voltage and load current:
1. Input Voltage: Within rated input-voltage tolerance band of unit.
 2. Load Current: Minimum of 3.0 crest factor and 85 percent total harmonic distortion.

2.3 INPUT-POWER, CIRCUIT-BREAKER SECTION

Coordinate this article with Drawings.

- A. Description: 3-pole, shunt-tripped, thermal-magnetic-type circuit breaker, rated for indicated interrupting capacity and 125 percent of input current of unit at 100 percent rated load at unit capacity rating.

Retain "Dual-Input Units" Subparagraph below if dual-input section is required.

1. Dual-Input Units:
 - a. Two input circuit breakers arranged to provide transfer between two input-voltage sources.
 - b. Controls and interfaces to allow selecting either open- or closed-transition transfer between two input-voltage sources.
 - c. Use a 120-V permissive signal from both upstream voltage sources to indicate acceptable conditions for closed-transition transfer.
 - d. Open second circuit breaker automatically after closed-transition transfer is completed.

2.4 ISOLATION TRANSFORMER SECTION

- A. Description: Dry-type, electrostatically shielded, three-phase, common-core, convection-air-cooled isolation transformer.

Retain option in first subparagraph below if transformer will supply nonlinear load; designate K-factor on Drawings. Coordinate with Drawings.

1. Comply with UL 1561 including requirements for nonsinusoidal load-current-handling capability defined by designated K-factor.
2. Cores: Electrical grade, non-aging silicon steel with high permeability and low hysteresis losses, one leg per phase.
3. Coil Material and Insulation: Copper windings, 220 deg C insulation class.
4. Temperature Rise: Designed for [80] [115] [150] deg C rise above 40 deg C ambient.
5. Output Impedance: 3.5 plus or minus 0.5 percent.
6. Regulation: 2 to 4 percent maximum, at full-resistive load; 5 percent maximum, at rated nonlinear load.
7. Taps: Six (6) full-capacity compensation taps at 2.5 percent increments; two (2) above and four (4) below nominal voltage.

Retain option in "Full-Load Efficiency" Subparagraph below if transformer is K-factor rated.

8. Full-Load Efficiency: Minimum 96 percent at rated nonlinear load.
9. Magnetic-Field Strength External to Transformer Enclosure: Less than 0.1 gauss at 450 mm.
10. Audible Noise: Comply with NEMA ST 20.
11. Electrostatic Shielding: Independently shield each winding with a full-width, double, copper, electrostatic shield arranged to minimize interwinding capacitance.
 - a. Coil leads and terminal trips shall be arranged to minimize capacitive coupling between input and output connections.
 - b. Shield Terminal: Separate, and marked "Shield" for grounding connection. Shield shall be connected to the reference ground point for the distribution panels.
 - c. Capacitance: Limit capacitance between primary and secondary windings to a maximum of 33 picofarads over a frequency range of 20 Hz to 1 MHz.
 - d. Common-Mode Noise Attenuation: 120 dB minimum, 0.5 to 1.5 kHz; minus 65 dB minimum, 1.5 to 100 kHz.
 - e. Normal-Mode Noise Attenuation: 52 dB minimum, 1.5 to 10 kHz.
12. Neutral Rating: 1.732 times the system full-load ampere rating.

2.5 SPD SYSTEM

Coordinate this article with Section 264313 "Surge Protection for Low-Voltage Electrical Power Circuits."

- A. Description: Integrated SPD system, complying with Section 264313 "Transient-Voltage Protection for Low-Voltage Electrical Power Circuits," to protect unit panelboard, and having the following features:
 1. Disconnect Device: Manual, three-pole, fused disconnect switch to de-energize SPD system while permitting power distribution units to continue operation. Fuses are rated at 200-kA interrupting capacity.
 2. Nonlinear Loading: System shall accommodate rated-load current with a minimum 3.0 crest factor and 85 percent total harmonic distortion.

2.6 OUTPUT PANELBOARDS

- A. Description: Panelboards complying with Section 262416 "Panelboards" except for mounting provisions. Mount in front of power distribution units behind flush doors. Include the following features:
 1. Construction: 42 pole, 208 V, 3 phase; capable of accepting branch circuit breakers rated to 100 A.
 2. Panelboard Rating: 225 A, with main circuit breaker.
 3. Panelboard Phase, Neutral, and Ground Buses: Copper, with neutral bus at least 1.732 times the nominal phase bus rating.

Retain "Isolated Ground Bus" Subparagraph below to suit Project.

4. Isolated Ground Bus: Copper, adequate for branch-circuit equipment ground conductors; insulated from supports.
5. Branch Circuit Breakers: **[Bolt]** **[Plug]** on.
6. Cable Racks: Removable and arranged for supporting and routing cables for panelboard entrance.
7. Access Panels: Arranged so additional branch-circuit wiring can be installed and connected in the future.

2.7 POWER DISTRIBUTION UNIT CONTROLS

A. Include the following control features:

1. Emergency, power-off switch integral with power distribution unit.
2. Emergency, power-off input terminals for connection to remote power-off switch.

Revise first subparagraph and associated subparagraphs below if alarm-only indicator is preferable to automatic shutdown of unit on alarm.

3. Over-under alarm shutdown with automatic unit disconnection for the following alarm conditions:
 - a. High temperature.
 - b. High and low input or output voltage.
 - c. Phase loss.
 - d. Ground fault.
 - e. Reverse phase rotation.
4. Ground-fault protection with automatic system shutdown.
5. Alarm Contacts: Electrically isolated, Form C (one normally open and one normally closed), summary alarm; contact set shall change state if any monitored function goes into alarm mode.
6. Remote Power-Off Control: Control circuit with connection to shunt trip of power distribution unit main power circuit breaker and terminals for connection to one or more remote power-off, push-button stations.
7. Auxiliary Control Outputs: **<Insert control function outputs.>**

2.8 MONITORING, STATUS, AND ALARM ANNUNCIATION

Coordinate this article with Drawings and with remote indication and control provisions.

A. Description: Microprocessor-based monitoring, status, and alarm annunciation panel mounted flush in front of power distribution unit to provide status display and failure-indicating interface for the following:

1. Power Monitoring:
 - a. Input Voltage: Line to line, rms.
 - b. Output Voltage: Line to line, rms.
 - c. Output Voltage: Line to neutral, rms.

- d. Output current.
2. Status Indication: Unit on.
3. Alarm Annunciation:
 - a. High temperature in transformer coil.
 - b. High and low input voltage.
 - c. High and low output voltage.
 - d. Phase loss.
 - e. Ground fault.
 - f. Frequency.
 - g. Phase rotation.
 - h. SPD module failure.
4. Audible Alarm and Silencing Switch: Alarm sounds when alarm indication occurs. Silencing switch shall silence audible alarm but leave visual indication active until alarm condition is corrected.

2.9 SOUND LEVEL

Retain one of two paragraphs in this Article to specify sound-level requirements.

- A. General: Fully assembled products comply with minimum sound-level requirements in NEMA ST 20 for transformers of corresponding ratings when factory tested according to IEEE C57.12.91.
- B. General: Fully assembled products have a minimum of 3 dB less than the maximum sound levels prescribed for transformers of corresponding ratings when factory tested according to IEEE C57.12.91.

2.10 FINISHES

- A. Manufacturer's standard finish over corrosion-resistant pretreatment and primer.

2.11 SOURCE QUALITY CONTROL

- A. Factory Tests: Design and routine tests shall comply with referenced standards.

Retain "Factory Sound-Level Tests" Paragraph below if lower-than-standard sound level is critical. See Editing Instruction No. 2 in the Evaluations.

- B. Factory Sound-Level Tests: Conduct sound-level tests on equipment. Comply with IEEE C57.12.91 and NEMA ST 20.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Arrange power distribution units to provide adequate access to equipment and circulation of cooling air.

If appropriate, retain first paragraph below for projects in areas of seismic activity.

- B. Anchor or restrain floor-mounting power distribution units according to manufacturer's written instructions[, **seismic codes applicable to Project,**] and requirements in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- C. Identify equipment and install warning signs according to Section 260553 "Identification for Electrical Systems."

3.2 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
 - 1. Separately Derived Systems: Make grounding connections to grounding electrodes as indicated; comply with NFPA 70.
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

Retain paragraph and subparagraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections and prepare test reports.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph and subparagraphs below to describe tests and inspections to be performed by any of the entities in three paragraphs above.

- B. Tests and Inspections:

Tests referenced in first subparagraph below are from NETA Acceptance Testing Specification and include inspection procedures to verify proper installation. They also include tests and measurements of

circuit breakers and transformers. Tests include verification of circuit-breaker trip ranges by means of current-injection, insulation-resistance, and turns-ratio tests of transformers and similar items. Cost of extensive testing may not be warranted for some projects. Revise subparagraph to suit Project.

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification for circuit breakers, molded case; and for transformers, dry type, air cooled, low voltage. Certify compliance with test parameters.
 2. Perform functional tests of power distribution units throughout their operating ranges. Test each monitoring, status, and alarm function.
- C. Remove malfunctioning units, replace with new units, and retest as specified above.
- D. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of conductor and bus connections.
1. Use an infrared-scanning device designed to measure temperature or to detect significant deviations from normal values. Provide documentation of device calibration.
 2. Perform two follow-up infrared scans of main breaker, transformer, and panelboards, one at 4 months and the other at 11 months after Substantial Completion.
 3. Prepare a certified report identifying connections checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.
- E. Test Labeling: On completion of satisfactory testing of each unit, attach a dated and signed "Satisfactory Test" label to tested component.

3.4 STARTUP SERVICE

Delete this Article if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
1. Verify that power distribution units are installed and connected according to the Contract Documents.
 2. Verify that electrical wiring installation complies with manufacturer's submittal and with written installation requirements in other electrical Sections.
 3. Complete installation and startup checks according to manufacturer's written instructions.

3.5 ADJUSTING

- A. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

- B. Adjust power distribution units to provide optimal voltage to equipment served throughout normal operating cycle of loads served. Record input and output voltages and adjustment settings, and incorporate into test results.

3.6 CLEANING

- A. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain power distribution units. Refer to Section 017900 "Demonstration and Training."
- B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262600

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SECTION 262713 - ELECTRICITY METERING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes:
 - 1. Equipment for **[electricity metering by utility company] [and][electricity metering by Owner]**.
 - 2. Service Entrance requirements
 - 3. Secondary Connection Cabinet requirements.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. KY Pulse: Term used by the metering industry to describe a method of measuring consumption of electricity that is based on a relay opening and closing in response to the rotation of the disk in the meter.
- B. PC: Personal computer.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For electricity-metering equipment.
 - 1. Dimensioned plans and sections or elevation layouts.

Retain subparagraph below if equipment includes wiring.

- 2. Wiring Diagrams: For power, signal, and control wiring. Identify terminals and wiring designations and color-codes to facilitate installation, operation, and maintenance. Indicate recommended types, wire sizes, and circuiting arrangements for field-installed wiring, and show circuit protection features.
- 3. Secondary Connection Cabinets: drawings to be provided to the customer must contain the following strict criteria:
 - a. Equipment orientation and placement of the SCC and the transformer. This is an absolute requirement and must be adhered to in order to ensure the safety of our operating personnel.
 - b. Special secondary wire will be used from the transformer secondary enclosure to the SCC. The cable is Series 8000 aluminum alloy.
 - c. 18" maximum depth conduit/cable trough depth, necessary for operating crews to properly train the cable into the SCC.

1.5 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- B. Install service entrance in accordance with Contract Documents, the Utility Company's rules and regulations, and NFPA 70, National Electric Code (NEC) as adopted and amended by the Denver Building Code.
- C. Coordinate with Xcel Energy "Blue Book" for service entrance, metering and SCC requirements.

1.7 DELIVERY, STORAGE, AND HANDLING

Retain this article if modular meter center is specified.

- A. Receive, store, and handle modular meter center according to NECA 400.

1.8 PROJECT CONDITIONS

Retain this article if interruption of existing electrical service is required.

- A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering.
 - 2. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 - 3. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.

1.9 COORDINATION

- A. Electrical Service Connections: Coordinate with utility companies and components they furnish as follows:
 - 1. Comply with requirements of utilities providing electrical power services.
 - a. Xcel Energy.
 - 2. Coordinate installation and connection of utilities and services, including provision for electricity-metering components.

1.10 SECONDARY CONNECTION CABINET REQUIREMENTS

- A. A Secondary Connection Cabinet (SCC) is required when a customer's need for secondary cable terminations exceeds the number of allowable connections available for customer owned secondary in the transformer secondary compartment. The schedule of allowable runs per phase is published in the "Xcel Energy Standard for Electric Installation and Use" (the Blue Book). That and several drawings from the Blue Book are found on the following Pages.
- B. The SCC will be the customer's responsibility for purchase and installation, which includes the concrete field pour of the pad as a foundation for both the transformer and the SCC. The pad also includes the conduit/trough for the secondary cable between the transformer and the SCC.

1.11 SOFTWARE SERVICE AGREEMENT

Services in this article may not be allowed for publicly funded projects.

Retain article if Owner's metering includes billing software. Note that a PC is not included in this Section and, if needed, should be obtained separately.

- A. Technical Support: Beginning with Substantial Completion, provide software support for **[two (2)] <Insert number>** years.
- B. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within **[two (2)] <Insert number>** years from date of Substantial Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
 - 1. Provide **[thirty (30)] <Insert number>** days' notice to Owner to allow scheduling and access to system and to allow Owner to upgrade his computer equipment if necessary.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 EQUIPMENT FOR ELECTRICITY METERING BY UTILITY COMPANY

- A. Meters will be furnished by utility company.

- B. Meter base will be furnished by the contractor.
- C. Metering Transformer: Furnished by the utility company and installed by the contractor.

Retain and revise the remainder of this article to reflect utility company's requirements for equipment to be provided by Contractor.

- D. Current-Transformer Cabinets: Comply with requirements of electrical-power utility company.

Retain one or both of first two paragraphs below. Retain both if Owner's meter is not in a modular meter center.

- E. Meter Sockets: Comply with requirements of electrical-power utility company.
- F. Meter Sockets: Steady-state and short-circuit current ratings shall meet indicated circuit ratings.
- G. Modular Meter Center: Factory-coordinated assembly of a main service terminal box with lugs only, wireways, tenant meter socket modules, and tenant feeder circuit breakers arranged in adjacent vertical sections. Assembly shall be complete with interconnecting buses and other features as specified below.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Siemens Energy & Automation, Inc.
 - d. Square D; a brand of Schneider Electric.
 - e. **<Insert manufacturer's name>.**
 - f. or approved equal.
2. Comply with requirements of utility company for meter center.
3. Housing: NEMA 250, [**Type 1**] [**Type 3R**] enclosure.

Coordinate first subparagraph below with Drawings for indication of available fault current at meter-center supply terminals.

4. Minimum Short-Circuit Rating: [**22,000**] [**42,000**] [**65,000**] [**100,000**] **<Insert number>** A symmetrical at rated voltage.

Retain one of first two subparagraphs below if meter center is specified to have main terminal box with main lugs. Fusible switch may require more space. Consult manufacturers' data. Coordinate with Drawings for indication of poles, frame or size, and trip or fuse.

5. Main Disconnect Device: Circuit breaker, series-combination rated for use with downstream feeder and branch circuit breakers.

6. Main Disconnect Device: Fusible switch, series-combination rated by circuit-breaker manufacturer to protect downstream feeder and branch circuit breakers.

Coordinate first subparagraph below with Drawings for indication of trip setting and interrupting capacity of circuit breakers.

7. Tenant Feeder Circuit Breakers: Series-combination-rated molded-case units, rated to protect circuit breakers in downstream tenant and to house loadcenters and panelboards that have 10,000-A interrupting capacity.
 - a. Identification: Complying with requirements in Section 260553 "Identification for Electrical Systems" with legend identifying tenant's address.
 - b. Physical Protection: Tamper resistant, with hasp for padlock.
8. Meter Socket: Rating coordinated with indicated tenant feeder circuit rating.
9. Surge Protection: For main disconnect device, comply with requirements in Section 264313 "Transient-Voltage Protection for Low-Voltage Electrical Power Circuits."

2.2 EQUIPMENT FOR ELECTRICITY METERING BY OWNER

Retain this article to specify components for Owner's metering of feeders to tenants or designated loads, with or without external alarm, control, and communication capabilities, or other optional features. See Evaluations. Coordinate with Drawings.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
2. E-Mon; a division of Hunt Power.
3. National Meter Industries.
4. Osaki Meter Sales, Inc.
5. Square D; a brand of Schneider Electric.
6. **<Insert manufacturer's name>.**
7. or approved equal.

B. General Requirements for Owner's Meters:

1. All submetering equipment shall be compatible with the existing Eaton PowerNet metering network.
2. Comply with UL 1244.

See Evaluations for discussion about meter accuracy.

3. Meters used for billing shall have an accuracy of **[0.2] [0.5] [1.0]** percent of reading, complying with requirements in ANSI C12.20.

4. Meters shall be certified by [**California Type Evaluation Program**] <Insert **agency**> as complying with [**Title 4, California Code of Regulations, Article 2.2**] <Insert **regulatory requirements**>.
5. Enclosure: NEMA 250, [**Type 1**] [**Type 3R**] minimum, with hasp for padlocking or sealing.
6. Identification: Comply with requirements in Section 260553 "Identification for Electrical Systems."
7. Memory Backup: Self-contained to maintain memory throughout power outages of 72 hours, minimum.
8. Sensors: Current-sensing type, with current or voltage output, selected for optimum range and accuracy for meters indicated for this application.

Split-core sensor in first subparagraph below is installed in switchboard or panelboard without disturbing feeder connection but is less accurate. Solid-core sensor is usually installed in a separate compartment or in a separate current-transformer cabinet. Coordinate with Drawings.

- a. Type: [**Split**] [**and**] [**solid**] core.

Current-transformer cabinet in first subparagraph below may be required for some solid-core current sensors. Consult manufacturers' literature. Coordinate with Drawings.

9. Current-Transformer Cabinet: Listed or recommended by metering equipment manufacturer for use with sensors indicated.

Subparagraph below specifies an optional feature for kilowatt-hour and demand meters. Retain subparagraph to have meter provide power consumption and demand information to a building automation system to support demand-limiting action by that system. Coordinate with design of building automation system.

10. Building Automation System (BAS) Interface: One digital KY pulse to a user-definable increment of energy measurement. Match signal to [**BAS**] <Insert **signal destination**> input and arrange to convey the instantaneous, integrated, demand level measured by meter to provide data for processing and possible programmed demand control action by destination system.
- C. Kilowatt-hour Meter: Electronic [**single**] [**three**] [**single- and three**]-phase meters, measuring electricity used.
1. Voltage and Phase Configuration: Meter shall be designed for use on circuits with voltage rating and phase configuration indicated for its application.

Retain one of two subparagraphs below.

2. Display: LCD with characters not less than 0.25 inch (6 mm) high, indicating accumulative kilowatt-hours and current kilowatt load. Retain accumulated kilowatt-hour in a nonvolatile memory, until reset.
3. Display: Digital electromechanical counter, indicating accumulative kilowatt-hours.

The demand interval in first paragraph below should be same as used by the utility.

- D. Kilowatt-hour/Demand Meter: Electronic **[single] [three] [single- and three]**-phase meters, measuring electricity use and demand. Demand shall be integrated over a **[15-minute] <Insert value>** interval.
1. Voltage and Phase Configuration: Meter shall be designed for use on circuits with voltage rating and phase configuration indicated for its application.
 2. Display: LCD with characters not less than **0.25 inch (6 mm)** high, indicating accumulative kilowatt-hours, **[current time and date,]current demand,[and] historic peak demand[, and time and date of historic peak demand]**. Retain accumulated kilowatt-hour and historic peak demand in a nonvolatile memory, until reset.
- E. Data Transmission Cable: Transmit KY pulse data over Class 1 control-circuit conductors in raceway. Comply with Section 260523 "Control-Voltage Electrical Power Cables."

See Evaluations for discussion about using metered data for allocation of utility costs.

- F. Software: PC based, a product of meter manufacturer, suitable for calculation of utility cost allocation **[and billing]**.
1. Utility Cost Allocation: Automatically import energy-usage records to allocate energy costs for the following:
 - a. At least **[15] <Insert number>** departments.
 - b. At least **[30] <Insert number>** tenants.
 - c. At least **[five] <Insert number>** processes.
 - d. At least **[five] <Insert number>** buildings.
 - e. **<Insert entity>**.
 2. Tenant or Activity Billing Software: Automatically import energy-usage records to automatically compute and prepare **[tenant bills] [activity demand and energy-use statements]** based on metering of energy use **[and peak demand]**. Maintain separate directory for each tenant's historical billing information. Prepare summary reports in user-defined formats and time intervals.

2.3 SERVICE CONNECTION CABINETS

- A. A service connection cabinet is required when the total number conductors or size of the conductors exceeds the values listed in Table II in Article 3 of this Section. If a service connection cabinet is required, it shall be purchased, installed and maintained at the expense of the customer. A concrete pad shall also be installed by the customer that will accommodate both the service connection cabinet and the pad-mounted transformer, which feeds the service connection cabinet. Arrangements for the utilization of a service connection cabinet may be made by contacting the assigned Company Area Engineer.

- B. The following are the approved suppliers of specified SCC's. They are available with or without metering provisions. The customers should present their requests to local electrical distributors for purchase from these suppliers. All suppliers will sell their cabinets though out the Xcel Energy service territory. They have specifications on file both for the metered and non-metered cabinets. Erickson sells a unit that has a service disconnect and metering provisions, the use of which is optional depending on the preference of the customer.

Verify that the phone numbers noted below are current.

1. EMI-Electrical Mechanical Industries.
 - a. Phone: 800-536-3678 or 763-588-0536.
2. Erickson Electrical Equipment Company.
 - a. Phone: 847-640-7701.
3. AMP-American Midwest Power.
 - a. Phone: 800-328-8658.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Comply with equipment installation requirements in NECA 1.

Retain first paragraph below to require installation of utility company's equipment. Coordinate with Drawings. Revise to suit utility company's requirements.

- B. Install meters furnished by utility company. Install raceways and equipment according to utility company's written requirements. Provide empty conduits for metering leads and extend grounding connections as required by utility company.

Retain paragraph below if modular meter center is specified.

- C. Install modular meter center according to NECA 400 switchboard installation requirements.
- D. Secondary Connection Cabinets
1. The number of conductors that may be terminated in a pad-mounted transformer is governed by the WA rating of the transformer and the size of the conductors as shown in Table II below. If a customer requires a larger number and/or size of conductors than listed in Table II, a service connection cabinet will be required.

TABLE I
 SECONDARY PEDESTAL

Copper		Aluminum	
Maximum Runs	Maximum Size	Maximum Runs	Maximum Size
5	350	5	350

TABLE II
 PAD MOUNTED TRANSFORMERS

KVA Rating	Copper		Aluminum	
	Maximum Runs	Maximum Size	240/120 Volt 1	Maximum Runs
240/120 Volt 1 (D All Sizes	2	500	2	750
208 Grd Y/120 Volt				
75	4	500	4	750
150	4	500	4	750
300	4	500	4	750
500	6	500	6	750
750	8	500	8	750
1000	8	500	8	750
480 Grd Y1277 Volt				
75	4	500	4	750
150	4	500	4	750
300	4	500	4	750
500	4	500	4	750
750	6	500	6	750
1000	6	500	6	750
1500	6	500	6	750
2000	8	500	8	750
2500	8	500	8	750

3.2 IDENTIFICATION

- A. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
1. Series Combination Warning Label: Self-adhesive type, with text as required by NFPA 70.
 2. Equipment Identification Labels: Adhesive film labels with clear protective overlay.

3.3 FIELD QUALITY CONTROL

Retain this article if Owner's electricity-metering equipment is specified.

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- B. Tests and Inspections:

1. Connect a load of known kilowatt rating, [1.5] <Insert number> kW minimum, to a circuit supplied by metered feeder.
2. Turn off circuits supplied by metered feeder and secure them in off condition.
3. Run test load continuously for eight hours minimum, or longer, to obtain a measurable meter indication. Use test-load placement and setting that ensures continuous, safe operation.
4. Check and record meter reading at end of test period and compare with actual electricity used, based on test-load rating, duration of test, and sample measurements of supply voltage at test-load connection. Record test results.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Electricity metering will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262713

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SECTION 262726 - WIRING DEVICES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Receptacles, receptacles with integral GFCI, and associated device plates.
 - 2. Twist-locking receptacles.
 - 3. Receptacles with integral surge-suppression units.
 - 4. Isolated-ground receptacles.
 - 5. Tamper-resistant receptacles.
 - 6. Weather-resistant receptacles.
 - 7. Snap switches and wall-box dimmers.
 - 8. Solid-state fan speed controls.
 - 9. Wall-switch and exterior occupancy sensors.
 - 10. Pendant cord-connector devices.
 - 11. Cord and plug sets.
 - 12. Floor service outlets, poke-through assemblies, and multioutlet assemblies.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. EMI: Electromagnetic interference.
- B. GFCI: Ground-fault circuit interrupter.
- C. Pigtail: Short lead used to connect a device to a branch-circuit conductor.
- D. RFI: Radio-frequency interference.
- E. SPD: Surge Protective Device.
- F. UTP: Unshielded twisted pair.

1.4 ADMINISTRATIVE REQUIREMENTS

Retain this article if receptacles for Owner-furnished equipment with plugs have unknown or special configurations.

- A. Coordination:
 - 1. Receptacles for Owner-Furnished Equipment: Match plug configurations.

Retain "Cord and Plug Sets" Subparagraph below if retaining "Cord and Plug Sets" Article.

- 2. Cord and Plug Sets: Match equipment requirements.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: List of legends and description of materials and process used for premarking wall plates.

Retain "Samples" Paragraph below if products have critical features needing hands-on appraisal.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: One for each type of device and wall plate specified, in each color specified.

1.6 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For wiring devices to include in all manufacturers' packing-label warnings and instruction manuals that include labeling conditions.

1.8 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Floor Service-Outlet Assemblies: [**One for every 10**] <Insert quantities>, but no fewer than [**one**] <Insert number>.
 - 2. Poke-Through, Fire-Rated Closure Plugs: [**One for every five**] <Insert quantities> floor service outlets installed, but no fewer than [**two**] <Insert number>.
 - 3. TVSS Receptacles: [**One for every 10**] <Insert quantities> of each type installed, but no fewer than [**two of each type**] <Insert number>.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

- A. Manufacturers' Names: Shortened versions (shown in parentheses) of the following manufacturers' names are used in other Part 2 articles:

Manufacturers listed below produce an extensive line of nationally distributed wiring devices.

1. Cooper Wiring Devices; Division of Cooper Industries, Inc. (Cooper).
2. Hubbell Incorporated; Wiring Device-Kellems (Hubbell).
3. Leviton Mfg. Company Inc. (Leviton).
4. Pass & Seymour/Legrand (Pass & Seymour).
5. <Insert manufacturer>
6. or approved equal.

- B. Source Limitations: Obtain each type of wiring device and associated wall plate from single source from single manufacturer.

2.2 GENERAL WIRING-DEVICE REQUIREMENTS

- A. Wiring Devices, Components, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Comply with NFPA 70.

Not all standard devices are available with a modular plug-in configuration. For example, this Section does not include specifications for modular devices.

- C. Devices that are manufactured for use with modular plug-in connectors may be substituted under the following conditions:
1. Connectors shall comply with UL 2459 and shall be made with stranding building wire.
 2. Devices shall comply with the requirements in this Section.

2.3 STRAIGHT-BLADE RECEPTACLES

- A. Unless noted otherwise, all general-use straight blade devices shall be gray.
- B. Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, and FS W-C-596.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

Catalog numbers in subparagraphs below are for 20-A, heavy-duty, specification-grade, nylon-face devices; revise catalog numbers to require other configurations and ratings.

- a. Cooper; 5351 (single), CR5362 (duplex).
- b. Hubbell; HBL5351 (single), HBL5352 (duplex).
- c. Leviton; 5891 (single), 5352 (duplex).
- d. Pass & Seymour; 5361 (single), 5362 (duplex).
- e. **<Insert manufacturer>**
- f. or approved equal.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

Isolated-ground receptacles are available in a variety of configurations and ratings including locking-blade types up to 50 A and 250 V. Revise "Isolated-Ground, Duplex Convenience Receptacles, 125 V, 20 A" Paragraph below to suit Project; indicate different types on Drawings.

- C. Isolated-Ground, Duplex Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, and FS W-C-596.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; IG5362RN.
 - b. Hubbell; IG5362.
 - c. Leviton; 5362-IG.
 - d. Pass & Seymour; IG5362.
 - e. **<Insert manufacturer>**
 - f. or approved equal.
2. Description: Straight blade; equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.

Receptacles in "Tamper-Resistant Convenience Receptacles, 125 V, 20 A" Paragraph below are for installation in pediatric-care locations.

- D. Tamper-Resistant Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498 Supplement sd, and FS W-C-596.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; TR8300.
 - b. Hubbell; HBL8300SGA.
 - c. Leviton; 8300-SGG.
 - d. Pass & Seymour; TR63H.
 - e. **<Insert manufacturer>**
 - f. or approved equal.

2.4 GFCI RECEPTACLES

- A. Unless noted otherwise, all GFI receptacles shall be gray.

Non-feed-through-type GFCI unit shall be selected where no protection of downstream receptacles is required.

- B. General Description:

1. Straight blade, feed through type.
2. Comply with NEMA WD 1, NEMA WD 6, UL 498, UL 943 Class A, and FS W-C-596.
3. Include indicator light that shows when the GFCI has malfunctioned and no longer provides proper GFCI protection.

- C. Duplex GFCI Convenience Receptacles, 125 V, 20 A:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

Catalog numbers in list below are for feed-through types, arranged to protect receptacles downstream on the same circuit; revise catalog numbers if non-feed-through types are required.

- a. Cooper; VGF20.
- b. Hubbell; GFR5352L.
- c. Pass & Seymour; 2095.
- d. Leviton; 7599.
- e. **<Insert manufacturer>**
- f. or approved equal.

- D. Tamper-Resistant GFCI Convenience Receptacles, 125 V, 20 A:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

Catalog numbers in list below are for feed-through types, arranged to protect receptacles downstream on the same circuit; revise catalog numbers if non-feed-through types are required.

- a. Hubbell; GFTR20.
- b. Pass & Seymour; 2095TR.
- c. **<Insert manufacturer>**
- d. or approved equal.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

2.5 SPD RECEPTACLES

- A. Unless noted otherwise, all SPD receptacles shall be gray.

See Editing Instruction No. 3 in the Evaluations for information on SPD ratings.

- B. General Description: Comply with NEMA WD 1, NEMA WD 6, UL 498, UL 1449, and FS W-C-596, with integral SPD in line to ground, line to neutral, and neutral to ground.

1. SPD Components: Multiple metal-oxide varistors; with a nominal clamp-level rating of 400 V and minimum single transient pulse energy dissipation of 240 J, according to IEEE C62.41.2 and IEEE C62.45.
2. Active SPD Indication: Visual and audible, with light visible in face of device to indicate device is "active" or "no longer in service."

- C. Duplex SPD Convenience Receptacles:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

Catalog numbers in list below are for products with visual-only indication.

- a. Cooper; 5362BLS.
- b. Hubbell; HBL5362SA.
- c. Leviton; 5380.
- d. Pass & Seymour; 5362BLSP.
- e. <Insert manufacturer>
- f. or approved equal.

2. Description: Straight blade, 125 V, 20 A; NEMA WD 6 Configuration 5-20R.

- D. Isolated-Ground, Duplex Convenience Receptacles:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

- a. Cooper; IG5362BLS.
- b. Hubbell; IG5362SA.
- c. Leviton; 5380-IG.
- d. Pass & Seymour; IG5362BLSP.
- e. <Insert manufacturer>
- f. or approved equal.

2. Description:

- a. Straight blade, 125 V, 20 A; NEMA WD 6 Configuration 5-20R.

- b. Equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.

2.6 HAZARDOUS (CLASSIFIED) LOCATION RECEPTACLES

- A. **[Available]** Wiring Devices for Hazardous (Classified) Locations: Comply with NEMA FB 11 and UL 1010.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cooper Crouse-Hinds.
 - b. EGS/Appleton Electric.
 - c. Killark; Division of Hubbell Inc.
 - d. **<Insert manufacturer>**
 - e. or approved equal.

2.7 TWIST-LOCKING RECEPTACLES

- A. Single Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 Configuration L5-20R, and UL 498.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; CWL520R.
 - b. Hubbell; HBL2310.
 - c. Leviton; 2310.
 - d. Pass & Seymour; L520-R.
 - e. **<Insert manufacturer>**
 - f. or approved equal.

- B. Isolated-Ground, Single Convenience Receptacles, 125 V, 20 A:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; IGL520R.
 - b. Hubbell; IG2310.
 - c. Leviton; 2310-IG.

- d. Pass & Seymour; IG4700.
- e. <Insert manufacturer>
- f. or approved equal.

2. Description:

- a. Comply with NEMA WD 1, NEMA WD 6 Configuration L5-20R, and UL 498.
- b. Equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.

2.8 PENDANT CORD-CONNECTOR DEVICES

Revise NEMA configuration in "Description" Paragraph below to suit Project. Delete "External Cable Grip" Subparagraph if not required.

A. Description:

- 1. Matching, locking-type plug and receptacle body connector.
- 2. NEMA WD 6 Configurations L5-20P and L5-20R, heavy-duty grade, and FS W-C-596.
- 3. Body: Nylon, with screw-open, cable-gripping jaws and provision for attaching external cable grip.
- 4. External Cable Grip: Woven wire-mesh type made of high-strength, galvanized-steel wire strand, matched to cable diameter, and with attachment provision designed for corresponding connector.

2.9 CORD AND PLUG SETS

Retain this article if cord and plug sets for equipment are furnished by Owner or are specified in other Sections. Coordinate with other Sections and with Part 3.

A. Description:

- 1. Match voltage and current ratings and number of conductors to requirements of equipment being connected.
- 2. Cord: Rubber-insulated, stranded-copper conductors, with Type SOW-A jacket; with green-insulated grounding conductor and ampacity of at least 130 percent of the equipment rating.
- 3. Plug: Nylon body and integral cable-clamping jaws. Match cord and receptacle type for connection.

2.10 TOGGLE SWITCHES

- A. Comply with NEMA WD 1, UL 20, and FS W-S-896.
- B. Unless noted otherwise, toggle switches shall be gray.

C. Switches, 120/277 V, 20 A:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

Catalog numbers in lists below are for 20-A devices; revise catalog numbers to require other configurations and ratings.

a. Single Pole:

- 1) Cooper; AH1221.
- 2) Hubbell; HBL1221.
- 3) Leviton; 1221-2.
- 4) Pass & Seymour; CSB20AC1.
- 5) **<Insert manufacturer's name; catalog number(s)>**.
- 6) or approved equal.

b. Two Pole:

- 1) Cooper; AH1222.
- 2) Hubbell; HBL1222.
- 3) Leviton; 1222-2.
- 4) Pass & Seymour; CSB20AC2.
- 5) **<Insert manufacturer's name; catalog number(s)>**.
- 6) or approved equal.

c. Three Way:

- 1) Cooper; AH1223.
- 2) Hubbell; HBL1223.
- 3) Leviton; 1223-2.
- 4) Pass & Seymour; CSB20AC3.
- 5) **<Insert manufacturer's name; catalog number(s)>**.
- 6) or approved equal.

d. Four Way:

- 1) Cooper; AH1224.
- 2) Hubbell; HBL1224.
- 3) Leviton; 1224-2.
- 4) Pass & Seymour; CSB20AC4.
- 5) or approved equal.

D. Pilot-Light Switches, 20 A:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:

- a. Cooper; AH1221PL for 120 and 277 V.
 - b. Hubbell; HBL1201PL for 120 and 277 V.
 - c. Leviton; 1221-LH1.
 - d. Pass & Seymour; PS20AC1RPL for 120 V, PS20AC1RPL7 for 277 V.
 - e. **<Insert manufacturer>**
 - f. or approved equal.
2. Description: Single pole, with neon-lighted handle, illuminated when switch is "off."

E. Key-Operated Switches, 120/277 V, 20 A:

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; AH1221L.
 - b. Hubbell; HBL1221L.
 - c. Leviton; 1221-2L.
 - d. Pass & Seymour; PS20AC1-L.
 - e. **<Insert manufacturer>**
 - f. or approved equal.
2. Description: Single pole, with factory-supplied key in lieu of switch handle.

F. Single-Pole, Double-Throw, Momentary-Contact, Center-off Switches: 120/277 V, 20 A; for use with mechanically held lighting contactors.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; 1995.
 - b. Hubbell; HBL1557.
 - c. Leviton; 1257.
 - d. Pass & Seymour; 1251.
 - e. **<Insert manufacturer>**
 - f. or approved equal.

G. Key-Operated, Single-Pole, Double-Throw, Momentary-Contact, Center-off Switches: 120/277 V, 20 A; for use with mechanically held lighting contactors, with factory-supplied key in lieu of switch handle.

Retain "Products" Subparagraph and list of manufacturers and products below to require specific products or a comparable product from other manufacturers.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Cooper; 1995L.

- b. Hubbell; HBL1557L.
- c. Leviton; 1257L.
- d. Pass & Seymour; 1251L.
- e. **<Insert manufacturer>**
- f. or approved equal.

2.11 WALL-BOX DIMMERS

- A. Dimmer Switches: Modular, full-wave, solid-state units with integral, quiet on-off switches, with audible frequency and EMI/RFI suppression filters.

Four-way switching may be added to "Control" Paragraph below after verifying availability with manufacturers.

- B. Control: Continuously adjustable [**slider**] [**toggle switch**] [**rotary knob**]; with single-pole or three-way switching. Comply with UL 1472.
- C. Incandescent Lamp Dimmers: 120 V; control shall follow square-law dimming curve. On-off switch positions shall bypass dimmer module.

Retain one of two subparagraphs below. UL 1472 covers ratings from 300 to 2000 W in increments of 50 W.

- 1. 600 W; dimmers shall require no derating when ganged with other devices. [**Illuminated when "off."**]
- 2. **<Insert wattage ratings and descriptions>**.

Retain "Fluorescent Lamp Dimmer Switches" Paragraph below with compatible dimming-type ballasts. Coordinate with Section 265100 "Interior Lighting." Use uniform ballast and lamp types to obtain consistent dimming characteristics.

- D. Fluorescent Lamp Dimmer Switches: Modular; compatible with dimmer ballasts; trim potentiometer to adjust low-end dimming; dimmer-ballast combination capable of consistent dimming with low end not greater than 20 percent of full brightness.

2.12 WALL PLATES

- A. Single and combination types shall match corresponding wiring devices.
 - 1. Plate-Securing Screws: Metal with head color to match plate finish.
 - 2. Material for Finished Spaces: Type 302/304 stainless steel 0.04 inch (1mm) thick.
 - 3. Material for Unfinished Spaces: Type 302/304 stainless steel 0.04 inch (1mm) thick.
 - 4. Material for Damp Locations: Type 302/304 stainless steel 0.04 inch (1mm) thick.
 - 5. Plastic covers will not be accepted.
- B. Wet-Location, Weatherproof Cover Plates: NEMA 250, complying with Type 3R, weather-resistant, Type 302/304 satin stainless steel with lockable cover.

2.13 FLOOR SERVICE FITTINGS

Service fittings in "Type" Paragraph below are available for voice and data communication cabling as well as for power.

- A. Type: Modular, **recessed**, dual-service units suitable for wiring method used.
- B. Compartments: Barrier separates power from voice and data communication cabling.
- C. Service Plate: [**Rectangular**] [**Round**], 302/304 stainless steel with satin finish.
 - 1. Plastic covers will not be accepted.
- D. Power Receptacle: NEMA WD 6 Configuration 5-20R, gray finish, unless otherwise indicated.
- E. Voice and Data Communication Outlet: [**Blank cover with bushed cable opening**] [**Two modular, keyed, color-coded, RJ-45 jacks for UTP cable complying with requirements in Section 271500 "Communications Horizontal Cabling."**]
- F. Protrusion above finished floor: 0.15", maximum.

2.14 POKE-THROUGH ASSEMBLIES

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

Coordinate poke-through device size, type, finish, color, and floor protrusion requirements with DEN Project Manager prior to specifying devices."

- A. Manufactures: Subject to compliance with requirements, provide products by one of the following:
 - 1. Hubbell Incorporated; Wiring Device-Kellems.
 - 2. Pass & Seymour/Legrand.
 - 3. Square D/Schneider Electric.
 - 4. Thomas & Betts Corporation.
 - 5. Wiremold/Legrand.
 - 6. **<Insert manufacturer>**
 - 7. or approved equal.
- B. Description:
 - 1. Factory-fabricated and -wired assembly of below-floor junction box with multichanneled, through-floor raceway/firestop unit and detachable matching floor service-outlet assembly.
 - 2. Comply with UL 514 scrub water exclusion requirements.

Coordinate "Service-Outlet Assembly" Subparagraph below with Section 271500 "Communications Horizontal Cabling."

3. Service-Outlet Assembly: [**Recessed type with two simplex receptacles**] [**Recessed type with four simplex receptacles**] [**Recessed type with two simplex receptacles and space for two RJ-45 jacks**] <insert assembly type>complying with requirements in Section 271500 "Communications Horizontal Cabling."

Larger-diameter assembly in "Size" Subparagraph below is available for four simplex receptacles and four voice and data communication outlets in a single, flush-type service outlet.

4. Size: Selected to fit nominal [**3-inch (75-mm)**] [**4-inch (100-mm)**] cored holes in floor and matched to floor thickness.

Revise "Fire Rating" Subparagraph below to coordinate with fire ratings.

5. Fire Rating: Unit is listed and labeled for fire rating of floor-ceiling assembly.
6. Closure Plug: Arranged to close unused [**3-inch (75-mm)**] [**4-inch (100-mm)**] cored openings and reestablish fire rating of floor.
7. Protrusion above finished floor: 0.15", maximum

Coordinate "Wiring Raceways and Compartments" Subparagraph below with Section 271500 "Communications Horizontal Cabling."

8. Wiring Raceways and Compartments: For a minimum of four No. 12 AWG conductors and a minimum of [**two (2)**] [**four (4)**], four-pair cables that comply with requirements in Section 271500 "Communications Horizontal Cabling."
9. Entire cover assembly shall be constructed of [**302/304 satin stainless steel**] [**brass**] [**brushed aluminum**]. Plastic covers will not be accepted.

2.15 PREFABRICATED MULTIOUTLET ASSEMBLIES

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Hubbell Incorporated; Wiring Device-Kellems.
 2. Wiremold/Legrand.
 3. <Insert manufacturer>
 4. or approved equal.

If not indicated on Drawings, add mounting heights, raceway sizes, and types and spacing of receptacle devices to "Description" Paragraph below. Add descriptions of special features in assemblies such as fused receptacles, special-purpose switches, and channels for communication wiring.

- B. Description:
 1. Two-piece surface metal raceway, with factory-wired multioutlet harness.
 2. Components shall be products from single manufacturer designed for use as a complete, matching assembly of raceways and receptacles.
 3. Covers to be 302/304 satin stainless steel. Plastic covers will not be accepted.

Some finish options may be available from manufacturers. Retain "Raceway Material" or "Multioutlet Harness" paragraphs below and revise to suit Project.

- C. Raceway Material: [**Metal, with manufacturer's standard finish**] [**PVC**].
- D. Multioutlet Harness:
 - 1. Receptacles: 15-A, 125-V, NEMA WD 6 Configuration 5-15R receptacles complying with NEMA WD 1, UL 498, and FS W-C-596.
 - 2. Receptacle Spacing: [**6 inches (150 mm)**] [**9 inches (230 mm)**] [**12 inches (300 mm)**] [**18 inches (460 mm)**].
 - 3. Wiring: No. 12 AWG solid, Type THHN copper, [**single circuit**] [**two circuit, connecting alternating receptacles**].

2.16 FINISHES

See Editing Instruction No. 2 in the Evaluations for a discussion of wiring-device colors. Coordinate with Drawings.

A. Device Color:

Retain "Wiring Devices Connected to Normal Power System" Subparagraph below unless colors are indicated or scheduled on Drawings. If retaining subparagraph, revise title if a separate emergency power system serving wiring devices is not provided.

- 1. Wiring Devices Connected to Normal Power System: Gray

Retain "Wiring Devices Connected to Emergency Power System" Subparagraph below if a separate emergency power system serving wiring devices are required.

- 2. Wiring Devices Connected to Emergency Power System: Red
- 3. SPD Devices: Blue.
- 4. Isolated-Ground Receptacles: Orange

B. Wall Plate Finish: 302/304 satin stainless steel. Plastic covers will not be accepted.

PART 3 - EXECUTION

3.1 INSTALLATION

NECA 1 referenced in first paragraph below includes device mounting-height requirements. See "Mounting Heights and Locations" Article in the Evaluations for device mounting heights in that standard.

- A. Comply with NECA 1, including mounting heights listed in that standard, unless otherwise indicated.

See Editing Instruction No. 4 in the Evaluations for timing and sequencing of construction to assist in avoiding contamination of devices during construction.

- B. Coordination with Other Trades:

1. Protect installed devices and their boxes. Do not place wall finish materials over device boxes and do not cut holes for boxes with routers that are guided by riding against outside of boxes.
2. Keep outlet boxes free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
3. Install device boxes in brick or block walls so that the cover plate does not cross a joint unless the joint is troweled flush with the face of the wall.
4. Install wiring devices after all wall preparation, including painting, is complete.

C. Conductors:

1. Do not strip insulation from conductors until right before they are spliced or terminated on devices.
2. Strip insulation evenly around the conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.
3. The length of free conductors at outlets for devices shall meet provisions of NFPA 70, Article 300, without pigtails.
4. Existing Conductors:
 - a. Cut back and pigtail, or replace all damaged conductors.
 - b. Straighten conductors that remain and remove corrosion and foreign matter.
 - c. Pigtailling existing conductors is permitted, provided the outlet box is large enough.

D. Device Installation:

1. Replace devices that have been in temporary use during construction and that were installed before building finishing operations were complete.
2. Keep each wiring device in its package or otherwise protected until it is time to connect conductors.
3. Do not remove surface protection, such as plastic film and smudge covers, until the last possible moment.
4. Connect devices to branch circuits using pigtails that are not less than **6 inches (152 mm)** in length.
5. When there is a choice, use side wiring with binding-head screw terminals. Wrap solid conductor tightly clockwise, two-thirds to three-fourths of the way around terminal screw.
6. Use a torque screwdriver when a torque is recommended or required by manufacturer.
7. When conductors larger than No. 12 AWG are installed on 15- or 20-A circuits, splice No. 12 AWG pigtails for device connections.
8. Tighten unused terminal screws on the device.
9. When mounting into metal boxes, remove the fiber or plastic washers used to hold device-mounting screws in yokes, allowing metal-to-metal contact.
10. Mounting heights shall be as shown on drawings. If no heights noted, standard device heights above finished floor are as follows:

- a. Wall switches: 48"
- b. Convenience receptacles: 18"

E. Receptacle Orientation:

Retain first subparagraph below if the position of the ground pin is important for consistency. Trade and professional literature is inconsistent in recommending benefits of either orientation.

- 1. Install ground pin of vertically mounted receptacles down, and on horizontally mounted receptacles install ground pin to the right.

F. Device Plates: Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening.

G. Dimmers:

- 1. Install dimmers within terms of their listing.
- 2. Verify that dimmers used for fan speed control are listed for that application.
- 3. Install unshared neutral conductors on line and load side of dimmers according to manufacturers' device listing conditions in the written instructions.

Coordinate both paragraphs below with Drawings.

H. Arrangement of Devices: Unless otherwise indicated, mount flush, with long dimension vertical and with grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.

I. Adjust locations of floor service outlets to suit arrangement of partitions and furnishings.

3.2 GFCI RECEPTACLES

- A. Install non-feed-through-type GFCI receptacles where protection of downstream receptacles is not required.

3.3 IDENTIFICATION

- A. Comply with Section 260553 "Identification for Electrical Systems."
- B. Identify each receptacle with panelboard identification and circuit number. Use hot, stamped, or engraved machine printing with black filled lettering on face of plate, and durable wire markers or tags inside outlet boxes.

3.4 FIELD QUALITY CONTROL

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 - 1. Test Instruments: Use instruments that comply with UL 1436.
 - 2. Test Instrument for Convenience Receptacles: Digital wiring analyzer with digital readout or illuminated digital-display indicators of measurement.

- B. Tests for Convenience Receptacles:
 - 1. Line Voltage: Acceptable range is 105 to 132 V.
 - 2. Percent Voltage Drop under 15-A Load: A value of 6 percent or higher is unacceptable.
 - 3. Ground Impedance: Values of up to 2 ohms are acceptable.
 - 4. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.
 - 5. Using the test plug, verify that the device and its outlet box are securely mounted.
 - 6. Tests shall be diagnostic, indicating damaged conductors, high resistance at the circuit breaker, poor connections, inadequate fault current path, defective devices, or similar problems. Correct circuit conditions, remove malfunctioning units and replace with new ones, and retest as specified above.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- C. Wiring device will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262726

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SECTION 262813 - FUSES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Cartridge fuses rated 600-V ac and less for use in **[control circuits] [enclosed switches] [panelboards] [switchboards] [enclosed controllers] [and] [motor-control centers]**.
 - 2. Plug fuses rated 125-V ac and less for use in plug-fuse-type **[enclosed switches] [fuseholders] [and] [panelboards]**.

Retain first subparagraph below if retaining rejection-base-type plug fuses and if Project contains fuseholders with Edison-base, plug-fuse sockets.

- 3. Plug-fuse adapters for use in Edison-base, plug-fuse sockets.
- 4. Spare-fuse cabinets.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for spare-fuse cabinets. Include the following for each fuse type indicated:

Retain "Ambient Temperature Adjustment Information" Subparagraph if variations in fuse performance due to ambient temperature extremes can affect system performance.

1. Ambient Temperature Adjustment Information: If ratings of fuses have been adjusted to accommodate ambient temperatures, provide list of fuses with adjusted ratings.
 - a. For each fuse having adjusted ratings, include location of fuse, original fuse rating, local ambient temperature, and adjusted fuse rating.
 - b. Provide manufacturer's technical data on which ambient temperature adjustment calculations are based.
2. Dimensions and manufacturer's technical data on features, performance, electrical characteristics, and ratings.

Retain subparagraphs below if final system short-circuit and coordination studies will be performed by the designer or will be assigned to an independent consultant. These curves are beneficial to Owner for future additions or reevaluations of settings of overcurrent protective devices.

3. Current-limitation curves for fuses with current-limiting characteristics.

Although some manufacturers no longer offer curves on translucent graph paper, curves can normally be downloaded from manufacturers' Web sites or be obtained, in electronic form, from various coordination software vendors as part of a subscription service. Retain option in first subparagraph below only if retained manufacturers offer curves on graph paper.

4. Time-current coordination curves (average melt) and current-limitation curves (instantaneous peak let-through current) for each type and rating of fuse. Submit **[in electronic format suitable for use in coordination software] [and] [in PDF format]**.
5. Coordination charts and tables and related data.

Retain subparagraph below if Project includes elevators and fused elevator shunt-trip switches.

6. Fuse sizes for elevator feeders and elevator disconnect switches.
7. Include data substantiating that materials comply with requirements.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fuses to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

1. Ambient temperature adjustment information.

2. Current-limitation curves for fuses with current-limiting characteristics.
3. Time-current coordination curves (average melt) and current-limitation curves (instantaneous peak let-through current) for each type and rating of fuse used on the Project. Submit **[in electronic format suitable for use in coordination software] [and] [in PDF format]**.
4. Coordination charts and tables and related data.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.5 MAINTENANCE MATERIAL SUBMITTALS

Coordinate this article with other electrical Sections, and Sections in other Divisions specifying fuses, for quantities of spare fuses to include. Do not include spare fuses in this Section if spare fuses are already specified in other electrical Sections or in Sections in other Divisions.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Fuses: Equal to **[ten (10)] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[three (3)] <Insert number>** of each size and type.

1.6 QUALITY ASSURANCE

- A. Source Limitations: Obtain fuses, for use within a specific product or circuit, from single source from single manufacturer.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with NEMA FU 1 for cartridge fuses.
- D. Comply with NFPA 70.
- E. Comply with UL 248-11 for plug fuses.

1.7 PROJECT CONDITIONS

For fuses installed outdoors or in unusual environmental conditions, revise this article to indicate minimum and maximum ambient temperatures and expected humidity range. See "Ambient Air Temperature Compensation" Paragraph in the Evaluations.

- A. Where ambient temperature to which fuses are directly exposed is less than **[40 deg F (5 deg C)] <Insert temperature>** or more than **[100 deg F (38 deg C)] <Insert temperature>**, apply manufacturer's ambient temperature adjustment factors to fuse ratings.

1.8 COORDINATION

- A. Coordinate fuse ratings with utilization equipment nameplate limitations of maximum fuse size and with system short-circuit current levels.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Cooper Bussmann.
 2. Edison; a brand of Cooper Bussmann.
 3. Ferraz Shawmut, Inc.
 4. Littelfuse, Inc.
 5. General Electric.
 6. Gould.
 7. Reliance.
 8. **<Insert manufacturer's name>.**
 9. or approved equal.

2.2 CARTRIDGE FUSES

Fuse "Class" defines fuse performance category, including interrupting rating. See Evaluations for more information on fuse characteristics. Include current rating and class for cartridge fuses either on Drawings or in "Fuse Applications" Article.

- A. Characteristics: NEMA FU 1, current-limiting, nonrenewable cartridge fuses with voltage ratings consistent with circuit voltages.

2.3 PLUG FUSES

Fuse "Type" defines fuse performance category and base types. See Editing Instruction No. 3 and "Plug Fuses" Article in the Evaluations. Include current rating and type designations for plug fuses either on Drawings or in "Fuse Applications" Article.

- A. Characteristics: UL 248-11, nonrenewable plug fuses; 125-V ac.

2.4 PLUG-FUSE ADAPTERS

Retain this article if rejection-base fuse adapters are required to retrofit Edison-base fuseholders or sockets with Type S, rejection-base plug fuses. See "Plug-Fuse Adapters" Article in the Evaluations. Adapters are designed to prevent installing wrong size fuses.

- A. Characteristics: Adapters for using Type S, rejection-base plug fuses in Edison-base fuseholders or sockets; ampere ratings matching fuse ratings; irremovable once installed.

2.5 SPARE-FUSE CABINET

- A. Characteristics: Wall-mounted steel unit with full-length, recessed piano-hinged door and key-coded cam lock and pull.
 1. Size: Adequate for storage of spare fuses specified with [15] <Insert number> percent spare capacity minimum.
 2. Finish: Gray, baked enamel.
 3. Identification: "SPARE FUSES" in 1-1/2-inch- (38-mm-) high letters on exterior of door.
 4. Fuse Pullers: For each size of fuse, where applicable and available, from fuse manufacturer.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine fuses before installation. Reject fuses that are moisture damaged or physically damaged.
- B. Examine holders to receive fuses for compliance with installation tolerances and other conditions affecting performance, such as rejection features.
- C. Examine utilization equipment nameplates and installation instructions. Install fuses of sizes and with characteristics appropriate for each piece of equipment.
- D. Evaluate ambient temperatures to determine if fuse rating adjustment factors must be applied to fuse ratings.

- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 FUSE APPLICATIONS

Retain this article if fuse class and type designations are not indicated on Drawings. Indicate fuse ampere ratings on Drawings. See Evaluations for discussions of fuse classes and types. Retain fuse classes and types by coordinating required average melt characteristics and peak let-through currents with Section 260573 "Overcurrent Protective Device Coordination Study." See "Cartridge versus Plug Fuses" Article in the Evaluations for additional guidance in making selections.

A. Cartridge Fuses:

Class T fuses in "Service Entrance" Subparagraph are normally used in main switches ahead of meter banks because of their compact size and excellent current-limiting characteristics. Their current-limiting feature often allows using circuit breakers with 10-kA interrupting rating at tenant meters. See "Cartridge Fuses" Article in the Evaluations for additional guidance in making selections.

1. Service Entrance: Class L, fast acting Class L, time delay Class RK1, fast acting Class RK1, time delay Class J, fast acting Class J, time delay Class T, fast acting.
2. Feeders: Class L, fast acting Class L, time delay Class RK1, fast acting Class RK1, time delay Class RK5, fast acting Class RK5, time delay Class J, fast acting.
3. Motor Branch Circuits: Class RK1 Class RK5, time delay.
4. Other Branch Circuits: Class RK1, time delay Class RK5, time delay Class J, fast acting Class J, time delay.
5. Control Circuits: Class CC, fast acting time delay.

B. Plug Fuses:

NFPA 70 limits types of plug fuses that can be used in new construction and for replacing plug fuses in existing installations. Limited ampere, voltage, and interrupting ratings and limited availability of fuseholders also reduce the feasibility of plug fuses in most new installations. Type S, rejection base and Edison base are two types still available in the U.S. See "Plug Fuses" Article in the Evaluations for additional guidance in making selections.

1. Motor Branch Circuits: Edison-base type, dual Edison-base type, single Type S, dual Type S, single-element time delay.
2. Other Branch Circuits: Edison-base type, single-element fast acting Edison-base type, dual-element time delay Edison-base type, single-element time delay Type S, dual-element time delay Type S, single-element time delay.

3.3 INSTALLATION

- A. Install fuses in fusible devices. Arrange fuses so rating information is readable without removing fuse.

Retain first paragraph below if Type S, rejection-base plug fuses are required for installation in existing facilities having fuseholders with Edison-base fuse sockets, or when fuseholders with Edison-base fuse sockets are specified for new construction.

- B. Install plug-fuse adapters in Edison-base fuseholders and sockets. Ensure that adapters are irremovable once installed.
- C. Install spare-fuse cabinet(s).

3.4 IDENTIFICATION

- A. Install labels complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems" and indicating fuse replacement information inside of door of each fused switch and adjacent to each fuse block, socket, and holder.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262813

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SECTION 262816 - ENCLOSED SWITCHES AND CIRCUIT BREAKERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Fusible switches.
 - 2. Nonfusible switches.
 - 3. Receptacle switches.
 - 4. Shunt trip switches.
 - 5. Molded-case circuit breakers (MCCBs).
 - 6. Molded-case switches.
 - 7. Enclosures.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. NC: Normally closed.
- B. NO: Normally open.
- C. SPDT: Single pole, double throw.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Enclosed switches and circuit breakers shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of enclosed switch, circuit breaker, accessory, and component indicated. Include dimensioned elevations, sections, weights, and manufacturers' technical data on features, performance, electrical characteristics, ratings, accessories, and finishes.
 1. Enclosure types and details for types other than NEMA 250, Type 1.
 2. Current and voltage ratings.
 3. Short-circuit current ratings (interrupting and withstand, as appropriate).

Retain first subparagraph below if using series rating of overcurrent protective devices.

4. Include evidence of NRTL listing for series rating of installed devices.
5. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices, accessories, and auxiliary components.

Retain subparagraph below if final system short-circuit and coordination studies will be performed by the designer or will be assigned to an independent consultant. These curves are also beneficial to Owner for future additions or reevaluations of settings of overcurrent protective devices. Although some

manufacturers no longer offer curves on translucent graph paper, curves can normally be downloaded from manufacturers' Web sites or be obtained, in electronic form, from various coordination software vendors as part of a subscription service. Retain option in subparagraph below only if manufacturers selected offer curves on graph paper.

6. Include time-current coordination curves (average melt) for each type and rating of overcurrent protective device; include selectable ranges for each type of overcurrent protective device. [**Submit on translucent log-log graph paper.**]
 7. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For enclosed switches and circuit breakers. Include plans, elevations, sections, details, and attachments to other work.
1. Wiring Diagrams: For power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified testing agency.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
1. Test procedures used.
 2. Test results that comply with requirements.
 3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

Retain paragraph below if retaining "Manufacturer's Field Service" Paragraph in "Field Quality Control" Article. Consider manufacturer's field services especially when retaining zone-selective interlocking because setting it to operate properly requires factory-trained expertise.

- C. Manufacturer's field service report.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For enclosed switches and circuit breakers to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
1. Manufacturer's written instructions for testing and adjusting enclosed switches and circuit breakers.

Retain option in subparagraph below only if manufacturers selected offer curves on graph paper.

2. Time-current coordination curves (average melt) for each type and rating of overcurrent protective device; include selectable ranges for each type of overcurrent protective device. [**Submit on translucent log-log graph paper.**]

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Coordinate first subparagraph below with Section 262813 "Fuses" for quantities of spare fuses and spare-fuse cabinet to be provided.

1. Fuses: Equal to [ten (10)] <Insert number> percent of quantity installed for each size and type, but no fewer than [three (3)] <Insert number> of each size and type.
2. Fuse Pullers: [Two (2)] <Insert number> for each size and type.
3. <Insert extra materials>.

1.9 QUALITY ASSURANCE

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- B. Source Limitations: Obtain enclosed switches and circuit breakers, overcurrent protective devices, components, and accessories, within same product category, from single source from single manufacturer.

Retain first paragraph below to allow drawing details based on one manufacturer's product to establish requirements and still allow competition. Coordinate with Section 016000, "Product Requirements."

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for enclosed switches and circuit breakers, including clearances between enclosures, and adjacent surfaces and other items. Comply with indicated maximum dimensions.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- E. Comply with NFPA 70.

1.10 PROJECT CONDITIONS

Specify unusual environmental or service conditions in first paragraph below. For equipment installed outdoors, indicate maximum and minimum ambient temperature and expected humidity range. For additional ambient compensation requirements for fuses, see Editing Instruction No. 5 in the Evaluations.

- A. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
1. Ambient Temperature: Not less than **minus 30 deg F** (minus 35 deg C) and not exceeding **120 deg F** (49 deg C).
 2. Altitude: **5500 feet** (1677 m).

Retain paragraph below if interruption of existing electric service is required.

- B. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 2. Indicate method of providing temporary electric service.
 3. Do not proceed with interruption of electric service without DEN Project Manager's written permission.
 4. Comply with NFPA 70E.

1.11 COORDINATION

Revise this article to delete or insert types of construction and encumbrances that affect switch and circuit-breaker installation.

- A. Coordinate layout and installation of switches, circuit breakers, and components with equipment served and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 FUSIBLE SWITCHES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
3. Siemens Energy & Automation, Inc.
4. Square D; a brand of Schneider Electric.
5. **<Insert manufacturer's name>.**
6. or approved equal.

Show pole quantities and voltage and ampere ratings of switches on Drawings. In first two paragraphs below, Type GD is for switches for light-commercial applications, 240-V ac, 30 to 600 A; Type HD is for all other single-throw switch uses. See Editing Instruction No. 2 in the Evaluations.

Retain one of last two options in first paragraph below depending on whether fuse applications and class designations are indicated on Drawings or specified in Section 262813 "Fuses." Show fuse ampere ratings on Drawings. General-duty switches are available with plug fuse interiors.

B. Type GD, General Duty, Single Throw, 240-V ac, 800 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with **[cartridge] [plug]** fuse interiors to accommodate **[specified] [indicated]** fuses, lockable handle with capability to accept two padlocks, and interlocked with cover in closed position.

Retain one of last two options in first paragraph below depending on whether fuse applications and class designations are indicated on Drawings or specified in Section 262813 "Fuses." Show fuse ampere ratings on Drawings.

C. Type HD, Heavy Duty, Single Throw, **[240] [600]**-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate **[specified] [indicated]** fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.

Some listed manufacturers offer the six-pole switch in amperage ratings higher than those in first paragraph below.

Retain one of last two options in first paragraph below depending on whether fuse applications and class designations are indicated on Drawings or specified in Section 262813 "Fuses." Show fuse ampere ratings on Drawings.

D. Type HD, Heavy Duty, Six Pole, Single Throw, **[240] [600]**-V ac, 200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate **[specified] [indicated]** fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.

Retain one of last two options in first paragraph below depending on whether fuse applications and class designations are indicated on Drawings or specified in Section 262813 "Fuses." Show fuse ampere ratings on Drawings.

- E. Type HD, Heavy Duty, Double Throw, [240] [600]-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate [specified] [indicated] fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
- F. Accessories:

Retain subparagraphs below with applicable switch paragraphs above. Verify that accessories specified are available and applicable to switch types and ratings in this article.

1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
3. Isolated Ground Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
4. Class R Fuse Kit: Provides rejection of other fuse types when Class R fuses are specified.
5. Auxiliary Contact Kit: [One (1)] [Two (2)] NO/NC (Form "C") auxiliary contact(s), arranged to activate before switch blades open.
6. Hookstick Handle: Allows use of a hookstick to operate the handle.

See Editing Instruction No. 7 in the Evaluations for guidance on using mechanical versus compression lugs. Some size lugs (and lugs in other than NEMA 250, Type 1 and NEMA 250, Type 3R enclosures) are frequently available only for copper conductors; coordinate with manufacturers' literature.

7. Lugs: [Mechanical] [Compression] type, suitable for number, size, and conductor material.
8. Service-Rated Switches: Labeled for use as service equipment.

Retain subparagraph below if retaining "Auxiliary Contact Kit" Subparagraph above and if remote-control power for remote indication is not specified in other Sections. See "Control Power Options" Article in the Evaluations for various sources available for control power. Although other voltages are available, the Section Text includes only those that are most frequently encountered and listed in manufacturers' literature. Integrally mounted control power is not available in safety switches.

9. Accessory Control Power Voltage: Remote mounted and powered; [24-V ac] [120-V ac] [208-V ac] [240-V ac] [6-V dc] [12-V dc] [24-V dc].

2.2 NONFUSIBLE SWITCHES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.

3. [Siemens Energy & Automation, Inc.](#)
4. [Square D; a brand of Schneider Electric.](#)
5. **<Insert manufacturer's name>.**
6. or approved equal.

Show pole quantities and voltage and ampere ratings of switches on Drawings. In first two paragraphs below, Type GD is for switches for light-commercial applications, 240-V ac, 30 to 600 A; Type HD is for all other single-throw switch uses. See Editing Instruction No. 2 in the Evaluations.

- B. Type GD, General Duty, Single Throw, 600 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept two padlocks, and interlocked with cover in closed position.
- C. Type HD, Heavy Duty, Single Throw, [240] [600]-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.

Some listed manufacturers offer the six-pole switch in amperage ratings higher than those in first paragraph below.

- D. Type HD, Heavy Duty, Six Pole, Single Throw, [240] [600]-V ac, 200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
- E. Type HD, Heavy Duty, Double Throw, [240] [600]-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
- F. Accessories:

Retain subparagraphs below with applicable switch paragraphs above. Verify that accessories specified are available and applicable to switch types and ratings in this article.

1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
3. Isolated Ground Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
4. Auxiliary Contact Kit: [One (1)] [Two (2)] NO/NC (Form "C") auxiliary contact(s), arranged to activate before switch blades open.
5. Hookstick Handle: Allows use of a hookstick to operate the handle.

See Editing Instruction No. 7 in the Evaluations for guidance on using mechanical versus compression lugs. Some size lugs (and lugs in other than NEMA 250, Type 1 and NEMA 250, Type 3R enclosures) are frequently available only for copper conductors; coordinate with manufacturers' literature.

6. Lugs: [Mechanical] [Compression] type, suitable for number, size, and conductor material.

Retain subparagraph below if retaining "Auxiliary Contact Kit" Subparagraph above and if remote-control power for remote indication is not specified in other Sections. See "Control Power Options" Article in the Evaluations for various sources available for control power. Although other voltages are available, the

Section Text includes only those that are most frequently encountered and listed in manufacturers' literature. Integrally mounted control power is not available in safety switches.

7. Accessory Control Power Voltage: Remote mounted and powered; [24-V ac] [120-V ac] [208-V ac] [240-V ac] [6-V dc] [12-V dc] [24-V dc].

2.3 RECEPTACLE SWITCHES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Siemens Energy & Automation, Inc.
 4. Square D; a brand of Schneider Electric.
 5. **<Insert manufacturer's name>.**
 6. or approved equal.

Listed manufacturers offer similar but different options for voltage and ampere ratings and the make and model of receptacles available for factory installation on their switches. See Editing Instruction No. 3 in the Evaluations. Not all listed voltage and ampere ratings and enclosure types listed in "Enclosures" Article are available from all listed manufacturers.

Show pole quantities and voltage and ampere ratings of switches on Drawings. Retain one of last two options in first paragraph below depending on whether fuse applications and class designations are indicated on Drawings or specified in Section 262813 "Fuses." Show fuse ampere ratings on Drawings.

- B. Type HD, Heavy-Duty, Single-Throw Fusible Switch: [240] [600]-V ac, [30] [60] [100] A; UL 98 and NEMA KS 1; horsepower rated, with clips or bolt pads to accommodate [specified] [indicated] fuses; lockable handle with capability to accept three padlocks; interlocked with cover in closed position.
- C. Type HD, Heavy-Duty, Single-Throw Nonfusible Switch: [240] [600]-V ac, [30] [60] [100] A; UL 98 and NEMA KS 1; horsepower rated, lockable handle with capability to accept three padlocks; interlocked with cover in closed position.
- D. Interlocking Linkage: Provided between the receptacle and switch mechanism to prevent inserting or removing plug while switch is in the on position, inserting any plug other than specified, and turning switch on if an incorrect plug is inserted or correct plug has not been fully inserted into the receptacle.
- E. Receptacle: Polarized, three-phase, four-wire receptacle (fourth wire connected to enclosure ground lug).

If more than one type or rating of receptacle-switch combination is required, consider showing location of each on Drawings and deleting subparagraph below; otherwise, insert required information.

1. Receptacle Manufacturer and Catalog Number: **<Insert manufacturer and catalog number>.**

2.4 SHUNT TRIP SWITCHES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Cooper Bussmann, Inc.](#)
2. [Ferraz Shawmut, Inc.](#)
3. [Littelfuse, Inc.](#)
4. **<Insert manufacturer's name>**.
5. or approved equal.

Show voltage and ampere ratings of shunt trip switches and fuses on Drawings. See Editing Instruction No. 4 and "Shunt Trip Switches" Article in the Evaluations for guidance on using shunt trip switches.

Retain option in first paragraph below if shunt trip switches are used as elevator shunt trip disconnects per ASME A17.1 and NFPA 70.

- B. General Requirements: Comply with[**ASME A17.1,**] UL 50, and UL 98, with 200-kA interrupting and short-circuit current rating when fitted with Class J fuses.
- C. Switches: Three-pole, horsepower rated, with integral shunt trip mechanism and Class J fuse block; lockable handle with capability to accept three padlocks; interlocked with cover in closed position.
- D. Control Circuit: 120-V ac; obtained from [**integral control power transformer, with primary and secondary fuses,**] **<Insert source of control power>** with a control power [**transformer**] [**source**] of enough capacity to operate shunt trip, connected pilot, and indicating and control devices.
- E. Accessories:

Not all accessories listed in subparagraphs below are available from every listed manufacturer. Verify availability and unique characteristics with manufacturers selected.

1. Oiltight key switch for key-to-test function.
2. Oiltight [**red**] [**green**] [**white**] [**yellow**] ON pilot light.
3. Isolated neutral lug; [**100**] [**200**] percent rating.

Retain first subparagraph below if using switch for hydraulic elevators with automatic recall. Show required interface wiring on Drawings.

4. Mechanically interlocked auxiliary contacts that change state when switch is opened and closed.
5. Form C alarm contacts that change state when switch is tripped.

Retain two subparagraphs below when interfacing elevators with the facility fire-alarm system is required. In first subparagraph, if retaining 24-V dc coil option, a separate 24-V dc source and an initiating contact must be provided by the facility fire-alarm system.

6. Three-pole, double-throw, fire-safety and alarm relay; [**120-V ac**] [**24-V dc**] coil voltage.

7. Three-pole, double-throw, fire-alarm voltage monitoring relay complying with NFPA 72.

2.5 MOLDED-CASE CIRCUIT BREAKERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Siemens Energy & Automation, Inc.
 4. Square D; a brand of Schneider Electric.
 5. **<Insert manufacturer's name>.**
 6. or approved equal.

Show pole quantities and voltage and ampere ratings of MCCBs and switches on Drawings. See Editing Instruction No. 6 in the Evaluations.

- B. General Requirements: Comply with UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents.
- C. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- D. Adjustable, Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
- E. Electronic Trip Circuit Breakers: Field-replaceable rating plug, rms sensing, with the following field-adjustable settings:

Retain one or more of four subparagraphs below and coordinate required adjustable settings with Section 260573 "Overcurrent Protective Device Coordination Study."

1. Instantaneous trip.
 2. Long- and short-time pickup levels.
 3. Long- and short-time time adjustments.
 4. Ground-fault pickup level, time delay, and I^2t response.
- F. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller, and let-through ratings less than NEMA FU 1, RK-5.
- G. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker and trip activation on fuse opening or on opening of fuse compartment door.

Retain first paragraph below for GFCI circuit breakers for personnel ground-fault protection as required by NFPA 70; retain second paragraph for equipment ground-fault protection (e.g., for self-limiting heat trace cables) as required by NFPA 70. GFCI and GFEP circuit breakers are only available fully rated up to interrupting ratings of 22 kA.

- H. Ground-Fault, Circuit-Interrupter (GFCI) Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
- I. Ground-Fault, Equipment-Protection (GFEP) Circuit Breakers: With Class B ground-fault protection (30-mA trip).
- J. Features and Accessories:

Not all features, accessories, and options in subparagraphs below are available for every rating and from every listed manufacturer. Verify availability and unique characteristics with manufacturers selected.

1. Standard frame sizes, trip ratings, and number of poles.

See Editing Instruction No. 7 in the Evaluations for guidance on using mechanical versus compression lugs.

2. Lugs: **[Mechanical]** **[Compression]** type, suitable for number, size, trip ratings, and conductor material.
3. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge lighting circuits.

Retain first option in first subparagraph below for solid-state trip units; retain second option for thermal-magnetic trip units.

4. Ground-Fault Protection: Comply with UL 1053; **[integrally mounted, self-powered]** **[remote-mounted and powered]** type with mechanical ground-fault indicator; relay with adjustable pickup and time-delay settings, push-to-test feature, internal memory, and shunt trip unit; and three-phase, zero-sequence current transformer/sensor.
5. Communication Capability: **[Circuit-breaker-mounted]** **[Universal-mounted]** **[Integral]** **[Din-rail-mounted]** communication module with functions and features compatible with power monitoring and control system, specified in Section 260913 "Electrical Power Monitoring and Control."
6. Shunt Trip: Trip coil energized from separate circuit, with coil-clearing contact.

An optional time-delay unit, which allows an adjustable time delay in release of the trip coil for overriding momentary fluctuations, is available for the undervoltage trip unit in first subparagraph below.

7. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
8. Auxiliary Contacts: **[One SPDT switch]** **[Two SPDT switches]** with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
9. Alarm Switch: One **[NO]** **[NC]** contact that operates only when circuit breaker has tripped.
10. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

Retain first option in first subparagraph below for solid-state trip units; retain second option for thermal-magnetic trip units.

11. Zone-Selective Interlocking: Integral with **[electronic]** **[ground-fault]** trip unit; for interlocking ground-fault protection function.
12. Electrical Operator: Provide remote control for on, off, and reset operations.

Retain subparagraph below if retaining options requiring integral or remote-control power in subparagraphs above and if control power for remote indication or operation is not specified in other Sections. See "Control Power Options" Article in the Evaluations for various sources available for control power. Although other voltages are available, the Section Text includes only those that are most frequently encountered and listed in manufacturers' literature. First option below may not be available in all voltages; coordinate with manufacturers' literature.

13. Accessory Control Power Voltage: **[Integrally mounted, self-powered]** **[Remote mounted and powered]**; **[24-V ac]** **[120-V ac]** **[208-V ac]** **[240-V ac]** **[6-V dc]** **[12-V dc]** **[24-V dc]**.

2.6 MOLDED-CASE SWITCHES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 3. Siemens Energy & Automation, Inc.
 4. Square D; a brand of Schneider Electric.
 5. **<Insert manufacturer's name>.**
 6. or approved equal.
- B. General Requirements: MCCB with fixed, high-set instantaneous trip only, and short-circuit withstand rating equal to equivalent breaker frame size interrupting rating.
- C. Features and Accessories:

Not all features, accessories, and options listed in subparagraphs below are available for every rating and from every listed manufacturer. Verify availability and unique characteristics with manufacturers selected.

1. Standard frame sizes and number of poles.

See Editing Instruction No. 7 in the Evaluations for guidance on using mechanical versus compression lugs.

2. Lugs: **[Mechanical]** **[Compression]** type, suitable for number, size, trip ratings, and conductor material.
3. Ground-Fault Protection: Comply with UL 1053; remote-mounted and powered type with mechanical ground-fault indicator; relay with adjustable pickup and time-delay settings, push-to-test feature, internal memory, and shunt trip unit; and three-phase, zero-sequence current transformer/sensor.
4. Shunt Trip: Trip coil energized from separate circuit, with coil-clearing contact.

An optional time-delay unit, which allows an adjustable time delay in release of the trip coil for overriding momentary fluctuations, is available for the undervoltage trip unit in first subparagraph below.

5. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
6. Auxiliary Contacts: [**One SPDT switch**] [**Two SPDT switches**] with "a" and "b" contacts; "a" contacts mimic switch contacts, "b" contacts operate in reverse of switch contacts.
7. Alarm Switch: One [**NO**] [**NC**] contact that operates only when switch has tripped.
8. Key Interlock Kit: Externally mounted to prohibit switch operation; key shall be removable only when switch is in off position.
9. Zone-Selective Interlocking: Integral with ground-fault shunt trip unit; for interlocking ground-fault protection function.
10. Electrical Operator: Provide remote control for on, off, and reset operations.

Retain subparagraph below if retaining options requiring integral or remote-control power in subparagraphs above and if control power for remote indication or operation is not specified in other Sections. See "Control Power Options" Article in the Evaluations for various sources available for control power. Although other voltages are available, the Section Text includes only those that are most frequently encountered and listed in manufacturers' literature. First option below may not be available in all voltages; coordinate with manufacturers' literature.

11. Accessory Control Power Voltage: [**Integrally mounted, self-powered**] [**Remote mounted and powered**]; [**24-V ac**] [**120-V ac**] [**208-V ac**] [**240-V ac**] [**6-V dc**] [**12-V dc**] [**24-V dc**].

2.7 ENCLOSURES

- A. Enclosed Switches and Circuit Breakers: NEMA AB 1, NEMA KS 1, NEMA 250, and UL 50, to comply with environmental conditions at installed location.

See "Enclosures" Article in the Evaluations for discussion of enclosure types. Coordinate subparagraphs below with Drawings by identifying the designated areas on plans or by including the required enclosure types. Availability of some enclosure types is limited by type of switch or circuit breaker; consult manufacturers for availability of, and limitations on, other than NEMA 250, Type 1 enclosures. General-duty switches are generally only available in NEMA 250, Type 1 or NEMA 250, Type 3R enclosures.

1. Indoor, Dry and Clean Locations: NEMA 250, [**Type 1**] <Insert type>.
2. Outdoor Locations: NEMA 250, [**Type 3R**] <Insert type>.
3. [**Kitchen**] [**Wash-Down**] Areas: NEMA 250, [**Type 4X**] <Insert type>, [**stainless steel**] <Insert material>.
4. Other Wet or Damp, Indoor Locations: NEMA 250, [**Type 4**] <Insert type>.
5. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: NEMA 250, Type 12.

Retain one of two options in subparagraph below to comply with the division and group listing of the environment. Frequently, one enclosure type will accommodate more than one hazardous environment rating. Consult manufacturers for availability of, and limitations on, hazardous environment enclosures. These enclosures do not apply to shunt trip or receptacle switches as specified in the Section Text.

6. Hazardous Areas Indicated on Drawings: NEMA 250, [**Type 7**] [**Type 9**] <Insert type>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine elements and surfaces to receive enclosed switches and circuit breakers for compliance with installation tolerances and other conditions affecting performance of the Work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install individual wall-mounted switches and circuit breakers with tops at uniform height unless otherwise indicated.

Retain first paragraph below if seismic controls are required for Project. Coordinate with Drawings.

- B. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."
- C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
- D. Install fuses in fusible devices.
- E. Comply with NECA 1.

3.3 IDENTIFICATION

- A. Comply with requirements in Section 260553 "Identification for Electrical Systems."
 - 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 - 2. Label each enclosure with engraved metal or laminated-plastic nameplate.

3.4 FIELD QUALITY CONTROL

Retain one of first three paragraphs below to identify who shall perform tests and inspections. If retaining paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Retain first paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first two paragraphs below to describe tests and inspections to be performed.

B. Acceptance Testing Preparation:

1. Test insulation resistance for each enclosed switch and circuit breaker, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

C. Tests and Inspections:

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
3. Perform the following infrared scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each enclosed switch and circuit breaker. Remove front panels so joints and connections are accessible to portable scanner.
 - b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each enclosed switch and circuit breaker 11 months after date of Substantial Completion.
 - c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
4. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- D. Enclosed switches and circuit breakers will be considered defective if they do not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- E. Prepare test and inspection reports, including a certified report that identifies enclosed switches and circuit breakers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.5 ADJUSTING

- A. Adjust moving parts and operable components to function smoothly, and lubricate as recommended by manufacturer.

Retain option in paragraph below if the indicated Section is included in the Contract Documents.

- B. Set field-adjustable circuit-breaker trip ranges[**as specified in Section 260573 "Overcurrent Protective Device Coordination Study."**]

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262816

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SECTION 262913 - ENCLOSED CONTROLLERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes the following enclosed controllers rated 600 V and less:
 - 1. Full-voltage manual.
 - 2. Full-voltage magnetic.
 - 3. Reduced-voltage magnetic.
 - 4. Reduced-voltage solid state.
 - 5. Multispeed.
- B. Related Section:

Retain subparagraph below for requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 262923 "Variable-Frequency Motor Controllers" for general-purpose, ac, adjustable-frequency, pulse-width-modulated controllers for use on variable torque loads in ranges up to 200 hp.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. CPT: Control power transformer.
- B. MCCB: Molded-case circuit breaker.
- C. MCP: Motor circuit protector.
- D. N.C.: Normally closed.
- E. N.O.: Normally open.
- F. OCPD: Overcurrent protective device.
- G. SCR: Silicon-controlled rectifier.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design; however, several listed manufacturers do not currently offer seismic certificates and they do not all test wall-mounted controllers for their ability to "withstand" a seismic event. Verify availability of seismic testing and certification with manufacturers. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Enclosed controllers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of enclosed controller. Include manufacturer's technical

data on features, performance, electrical characteristics, ratings, and enclosure types and finishes.

1. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For each enclosed controller. Include dimensioned plans, elevations, sections, details, and required clearances and service spaces around controller enclosures.

1. Show tabulations of the following:

- a. Each installed unit's type and details.
- b. Factory-installed devices.
- c. Nameplate legends.
- d. Short-circuit current rating of integrated unit.

Retain first subparagraph below if series rating of OCPDs is used or if combination controllers are specified.

- e. Listed and labeled for integrated short-circuit current (withstand) rating of OCPDs in combination controllers by an NRTL acceptable to authorities having jurisdiction.

Retain first subparagraph below if combination controllers are specified.

- f. Features, characteristics, ratings, and factory settings of individual OCPDs in combination controllers.

2. Wiring Diagrams: For power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

A. Qualification Data: For qualified testing agency.

Retain first paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Certificates: For enclosed controllers, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

Large projects with multiple sizes and types of controllers might include different types of overload relays. Retain one or both paragraphs below to suit type(s) of motor overload protection. See Evaluations for discussion of types of overload protection.

- D. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.
- E. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor running overload protection suit actual motors to be protected.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For enclosed controllers to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

- 1. Routine maintenance requirements for enclosed controllers and installed components.

Retain first subparagraph below if circuit breakers are specified in combination controllers; retain second subparagraph if field-adjustable overload relays are specified; retain third subparagraph if reduced-voltage solid-state controllers are specified.

- 2. Manufacturer's written instructions for testing and adjusting circuit breaker and MCP trip settings.
- 3. Manufacturer's written instructions for setting field-adjustable overload relays.
- 4. Manufacturer's written instructions for testing, adjusting, and reprogramming reduced-voltage solid-state controllers.

- B. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MATERIALS MAINTENANCE SUBMITTALS

Revise this article to include extra materials that Owner may require, which may fail more frequently due to continual use.

Coordinate quantity of fuses with Section 262813 "Fuses" for required space in spare-fuse cabinet.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fuses for Fused Switches: Equal to **[ten (10)] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[three (3)] <Insert number>** of each size and type.
 - 2. Control Power Fuses: Equal to **[ten (10)] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[two (2)] <Insert number>** of each size and type.
 - 3. Indicating Lights: **[Two (2)] <Insert number>** of each type and color installed.
 - 4. Auxiliary Contacts: Furnish **[one (1)] <Insert number>** spare(s) for each size and type of magnetic controller installed.
 - 5. Power Contacts: Furnish **[three (3)] <Insert number>** spares for each size and type of magnetic contactor installed.
 - 6. **<Insert extra materials>**.

1.9 QUALITY ASSURANCE

Retain first paragraph below if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with NFPA 70.

Retain paragraph below for projects in seismic areas. If retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

- D. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems."

1.10 DELIVERY, STORAGE, AND HANDLING

Retain this article for large combination and solid-state controllers.

Retain first paragraph below for enclosed sites with conditioned storage spaces. Retain second paragraph if site conditions require supplemental heating to prevent condensation. If retaining second

paragraph, retain first option for controllers that do not have factory-installed space heaters as specified in Part 2; otherwise, retain second option.

- A. Store enclosed controllers indoors in clean, dry space with uniform temperature to prevent condensation. Protect enclosed controllers from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- B. If stored in areas subject to weather, cover enclosed controllers to protect them from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside controllers; **[install temporary electric heating, with at least 250 W per controller] [connect factory-installed space heaters to temporary electrical service].**

1.11 PROJECT CONDITIONS

Revise first paragraph below to specify unusual environmental or service conditions. For equipment installed outdoors, indicate maximum and minimum ambient temperature and expected humidity range. For additional ambient compensation requirements for fuses, MCCBs, and overload relays, see Editing Instructions No. 3, No. 4, and No. 6 in the Evaluations.

- A. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
 - 1. Ambient Temperature Range: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).
 - 2. Altitude: 5500 feet (2010 m) above sea level.

Retain paragraph below if interruption of existing electrical distribution systems is required.

- B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 - 2. Indicate method of providing temporary utilities.
 - 3. Do not proceed with interruption of electrical systems without DEN Project Manager's written permission.
 - 4. Comply with NFPA 70E.

1.12 COORDINATION

- A. Coordinate layout and installation of enclosed controllers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

Retain one or both paragraphs below if required for base-supported enclosed controllers.

- B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.
- C. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 FULL-VOLTAGE CONTROLLERS

Show controller pole quantities, voltage, NEMA size and type, accessories, short-circuit current rating (or available short-circuit currents), and enclosure type for each controller on Drawings. See "Full-Voltage Controllers" Article in the Evaluations for selection considerations. Enclosed controllers without integral OCPDs (e.g., fuses, MCPs, or thermal-magnetic circuit breakers) may have very low short-circuit current ratings when used in series with upstream devices. See Editing Instruction No. 2 in the Evaluations.

Not all features, accessories, and options in this article are available for every rating, with every enclosure type, and from every listed manufacturer. Verify availability and unique characteristics with manufacturers. Show on Drawings those features and accessories that apply to each controller.

- A. General Requirements for Full-Voltage Controllers: Comply with NEMA ICS 2, general purpose, Class A.

Motor-starting switches do not have integral overload relays. See "Motor-Starting Switches" Article in the Evaluations for additional guidance on their use.

- B. Motor-Starting Switches: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off or on.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.

- d. Siemens Energy & Automation, Inc.
- e. Square D; a brand of Schneider Electric.
- f. <Insert manufacturer>
- g. or approved equal.

2. Configuration: [**Nonreversing**] [**Reversing**] [**Two speed**].

First option in first subparagraph below is available only with NEMA 250, Type 1 enclosures but not from all listed manufacturers. Consult manufacturers for availability of flush enclosures and finishes for flush cover plates because each manufacturer offers different types.

3. [**Flush**] [**Surface**] mounting.

Not all manufacturers offer a green pilot light; pilot lights are not available in hazardous and some cast-type enclosures.

4. [**Red**] [**Green**] pilot light.
5. Additional Nameplates: FORWARD and REVERSE for reversing switches, HIGH and LOW for two-speed switches.

One- and two-pole, fractional horsepower manual controllers are suitable for use with single-phase ac motors up to 1 hp. See "Fractional Horsepower Manual Controllers" Article in the Evaluations for additional guidance on their use.

- C. Fractional Horsepower Manual Controllers: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. <Insert manufacturer>
 - g. or approved equal.
2. Configuration: [**Nonreversing**] [**Two speed**].

See Editing Instruction No. 5 and "Overload Protection" Article in the Evaluations for additional guidance on retaining options in first subparagraph below. Although Class 10 seems to be "standard" for this equipment, some manufacturers may offer others. Retain first option below unless another class is required and available.

3. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, [**Class 10**] <Insert class> tripping characteristics; heaters matched to nameplate full-load current of actual protected motor; external reset push button[; **bimetallic type**] [; **melting alloy type**].

First option in first subparagraph below is available only with NEMA 250, Type 1 enclosures but not from all listed manufacturers. Consult manufacturers for availability of flush enclosures and finishes for flush cover plates because each manufacturer offers different types.

4. **[Flush] [Surface]** mounting.

Not all manufacturers offer a green pilot light; pilot lights are not available in hazardous and some cast-type enclosures.

5. **[Red] [Green]** pilot light.
6. Additional Nameplates: **[HIGH and LOW for two-speed controllers] <Insert special markings>**.

One-, two-, and three-pole integral horsepower manual controllers are suitable for use with single- and three-phase ac motors up to 10 hp at 480-V ac. See "Integral Horsepower Manual Controllers" Article in the Evaluations for additional guidance on their use.

- D. Integral Horsepower Manual Controllers: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.
2. Configuration: **[Nonreversing] [Reversing] [Two speed]**.

See Editing Instruction No. 5 and "Overload Protection" Article in the Evaluations for additional guidance on retaining options in first subparagraph below. Although Class 10 seems to be "standard" for this equipment, some manufacturers may offer others. Retain first option below unless another class is required and available.

3. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, **[Class 10] <Insert class>** tripping characteristics; heaters and sensors in each phase, matched to nameplate full-load current of actual protected motor and having appropriate adjustment for duty cycle; external reset push button[; **bimetallic type] [; melting alloy type]**.

First option in first subparagraph below is available only with NEMA 250, Type 1 enclosures but not from all listed manufacturers. Consult manufacturers for availability of flush enclosures and finishes for flush cover plates because each manufacturer offers different types.

4. **[Flush] [Surface]** mounting.

Not all manufacturers offer a green pilot light; pilot lights are not available in hazardous and some cast-type enclosures.

5. **[Red] [Green]** pilot light.
6. Additional Nameplates: **[FORWARD and REVERSE for reversing controllers] [HIGH and LOW for two-speed controllers] <Insert special markings>**.
7. **[N.O.] [N.C.]** auxiliary contact.

Three-pole integral horsepower magnetic controllers are suitable for use with three-phase ac motors up to 1600 hp, and from NEMA ICS 2, Size 00 to Size 9; however, not all listed manufacturers offer enclosed controllers up to Size 9. Two- and four-pole models are also available in varying minimum and maximum horsepower ratings and NEMA sizes. See "Magnetic Controllers" Article in the Evaluations for additional guidance on their use.

E. Magnetic Controllers: Full voltage, across the line, electrically held.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.
2. Configuration: **[Nonreversing] [Reversing]**.
3. Contactor Coils: Pressure-encapsulated type **[with coil transient suppressors]**.
 - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
4. Power Contacts: Totally enclosed, double-break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: **[24] [120] <Insert value>-V ac**; obtained from **[integral CPT, with primary and secondary fuses] <Insert source of control power>**, with **[CPT] [control power source]** of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

Retain first subparagraph below if retaining CPT in last subparagraph above and spare CPT capacity is required. Spare capacity is normally available in 100-VA increments. Consult manufacturers for maximum spare capacity and CPT sizes available for different NEMA and enclosure sizes because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

- a. CPT Spare Capacity: **[50] [100] [200] <Insert number> VA**.

Retain one or more of first three subparagraphs below. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 5 and "Overload Protection" Article in the Evaluations for additional guidance.

6. Melting Alloy Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
 - c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
7. Bimetallic Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
 - c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below only if applicable. See Editing Instruction No. 6 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- d. Ambient compensated.
 - e. Automatic resetting.
8. Solid-State Overload Relay:
 - a. Switch or dial selectable for motor running overload protection.
 - b. Sensors in each phase.
 - c. **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added-cost features.

- d. Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
 - e. Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

9. **[N.C.] [N.O.]**, isolated overload alarm contact.
10. External overload reset push button.

Combination controllers are magnetic controllers combined with a disconnecting means, OCPD, or both. See Editing Instruction No. 2 and "Combination Controllers" Article in the Evaluations for guidance on using combination controllers and the different types of disconnecting means and OCPDs. Indicate requirements for disconnecting means and OCPDs on Drawings. Revise paragraph below if overload relays differ from those indicated in "Magnetic Controllers" Paragraph above.

- F. Combination Magnetic Controller: Factory-assembled combination of magnetic controller, OCPD, and disconnecting means.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by

one of the following:

- a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
- b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
- c. Rockwell Automation, Inc.; Allen-Bradley brand.
- d. Siemens Energy & Automation, Inc.
- e. Square D; a brand of Schneider Electric.
- f. **<Insert manufacturer>**
- g. or approved equal.

Disconnecting means and OCPDs must be closely coordinated with calculated short-circuit current values at the controller locations because they are directly related to the short-circuit withstand ratings of their combination controllers. Although fusible switches (with appropriate fuses) can provide Type 2 controller protection from very high short-circuit currents, not all circuit breakers or MCPs can. See Editing Instruction No. 7 in the Evaluations for explanation of protection types and when they should be considered.

2. Fusible Disconnecting Means:

- a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate [**Class J**] [**Class R**] [**indicated**] fuses.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

3. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

Nonfusible switches have no inherent short-circuit or interrupting current ratings and so must be used in series with upstream fuses or specific types and ratings of circuit breakers. See "Application of Switches and Circuit Breakers" Article in the Evaluations.

4. Nonfusible Disconnecting Means:

- a. NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

MCP disconnecting means in first subparagraph below must be used in combination with integral overload relays.

5. MCP Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor

- locked-rotor amperes.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
- d. [N.C.] [N.O.] alarm contact that operates only when MCP has tripped.

First subparagraph below is an optional, added-cost feature.

- e. Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

6. MCCB Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
- b. Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- c. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- d. Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
- e. [N.C.] [N.O.] alarm contact that operates only when MCCB has tripped.

2.2 REDUCED-VOLTAGE MAGNETIC CONTROLLERS

Show controller pole quantities, voltage, NEMA size and type, accessories, short-circuit current rating (or available short-circuit currents), and enclosure type for each controller on Drawings. See "Reduced-Voltage Magnetic Controllers" Article in the Evaluations for selection considerations. Enclosed controllers without integral OCPDs (e.g., fuses, MCPs, or thermal-magnetic circuit breakers) may have very low short-circuit current ratings when used in series with upstream devices. See Editing Instruction No. 2 in the Evaluations. Reduced-voltage magnetic controllers are available in either open- or closed-transition modes; however, the Section Text includes closed-transition mode. Open-transition mode may be added to suit Project.

Not all features, accessories, and options in this article are available for every rating, with every enclosure type, and from every listed manufacturer. Verify availability and unique characteristics with manufacturers. Show on Drawings those features and accessories that apply to each controller.

- A. General Requirements for Reduced-Voltage Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A; closed-transition; adjustable time delay on transition.

B. Reduced-Voltage Magnetic Controllers: Reduced voltage, electrically held.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.
2. Configuration:
 - a. Wye-Delta Controller: Four contactors, with a three-phase starting resistor/reactor bank.
 - b. Part-Winding Controller: Separate START and RUN contactors, field-selectable for 1/2- or 2/3-winding start mode, with either six- or nine-lead motors; with separate overload relays for starting and running sequences.
 - c. Autotransformer Reduced-Voltage Controller: Medium-duty service, with integral overtemperature protection; taps for starting at 50, 65, and 80 percent of line voltage; two START and one RUN contactors.
3. Contactor Coils: Pressure-encapsulated type[**with coil transient suppressors**].
 - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
4. Power Contacts: Totally enclosed, double-break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: [24] [120] **<Insert value>**-V ac; obtained from [integral CPT, **with primary and secondary fuses**] **<Insert source of control power>**, with [CPT] [control power source] of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

Retain first subparagraph below if retaining CPT in last subparagraph above and spare CPT capacity is required. Spare capacity is usually available in 100-VA increments. Consult manufacturers for maximum spare capacity and CPT sizes available for different NEMA and enclosure sizes because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

- a. CPT Spare Capacity: [50] [100] [200] **<Insert number>** VA.

Retain one or more of first three subparagraphs below. If retaining more than one, show on Drawings where each type is required. See Editing Instructions No. 5 and "Overload Protection" Article in the Evaluations for additional guidance.

6. Melting Alloy Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
 - c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

7. Bimetallic Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
 - c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below only if applicable. See Editing Instruction No. 6 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- d. Ambient compensated.
 - e. Automatic resetting.
8. Solid-State Overload Relay:
 - a. Switch or dial selectable for motor running overload protection.
 - b. Sensors in each phase.
 - c. **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added-cost features.

- d. Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
 - e. Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

9. **[N.C.] [N.O.]**, isolated overload alarm contact.
10. External overload reset push button.

Combination controllers are magnetic controllers combined with a disconnecting means, OCPD, or both. See Editing Instruction No. 2 and "Combination Controllers" Article in the Evaluations for guidance on using combination controllers and the different types of disconnecting means and OCPDs. Indicate requirements for disconnecting means and OCPDs on Drawings. Revise paragraph below if overload relays differ from those indicated in "Reduced-Voltage Magnetic Controllers" Paragraph above.

- C. Combination Reduced-Voltage Magnetic Controller: Factory-assembled combination of reduced-voltage magnetic controller, OCPD, and disconnecting means.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.

Disconnecting means and OCPDs must be closely coordinated with calculated short-circuit current values at the controller locations because they are directly related to the short-circuit withstand ratings of their combination controllers. Although fusible switches (with appropriate fuses) can provide Type 2 controller protection from very high short-circuit currents, not all circuit breakers or MCPs can. See Editing Instruction No. 7 in the Evaluations for explanation of protection types and when they should be considered.

2. Fusible Disconnecting Means:
 - a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate **[Class J] [Class R] [indicated]** fuses.
 - b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

Nonfusible switches have no inherent short-circuit or interrupting current ratings and so must be used in series with upstream fuses or specific types and ratings of circuit breakers. See "Application of Switches and Circuit Breakers" Article in the Evaluations.

3. Nonfusible Disconnecting Means:
 - a. NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
 - b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

MCP disconnecting means in first subparagraph below must be used in combination with integral overload relays.

4. MCP Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
- d. [N.C.] [N.O.] alarm contact that operates only when MCP has tripped.

First subparagraph below is an optional, added-cost feature.

- e. Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

5. MCCB Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
- b. Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- c. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- d. Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
- e. [N.C.] [N.O.] alarm contact that operates only when MCCB has tripped.

2.3 REDUCED-VOLTAGE SOLID-STATE CONTROLLERS

Show controller pole quantities, voltage, NEMA size and type, accessories, short-circuit current rating (or available short-circuit currents), and enclosure type for each controller on Drawings. See "Reduced-Voltage Controllers," "Reduced-Voltage Solid-State Controllers," and "Solid-State Controllers" articles in the Evaluations for selection considerations. Enclosed controllers without integral OCPDs (e.g., fuses, MCPs, or thermal-magnetic circuit breakers) may have very low short-circuit current ratings when used in series with upstream devices. See Editing Instructions No. 2 and No. 8 in the Evaluations.

Standard and optional features vary considerably among manufacturers of solid-state controllers. Not all features, accessories, and options in this article are available for every rating, with every enclosure type, and from every listed manufacturer. Also, features and options depend on motor characteristics and

operating criteria of driven equipment. Verify availability and unique characteristics with manufacturers. Show on Drawings those features and accessories that apply to each controller.

- A. General Requirements for Reduced-Voltage Solid-State Controllers: Comply with UL 508.

Three-pole, reduced-voltage solid-state controllers are available for use with three-phase ac motors 3 to 600 hp, and in voltages from 208- to 575-V ac; however, not all listed manufacturers may offer enclosed controllers in all these ratings and voltage ranges.

- B. Reduced-Voltage Solid-State Controllers: An integrated unit with power SCRs, heat sink, microprocessor logic board, door-mounted digital display and keypad, bypass contactor, and overload relay; suitable for use with NEMA MG 1, Design B, polyphase, medium induction motors.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.
2. Configuration: **[Standard duty] [Severe duty]; [nonreversible] [reversible]**.
3. Starting Mode: **[Voltage ramping] [Current limit] [Torque control] [Torque control with voltage boost][; field selectable]**.
4. Stopping Mode: **[Coast to stop] [Adjustable torque deceleration] [Adjustable braking][; field selectable]**.

Most manufacturers provide shorting contactors to bypass the SCRs at full speed instead of the controller operating continually through the SCRs. Bypass contactors are usually of less than full-voltage rating, and many are IEC-rated controllers. They are not sized nor intended for starting the motor across the line. Some manufacturers, however, offer the alternative of full-voltage bypass contactors for severe-duty applications, to completely bypass the SCRs on failure (allowing use of the controller as a full-voltage controller).

5. Shorting (Bypass) Contactor: Operates automatically when full voltage is applied to motor, and bypasses the SCRs. Solid-state controller protective features shall remain active when the shorting contactor is in the bypass mode.
6. Shorting[**and Input Isolation**] Contactor Coils: Pressure-encapsulated type; manufacturer's standard operating voltage, matching control power or line voltage, depending on contactor size and line-voltage rating.[**Provide coil transient suppressors.**]
7. Logic Board: Identical for all ampere ratings and voltage classes, with environmental protective coating.

8. Control Circuits: [24] [120] <Insert value>-V ac; obtained from [integral CPT, with primary and secondary fuses] <Insert source of control power>, with [CPT] [control power source] of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

Retain first subparagraph below if retaining CPT in last subparagraph above and spare CPT capacity is required. Spare capacity is usually available in 100-VA increments. Consult manufacturers for maximum spare capacity and CPT sizes available for different NEMA and enclosure sizes because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

- a. CPT Spare Capacity: [100] [200] <Insert number> VA.
9. Adjustable acceleration-rate control using voltage or current ramp, and adjustable starting torque control with up to [400] <Insert value> percent current limitation for 20 seconds.
10. SCR bridge shall consist of at least two SCRs per phase, providing stable and smooth acceleration [with] [without] external feedback from the motor or driven equipment.
11. Keypad, front accessible; for programming the controller parameters, functions, and features; shall be manufacturer's standard and include not less than the following functions:
 - a. Adjusting motor full-load amperes, as a percentage of the controller's rating.
 - b. Adjusting current limitation on starting, as a percentage of the motor full-load current rating.
 - c. Adjusting linear acceleration and deceleration ramps, in seconds.
 - d. Initial torque, as a percentage of the nominal motor torque.
 - e. Adjusting torque limit, as a percentage of the nominal motor torque.
 - f. Adjusting maximum start time, in seconds.
 - g. Adjusting voltage boost, as a percentage of the nominal supply voltage.
 - h. Selecting stopping mode, and adjusting parameters.
 - i. Selecting motor thermal overload protection class between 5 and 30.
 - j. Activating and de-activating protection modes.
 - k. Selecting or activating communication modes.
 - l. <Insert function>.
12. Digital display, front accessible; for showing motor, controller, and fault status; shall be manufacturer's standard and include not less than the following:
 - a. Controller Condition: Ready, starting, running, stopping.
 - b. Motor Condition: Amperes, voltage, power factor, power, and thermal state.
 - c. Fault Conditions: Controller thermal fault, motor overload alarm and trip, motor underload, overcurrent, shorted SCRs, line or phase loss, phase reversal, and line frequency over or under normal.
 - d. <Insert items>.
13. Controller Diagnostics and Protection:
 - a. Microprocessor-based thermal protection system for monitoring SCR and motor thermal characteristics, and providing controller overtemperature and motor-overload alarm and trip; settings selectable via the keypad.

- b. Protection from line-side reverse phasing; line-side and motor-side phase loss; motor jam, stall, and underload conditions; and line frequency over or under normal.

Retain one of first two subparagraphs below for providing motor protection on a controller fault.

- c. Input isolation contactor that opens when the controller diagnostics detect a faulted solid-state component or when the motor is stopped.

Retain first subparagraph below if specifying combination controllers.

- d. Shunt trip that opens the disconnecting means when the controller diagnostics detect a faulted solid-state component.
- e. **<Insert items>**.

14. Remote Output Features:

- a. All outputs prewired to terminal blocks.
- b. Form C status contacts that change state when controller is running.
- c. Form C alarm contacts that change state when a fault condition occurs.
- d. **<Insert items>**.

15. Optional Features:

- a. Analog output for field-selectable assignment of motor operating characteristics; **[0 to 10-V dc] [4 to 20-mA dc]**.
- b. Additional field-assignable Form C contacts, as indicated, for alarm outputs.
- c. Surge suppressors in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
- d. Full-voltage bypass contactor operating **[automatically] [manually, with NORMAL/BYPASS selector switch]**. Power contacts shall be totally enclosed, double break, and silver-cadmium oxide; and assembled to allow inspection and replacement without disturbing line or load wiring.

Manufacturers typically integrate overload functions into solid-state controllers and use separate thermal or solid-state overload relays only if full-voltage bypass controllers are specified. Retain one or more of first three subparagraphs below if specifying full-voltage bypass contactors. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 5 and "Overload Protection" Article in the Evaluations for additional guidance.

- e. Melting Alloy Overload Relays:
 - 1) Inverse-time-current characteristic.
 - 2) **[Class 10] [Class 20] [Class 30]** tripping characteristic.
 - 3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
- f. Bimetallic Overload Relays:
 - 1) Inverse-time-current characteristic.
 - 2) **[Class 10] [Class 20] [Class 30]** tripping characteristic.

- 3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below only if applicable. See Editing Instruction No. 6 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- 4) Ambient compensated.
- 5) Automatic resetting.

g. Solid-State Overload Relay:

- 1) Switch or dial selectable for motor running overload protection.
- 2) Sensors in each phase.
- 3) **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added cost features.

- 4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
- 5) Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

- h. **[N.C.] [N.O.]**, isolated overload alarm contact.
- i. External overload reset push button.

Combination controllers are solid-state controllers combined with a disconnecting means, OCPD, or both. See Editing Instruction No. 2 and "Combination Controllers" Article in the Evaluations for guidance on using combination controllers and the different types of disconnecting means and OCPDs. Indicate requirements for disconnecting means and OCPDs on Drawings. Revise paragraph below if overload relays differ from those indicated in "Reduced-Voltage Solid-State Controllers" Paragraph above.

- C. Combination Reduced-Voltage Solid-State Controller: Factory-assembled combination of reduced-voltage solid-state controller, OCPD, and disconnecting means.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.

Disconnecting means and OCPDs must be closely coordinated with calculated short-circuit current values at the controller locations because they are directly related to the short-circuit withstand ratings of their combination controllers. Although fusible switches (with appropriate fuses) can provide Type 2 controller protection from very high short-circuit currents, not all circuit breakers or MCPs can. See Editing Instruction No. 7 in the Evaluations for explanation of protection types and when they should be considered. The Section Text does not include nonfusible disconnecting means because they are usually not an option with solid-state controllers.

2. Fusible Disconnecting Means:

- a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate **[Class J]** **[Class L]** **[indicated]** fuses.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

MCP disconnecting means must be used in combination with integral overload relays.

3. MCP Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
- d. **[N.C.] [N.O.]** alarm contact that operates only when MCP has tripped.

First subparagraph below is an optional, added-cost feature.

- e. Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

4. MCCB Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
- b. Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- c. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- d. Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
- e. [N.C.] [N.O.] alarm contact that operates only when MCCB has tripped.

5. Molded-Case Switch Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with in-line fuse block for Class J or L power fuses (depending on ampere rating), providing an interrupting capacity to comply with available fault currents; MCCB with fixed, high-set instantaneous trip only.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with molded-case switch handle.
- d. [N.C.] [N.O.] alarm contact that operates only when molded-case switch has tripped.

2.4 MULTISPEED MAGNETIC CONTROLLERS

Show controller pole quantities, voltage, NEMA size and type, accessories, short-circuit current rating (or available short-circuit currents), and enclosure type for each controller on Drawings. See "Multispeed Controllers" Article in the Evaluations for selection considerations. Enclosed controllers without integral OCPDs (e.g., fuses, MCPs, or thermal-magnetic circuit breakers) may have very low short-circuit current ratings when used in series with upstream devices. See Editing Instruction No. 2 in the Evaluations. The Section Text includes only two-speed controllers; however, most manufacturers catalog controllers offering more than two speeds. Multispeed controllers supporting more than two speeds may be added to suit Project.

Not all features, accessories, and options in this article are available for every rating, with every enclosure type, and from every listed manufacturer. Verify availability and unique characteristics with manufacturers. Show on Drawings those features and accessories that apply to each controller.

- A. General Requirements for Multispeed Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A.
- B. Multispeed Magnetic Controllers: Two speed, full voltage, across the line, electrically held.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 - c. Rockwell Automation, Inc.; Allen-Bradley brand.
 - d. Siemens Energy & Automation, Inc.
 - e. Square D; a brand of Schneider Electric.
 - f. **<Insert manufacturer>**
 - g. or approved equal.
2. Configuration: **[Nonreversing] [Reversing]; [consequent pole] [two winding]**.
 3. Contactor Coils: Pressure-encapsulated type **[with coil transient suppressors]**.
 - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
 4. Power Contacts: Totally enclosed, double break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
 5. Control Circuits: **[24] [120] <Insert value>-V ac**; obtained from **[integral CPT, with primary and secondary fuses] <Insert source of control power>**, with **[CPT] [control power source]** of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

Retain first subparagraph below if retaining CPT in last subparagraph above and spare CPT capacity is required. Spare capacity is usually available in 100-VA increments. Consult manufacturers for maximum spare capacity and CPT sizes available for different NEMA and enclosure sizes because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

- a. CPT Spare Capacity: **[50] [100] [200] <Insert number> VA**.

Retain one or both of first two subparagraphs below. If retaining both, indicate on Drawings where each type is required. Compelling and accelerating relays cannot be specified together for the same controller. Compelling, accelerating, and decelerating relays can be used for all multispeed controllers; antiplugging relays are used only for reversing multispeed controllers.

6. Compelling relays shall ensure that motor will start only at low speed.
7. Accelerating timer relays shall ensure properly timed acceleration through speeds lower than that selected.
8. Decelerating timer relays shall ensure automatically timed deceleration through each speed.
9. Antiplugging timer relays shall ensure a time delay when transferring from FORWARD to REVERSE and back.

Retain one or more of first three subparagraphs below. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 5 and "Overload Protection" Article in the Evaluations for additional guidance.

10. Melting Alloy Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.

- c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

11. Bimetallic Overload Relays:

- a. Inverse-time-current characteristic.
- b. **[Class 10] [Class 20] [Class 30]** tripping characteristic.
- c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below only if applicable. See Editing Instruction No. 6 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- d. Ambient compensated.
- e. Automatic resetting.

12. Solid-State Overload Relay:

- a. Switch or dial selectable for motor running overload protection.
- b. Sensors in each phase.
- c. **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added-cost features.

- d. Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
- e. Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

- 13. **[N.C.] [N.O.]**, isolated overload alarm contact.
- 14. External overload reset push button.

Combination controllers are magnetic controllers combined with a disconnecting means, OCPD, or both. See Editing Instruction No. 2 and "Combination Controllers" Article in the Evaluations for guidance on using combination controllers and the different types of disconnecting means and OCPDs. Indicate requirements for disconnecting means and OCPDs on Drawings. Revise paragraph below if overload relays differ from those indicated in "Multispeed Magnetic Controllers" Paragraph above.

- C. Combination Multispeed Magnetic Controller: Factory-assembled combination of reduced-voltage magnetic controller, OCPD, and disconnecting means.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.

- b. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
- c. Rockwell Automation, Inc.; Allen-Bradley brand.
- d. Siemens Energy & Automation, Inc.
- e. Square D; a brand of Schneider Electric.
- f. <Insert manufacturer>
- g. or approved equal.

Disconnecting means and OCPDs must be closely coordinated with calculated short-circuit current values at the controller locations because they are directly related to the short-circuit withstand ratings of their combination controllers. Although fusible switches (with appropriate fuses) can provide Type 2 controller protection from very high short-circuit currents, not all circuit breakers or MCPs can. See Editing Instruction No. 7 in the Evaluations for explanation of protection types and when they should be considered.

2. Fusible Disconnecting Means:

- a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate [Class J] [Class R] [indicated] fuses.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

Nonfusible switches have no inherent short-circuit or interrupting current ratings and so must be used in series with upstream fuses or specific types and ratings of circuit breakers. See "Application of Switches and Circuit Breakers" Article in the Evaluations.

3. Nonfusible Disconnecting Means:

- a. NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain first subparagraph below if external control power is used or for remote indication of disconnecting means position.

- c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

MCP disconnecting means in first subparagraph below must be used in combination with integral overload relays.

4. MCP Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.

- b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both of first two subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- c. Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
- d. [N.C.] [N.O.] alarm contact that operates only when MCP has tripped.

First subparagraph below is an optional, added-cost feature.

- e. Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

5. MCCB Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
- b. Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- c. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

Retain one or both subparagraphs below. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and N.O. or N.C. contact requirements on Drawings.

- d. Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
- e. [N.C.] [N.O.] alarm contact that operates only when MCCB has tripped.

2.5 ENCLOSURES

- A. Enclosed Controllers: NEMA ICS 6, to comply with environmental conditions at installed location.

See "Enclosures" Article in the Evaluations for discussion of enclosure types. Coordinate subparagraphs below with Drawings by identifying the designated areas on plans or by including the required enclosure types. Enclosure materials and finishes may be added to the Section Text. Availability of some enclosure types is limited by type of controller; consult manufacturers for availability of, and limitations on, other than NEMA ICS 6, Type 1 enclosures. Reduced-voltage solid-state controllers are not usually available in other than Types 1, 3R, and 12.

- 1. Dry and Clean Indoor Locations: [Type 1] <Insert type>.
- 2. Outdoor Locations: [Type 3R] [Type 4X] <Insert type>.
- 3. [Kitchen] [Wash-Down] Areas: [Type 4X] <Insert type>, [stainless steel] <Insert material>.
- 4. Other Wet or Damp Indoor Locations: [Type 4] <Insert type>.
- 5. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

Retain one or both options in subparagraph below to comply with the division and group listing of the environment. Frequently, one enclosure type will accommodate more than one hazardous environment rating. Consult manufacturers for availability of, and limitations on, hazardous environment enclosures. These enclosures do not normally apply to reduced-voltage solid-state controllers as specified in the Section Text. If possible, avoid installing combination magnetic controllers in hazardous environments.

6. Hazardous Areas Indicated on Drawings: **[Type 7] [Type 9] <Insert type>**.

2.6 ACCESSORIES

Accessories listed in this article pertain primarily to enclosed magnetic controllers, with limited applications to solid-state controllers and even more limited applications to manual controllers; accessories are also limited in application by controller and enclosure types. Retain applicable accessories below. Indicate requirements for and quantities of accessories on Drawings. See "Accessories" Article in the Evaluations for additional guidance; consult manufacturers for availability of, and limitations on, other accessories.

- A. General Requirements for Control Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.
 1. Push Buttons, Pilot Lights, and Selector Switches: **[Heavy] [Standard]-duty, [oiltight]** type.
 - a. Push Buttons: **[Covered] [Lockable] [Recessed] [Shielded] [Shrouded] [Unguarded]** types; **[maintained] [momentary]** as indicated.
 - b. Pilot Lights: **[Incandescent] [LED] [Neon] [Resistor] [Transformer]** types; colors as indicated; **push to test**.
 - c. Selector Switches: **[Rotary] <Insert description>** type.
 2. Elapsed Time Meters: Heavy duty with digital readout in hours; **nonresettable** [**resettable**].

Retain subparagraph below if metering (for amperes, voltage, frequency, watts, power factor, etc.) is required for controllers. Indicate on Drawings where and which types of metering and selector switches are required. Normally, metering is limited to enclosure Types 1 and 12; consult manufacturers on availability of meters in other types of enclosures. Some listed manufacturers offer digital metering through the communication output of the solid-state overload relays; consult manufacturers for availability.

3. Meters: Panel type, **2-1/2-inch** (64-mm) minimum size with 90- or 120-degree scale and plus or minus two percent accuracy. Where indicated, provide selector switches with an off position.
- B. **[N.C.] [N.O.] [Reversible N.C./N.O.]** auxiliary contact(s).
 - C. Control Relays: Auxiliary and adjustable **[pneumatic] [solid-state]** time-delay relays.

Features in first paragraph below are available in individual relays or combined into a single multipurpose relay. Consult manufacturers for availability. Consider specifying phase-failure relays for single-phasing protection in fusible-switch combination controllers if solid-state overload relays are not specified.

- D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays:
Solid-state sensing circuit with isolated output contacts for hard-wired connections.
Provide adjustable undervoltage, overvoltage, and time-delay settings.
- E. Breather and drain assemblies, to maintain interior pressure and release condensation in [Type 4] [Type 4X] [Type 7] [Type 9] <Insert type> enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- F. Space heaters, with N.C. auxiliary contacts, to mitigate condensation in [Type 3R] [Type 4X] [Type 12] <Insert type> enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- G. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
- H. Cover gaskets for Type 1 enclosures.
- I. Terminals for connecting power factor correction capacitors to the [line] [load] side of overload relays.
- J. Spare control wiring terminal blocks, quantity as indicated[; **unwired**] [; **wired**].
- K. <Insert accessories>.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and surfaces to receive enclosed controllers, with Installer present, for compliance with requirements and other conditions affecting performance of the Work.
- B. Contractor shall make all necessary field measurements to verify that equipment shall fit in allocated space in full compliance with minimum required clearances specified in local codes and standards.

Retain first paragraph below for large and solid-state controllers requiring protection from condensation.

- C. Examine enclosed controllers before installation. Reject enclosed controllers that are wet, moisture damaged, or mold damaged.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.
- E. Verify that required utilities are available, in proper location and ready for use.
- F. Beginning of installation means installer accepts conditions.

3.2 INSTALLATION

- A. Wall-Mounted Controllers: Install enclosed controllers on walls with tops at uniform height unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not at walls, provide freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems."

Retain first paragraph below for equipment supported on slabs-on-grade.

- B. Floor-Mounted Controllers: Install enclosed controllers on 4-inch (100-mm) nominal-thickness concrete base. Comply with requirements for concrete base specified in [Section 033000 "Cast-in-Place Concrete."] [Section 033053 "Miscellaneous Cast-in-Place Concrete."]
1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 4. Install anchor bolts to elevations required for proper attachment to supported equipment.

Retain first paragraph below if seismic controls are Project requirement. Coordinate with Drawings.

- C. Seismic Bracing: Comply with requirements specified in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

Retain first five paragraphs below, as appropriate, to coincide with selections made in Part 2.

- E. Install fuses in each fusible-switch enclosed controller.
- F. Install fuses in control circuits if not factory installed. Comply with requirements in Section 262813 "Fuses."
- G. Install heaters in thermal overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.
- H. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
- I. Install power factor correction capacitors. Connect to the [line] [load] side of overload relays. If connected to the load side of overload relays, adjust overload heater sizes to accommodate the reduced motor full-load currents. Connect bus assemblies and components to wiring system and to ground as indicated and instructed by manufacturer.

1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.
2. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

J. Comply with NECA 1.

3.3 IDENTIFICATION

- A. Identify enclosed controllers, components, and control wiring. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 2. Label each enclosure with engraved nameplate.
 3. Label each enclosure-mounted control and pilot device.

3.4 CONTROL WIRING INSTALLATION

Retain this article if remote-control or remote-status indication is required.

- A. Install wiring between enclosed controllers and remote devices[**and facility's central control system**]. Comply with requirements in Section 260523 "Control-Voltage Electrical Power Cables."
- B. Bundle, train, and support wiring in enclosures.
- C. Connect selector switches and other automatic-control selection devices where applicable.
1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switch is in manual-control position.
 2. Connect selector switches with enclosed-controller circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.5 FIELD QUALITY CONTROL

See Editing Instruction No. 9 in the Evaluations for guidance on the level of field quality control appropriate for Project. Retain one of first two paragraphs below to identify who shall perform tests and inspections. Retain and edit "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first two paragraphs below to describe tests and inspections to be performed.

C. Acceptance Testing Preparation:

1. Test insulation resistance for each enclosed controller, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

D. Tests and Inspections:

1. Inspect controllers, wiring, components, connections, and equipment installation. [**Test and adjust controllers, components, and equipment.**]
2. Test insulation resistance for each enclosed-controller element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at controller locations are within plus or minus 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify DEN Project Manager before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

NETA ATS allows three methods to test and inspect bolted electrical connections for high resistance; the infrared (thermographic) method is the most thorough and costly. Retain first subparagraph below if this method is preferred.

8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multi-pole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
 - b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multi-pole enclosed controller 11 months after date of Substantial Completion.
 - c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. Enclosed controllers will be considered defective if they do not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- F. Prepare test and inspection reports including a certified report that identifies enclosed controllers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.6 ADJUSTING

Retain applicable paragraphs below to correspond to selections made in Part 2.

- A. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
- B. Adjust overload-relay heaters or settings if power factor correction capacitors are connected to the load side of the overload relays.
- C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable instantaneous trip elements. Initially adjust to six times the motor nameplate full-load ampere ratings and attempt to start motors several times, allowing for motor cooldown between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify DEN Project Manager before increasing settings.
- D. Set the taps on reduced-voltage autotransformer controllers at [50] [65] [80] percent.
- E. Set field-adjustable switches and program microprocessors for required start and stop sequences in reduced-voltage solid-state controllers.

Retain option in paragraph below unless settings are included on Drawings.

- F. Set field-adjustable circuit-breaker trip ranges[**as specified in Section 260573 "Overcurrent Protective Device Coordination Study."**]

3.7 PROTECTION

Retain this article if retaining "Delivery, Storage, and Handling" Article and if retaining space heaters in "Accessories" Article.

- A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until enclosed controllers are ready to be energized and placed into service.
- B. Replace controllers whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist in training Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers[, **and to use and reprogram microprocessor-based, reduced-voltage solid-state controllers**].
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262913

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SECTION 262923 - VARIABLE-FREQUENCY MOTOR CONTROLLERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1, which requires the use of mechanical or electrical variable-speed drives on fan motors used in VAV system fans that are 15 hp and larger and on motors in variable-flow hydronic systems that are larger than 50 hp.

Energy savings resulting from the use of variable-frequency motor controllers on motors other than required by Prerequisite EA 2 can be combined with other energy-saving measures to meet the requirements of LEED-NC, LEED-CS, and LEED for Schools Credit EA 1.

LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1 require the development of a Measurement & Verification Plan to achieve this credit. Energy used by each VFC can be used in the simulation calibration process required by the International Performance Measurement & Verification Protocol, Volume III, Chapter 4, "Whole Building Calibrated Simulation" (Option D) to verify the building's compliance with this credit.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

This Section is limited to separately enclosed, pre-assembled, combination VFCs furnished by a VFC manufacturer; it does not include panel-mounted variable-frequency drives intended to be field-installed in separate enclosures by contractors or incorporated into machinery or processes as part of a packaged system. The Section Text does not include VFCs for constant-horsepower loads because they are seldom used in commercial (e.g., plumbing and HVAC) applications; however, they can be added to suit Project.

Edit to suit Project.

- A. Section includes separately enclosed, pre-assembled, combination VFCs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.
- B. Related Sections:

Retain Section in subparagraph below that contains requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 262419 "Motor-Control Centers" for VFCs installed in motor-control centers.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. BAS: Building automation system.
- B. CE: Conformance Europeene (European Compliance).
- C. CPT: Control power transformer.
- D. EMI: Electromagnetic interference.
- E. IGBT: Insulated-gate bipolar transistor.
- F. LAN: Local area network.
- G. LED: Light-emitting diode.
- H. MCP: Motor-circuit protector.
- I. NC: Normally closed.
- J. NO: Normally open.
- K. OCPD: Overcurrent protective device.
- L. PCC: Point of common coupling.
- M. PID: Control action, proportional plus integral plus derivative.
- N. PWM: Pulse-width modulated.

- O. RFI: Radio-frequency interference.
- P. TDD: Total demand (harmonic current) distortion.
- Q. THD(V): Total harmonic voltage demand.
- R. VFC: Variable-frequency motor controller.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design; however, several listed manufacturers do not currently offer seismic certificates and some do not test wall-mounted controllers for their ability to "withstand" a seismic event. Verify availability of seismic testing and certification with manufacturers. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction. See "Seismic Considerations" Article in the Evaluations.

- A. Seismic Performance: VFCs shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type and rating of VFC indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.

1. Include data substantiating that materials comply with requirements.

- B. LEED Submittals:

LEED-NC and LEED for Schools Credit EA 5 requires continuous metering equipment for monitoring building energy-consumption performance over time. VFCs providing input to a BAS on energy usage can support this requirement. Coordinate with requirements in "Controls and Indication" Article.

1. Product Data for Credit EA 5: For continuous metering equipment for energy consumption.

- C. Shop Drawings: For each VFC indicated. Include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details,

including required clearances and service space around equipment.

1. Show tabulations of installed devices, equipment features, and ratings. Include the following:
 - a. Each installed unit's type and details.
 - b. Factory-installed devices.
 - c. Enclosure types and details.
 - d. Nameplate legends.
 - e. Short-circuit current (withstand) rating of enclosed unit.
 - f. Features, characteristics, ratings, and factory settings of each VFC and installed devices.

Retain first subparagraph below if specifying modifications in Part 2 articles.

- g. Specified modifications.
2. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below if Drawings do not include detailed plans or if Project involves unusual coordination requirements. See "Installation Considerations" Article in the Evaluations for additional guidance on when to retain paragraph.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFCs. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For qualified testing agency.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Seismic Qualification Certificates: For VFCs, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based, and their installation requirements.

Retain "Product Certificates" Paragraph below for product certificates from manufacturers.

- D. Product Certificates: For each VFC, from manufacturer.

Retain "Harmonic Analysis Study and Report" Paragraph below if an analysis is required from VFC manufacturer. Ensure that the information necessary for manufacturer to perform the analysis is included in the Construction Documents, including specified TDD and THD(V) limits. See "Harmonic Distortion" Article in the Evaluations and the Drawing Coordination Checklist for additional information.

- E. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze **[possible]** **[designated]** operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) **[at each VFC]** **[at the defined PCC]** to specified levels.
- F. Source quality-control reports.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- G. Field quality-control reports.

Large projects with multiple sizes and types of VFCs, with bypass contactors, might include different types of overload relays. Retain one or both paragraphs below to suit type(s) of motor overload protection if retaining motor-running overload protection in "Bypass Systems" Article. See Evaluations for discussion.

- H. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.
- I. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

Retain first subparagraph below if circuit breakers are specified in VFCs; retain second if field-adjustable overload relays are specified.

1. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
2. Manufacturer's written instructions for setting field-adjustable overload relays.

3. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
 4. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
 5. Manufacturer's installation information including equipment anchorage provisions.
- B. Certified production test reports.
- C. Seismic certification.
- D. Recommended renewal parts list.
- E. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

Verify requirements for as-built plans with DEN Project Manager.

- F. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIAL SUBMITTALS

Revise this article to include extra materials that Owner may require and that may fail more frequently due to continual use. Coordinate extra materials with features retained in Part 2.

Coordinate quantity of fuses with Section 262813 "Fuses" for required space in spare-fuse cabinet.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Power Fuses: Equal to **[ten (10)] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[three (3)] <Insert number>** of each size and type.
 2. Control Power Fuses: Equal to **[ten (10)] <Insert number>** percent of quantity installed for each size and type, but no fewer than **[two (2)] <Insert number>** of each size and type.
 3. Indicating Lights: **[Two (2)] <Insert number>** of each type and color installed.
 4. Auxiliary Contacts: Furnish **[one (1)] <Insert number>** spare(s) for each size and type of magnetic controller installed.
 5. Power Contacts: Furnish **[three (3)] <Insert number>** spares for each size and type of magnetic contactor installed.
 6. **<Insert extra materials>**.

1.9 QUALITY ASSURANCE

Retain "Testing Agency Qualifications" Paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with NFPA 70.
- D. The Manufacturer of this equipment shall have been pre-qualified by Owner.
- E. When requested by the DEN Project Manager, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.
- F. Installers shall specialize in installation of equipment with a minimum of five (5) years of experience.

Retain "IEEE Compliance" Paragraph below for projects in seismic areas. If retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

- G. IEEE Compliance: Fabricate and test VFC according to IEEE 344 to withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems."

1.10 DELIVERY, STORAGE, AND HANDLING

Retain first option in paragraph below for controllers that are not required to have factory-installed space heaters; otherwise, retain second option.

- A. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and **[install temporary electric heating, with at least 250 W per controller] [connect factory-installed space heaters to temporary electrical service]**.

1.11 PROJECT CONDITIONS

The conditions listed in "Environmental Limitations" Paragraph below are manufacturers' and industry standards for using VFC without derating or special enclosures and accessories. Revise paragraph to specify unusual environmental or service conditions; consult manufacturers for limitations and coordinate with equipment ratings. For equipment installed outdoors or indoors in unconditioned spaces, indicate maximum and minimum ambient temperature and expected humidity range; see Editing Instruction No. 2

in the Evaluations. For additional ambient compensation requirements for fuses, circuit breakers, and overload relays, see Editing Instructions No. 4, No. 5, and No. 7 in the Evaluations.

- A. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions unless otherwise indicated:
1. Ambient Temperature Range: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).
 2. Ambient Storage Temperature: Minus 30 deg F (minus 35 deg C) to 140 deg F (60 deg C)
 3. Humidity: Less than 95 percent (noncondensing).
 4. Altitude: 5500 feet (1677 m) above sea level.
 5. **<Insert unusual service condition>**.

Retain "Interruption of Existing Electrical Systems" Paragraph below if interruption of existing electrical distribution systems is required.

- B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown..
 2. Indicate method of providing temporary electrical service.
 3. Do not proceed with interruption of electrical systems without DEN Project Manager's written permission.
 4. Comply with NFPA 70E.

Dimensions of VFCs, especially those with bypass systems, specialty enclosures, or various options, can vary considerably in size between manufacturers. Retain "Product Selection for Restricted Space" Paragraph below with "Basis-of-Design Product" Paragraph in "Manufactured Units" Article if installation space for VFCs is limited; show maximum dimensions on Drawings. See "Installation Considerations" and "Large Equipment" articles in the Evaluations for additional guidance.

- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items.
- D. Field Measurements: Verify existing dimensions by field measurements. Verify clearances and locate obstructions within manufacturing and installation tolerances of enclosed assemblies

1.12 COORDINATION

- A. Coordinate features of motors, load characteristics, installed units, and accessory devices to be compatible with the following:

1. Torque, speed, and horsepower requirements of the load.
2. Ratings and characteristics of supply circuit and required control sequence.
3. Ambient and environmental conditions of installation location.

Frequently, VFCs rated above 30 hp, and especially those incorporating a bypass system, require floor mounting. Retain one or both of two paragraphs below if required for VFCs.

- B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

Installing VFCs on roofs exposed to the weather may amount to "unusual service conditions" for many VFCs. If retaining paragraph below, coordinate with Project conditions in "Environmental Limitations" and "Unit Operating Requirements" paragraphs. See Editing Instruction No. 2 for additional information on unusual service conditions.

- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.
- D. The drawings are diagrammatic and indicate the general arrangement of electrical work. Locations are approximate and shall be subject to minor modifications as dictated by field conditions and as directed by DEN Project Manager.

1.13 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods with manufacturers listed in Part 2 articles.

1. Warranty Period: Minimum **[five (5)]** <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.14 CONSTRUCTION WASTE MANAGEMENT

1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain "Manufacturers" Paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. ABB.
 2. Baldor Electric Company.
 3. Danfoss Inc.; Danfoss Drives Div.
 4. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 5. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 6. Rockwell Automation, Inc.; Allen-Bradley Brand.
 7. Siemens Energy & Automation, Inc.
 8. Square D; a brand of Schneider Electric.
 9. Toshiba International Corporation.
 10. Yaskawa Electric America, Inc; Drives Division.
 11. <Insert manufacturer>
 12. or approved equal.

Show VFC pole quantities, voltage, accessories, size and type, short-circuit current (withstand) rating (or available short-circuit currents), and enclosure type for each controller on Drawings. See "Specifying VFCs" Article and Editing Instruction No. 9 in the Evaluations for selection considerations.

Standard and optional features vary considerably among VFC manufacturers. Not all features, accessories, and options in this article are available for every rating, with every type of enclosure, and from every listed manufacturer. Also, features and options depend on motor characteristics and operating criteria of driven equipment. Verify, with manufacturer, availability and unique characteristics. Show on Drawings the features and accessories that apply to each VFC.

- B. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and [UL 508C] <Insert standard>.

Retain first option in "Application" Paragraph below for constant-torque loads such as positive-displacement pumps and reciprocating and screw compressors; retain second option for variable-torque loads such as centrifugal blowers, compressors, fans, and pumps.

- C. Application: [Constant torque] [and] [variable torque] <Insert application>.

Low-voltage VFCs are available for use with three-phase ac motors from 1/2 to 500 hp (depending on voltage rating), and in single- or three-phase input voltages from 200- to 575-V ac; however, not all listed manufacturers may offer VFCs in all these ratings and voltage ranges. Using single-phase voltages for VFCs controlling three-phase motors may require substantial derating of the VFCs; consult manufacturers for limitations and derating requirements.

- D. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT, PWM inverter) factory packaged in an enclosure, with integral disconnecting means

and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

Retain one or both of first two subparagraphs below as required to support motors and driven equipment specified in other Divisions. See "Multispeed and Variable-Speed Considerations" Article in the Evaluations in Section 230513 "Common Motor Requirements for HVAC Equipment," for guidance on motor requirements and applications using VFCs.

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
 2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
 3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.
- E. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

Retain first option in "Output Rating" Paragraph below for variable-torque drives; retain second option for constant-torque drives.

- F. Output Rating: Three-phase; 10 to **[60 Hz, with voltage proportional to frequency throughout voltage range] [66 Hz, with torque constant as speed changes]**; maximum voltage equals input voltage.
- G. Unit Operating Requirements:

Increases in technology are allowing manufacture of VFCs with greater tolerance to system anomalies and better operating performance. Most listed manufacturers offer VFCs that tolerate the greater optional variances, or they offer the higher levels of performance included in subparagraphs below. Consult manufacturers if Project system conditions fall outside the selected parameters in first three subparagraphs because corrective actions or additional modifications may be required before VFCs can be applied. In "Input AC Voltage Tolerance" Subparagraph, voltage tolerance is more a factor of voltage limitations for industrial control devices (e.g., magnetic contactors) in an enclosed VFC and not the VFC's power converter, which can usually tolerate greater voltage variations.

1. Input AC Voltage Tolerance: Plus 10 and minus **[10] [15]** percent of VFC input voltage rating.
2. Input AC Voltage Unbalance: Not exceeding **[3] [5]** percent.
3. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.
4. Minimum Efficiency: **[96] [97] <Insert number>** percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: **[96] [98] <Insert number>** percent under any load or speed condition.

Retain "Minimum Short-Circuit Current (Withstand) Rating" Subparagraph below if all VFCs on a Project are required to have the same short-circuit current rating. Delete subparagraph if short-circuit ratings vary for individual VFCs, and indicate the ratings on Drawings.

6. Minimum Short-Circuit Current (Withstand) Rating: **[10] [22] [65] [100] <Insert value>** kA.

VFCs are available that are suitable for use under environmental conditions different than those indicated in the four "rating" subparagraphs below; however, derating or special modifications, or both, may be required. Coordinate with "Project Conditions" Article, and consult manufacturers for required modifications or derating, or both, to accommodate unusual service conditions.

7. Ambient Temperature Rating: **Minus 30 deg F** (minus 35 deg C) to 120 deg F (49 deg C).
8. Ambient Storage Temperature Rating: Minus 30 deg F (minus 35 deg C) to 120 **deg F** (49 deg C)
9. Humidity Rating: Less than 95 percent (noncondensing).
10. Altitude Rating: **5500 feet** (1677 m) above sea level.

Retain "Vibration Withstand" Subparagraph below if VFCs are likely to be installed on vibrating equipment such as a built-up air-handling unit or skid-mounted pump assembly.

11. Vibration Withstand: Comply with IEC 60068-2-6.

Retain first option in "Overload Capability" Subparagraph below for variable-torque VFCs; retain second option for constant-torque VFCs.

12. Overload Capability: **[1.1] [1.5]** times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
13. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
14. Speed Regulation: Plus or minus **[5] [10]** percent.

Carrier frequencies above 2.5 kHz are seldom desired for motors more than 200 hp due to the increased possibility of overheating the motor windings. For large horsepower motors being used with VFCs, consult motor manufacturers for recommended limitations on carrier frequencies to mitigate motor winding overtemperatures.

15. Output Carrier Frequency: Selectable; 0.5 to **[15] <insert number>** kHz.
16. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

- H. Inverter Logic: Microprocessor based, **[16] [32]** bit, isolated from all power circuits.
- I. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.

Retain one of two "Signal" subparagraphs below with "Isolated Control Interface" Paragraph above. Coordinate retained subparagraph with selections made in "Control Signal Interfaces" Paragraph in "Controls and Indication" Article.

1. Signal: Electrical.
2. Signal: Pneumatic.

- J. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: **[0.1 to 999.9] <Insert range>** seconds.
4. Deceleration: **[0.1 to 999.9] <Insert range>** seconds.
5. Current Limit: 30 to minimum of 150 percent of maximum rating.
6. **<Insert adjustment and parameters>**.

K. Self-Protection and Reliability Features:

Coordinate Project-specific self-protection and reliability features with manufacturers, because standard and optional features vary considerably among manufacturers.

1. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
3. Under- and overvoltage trips.
4. Inverter overcurrent trips.
5. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
6. Critical frequency rejection, with [**three (3)**] <Insert number> selectable, adjustable deadbands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
8. Loss-of-phase protection.
9. Reverse-phase protection.
10. Short-circuit protection.
11. Motor overtemperature fault.
12. <Insert protection or reliability feature>.

"Automatic Reset/Restart" and "Power-Interruption Protection" paragraphs below are mutually exclusive in the same VFC. Retain both paragraphs if required for separate VFCs, and indicate on Drawings where each type is required.

- L. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
- M. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.

Retain "Bidirectional Autospeed Search" Paragraph below if retaining "Automatic Reset/Restart" Paragraph above or automatic and manual "Bypass Mode" Paragraph in "Bypass Systems" Article, or both.

- N. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
- O. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

- P. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

Not all manufacturers offer all options in "Integral Input Disconnecting Means and OCPD" Paragraph below. Coordinate with manufacturers for available options. Coordinate selection of the disconnecting means and OCPD with short-circuit current (withstand) ratings required for Project. See "Application of Switches and Circuit Breakers" Article and Editing Instructions No. 3, No. 4, No. 5, and No. 8 in the Evaluations for selection considerations.

- Q. Integral Input Disconnecting Means and OCPD: [**NEMA AB 1, instantaneous-trip circuit breaker**] [**NEMA AB 1, molded-case switch, with power fuse block and current-limiting fuses**] [**NEMA AB 1, thermal-magnetic circuit breaker**] [**NEMA KS 1, nonfusible switch, with power fuse block and current-limiting fuses**] [**NEMA KS 1, fusible switch**] with pad-lockable, door-mounted handle mechanism.

Retain first "Disconnect Rating" Subparagraph below for VFCs without bypass systems; retain second for VFCs with bypass systems.

1. Disconnect Rating: Not less than 115 percent of VFC input current rating.
2. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.

Retain "Auxiliary Contacts" Subparagraph below if retaining fusible or nonfusible switches in "Integral Input Disconnecting Means and OCPD" Paragraph and external control power is used; or, use for remote indication of disconnecting means position.

3. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.

Retain one or both of two subparagraphs below if retaining any circuit-breaker-type disconnecting means in "Integral Input Disconnecting Means and OCPD" Paragraph. Retain first subparagraph if external control power is used or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and NO or NC contact requirements on Drawings.

4. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
5. [**NC**] [**NO**] alarm contact that operates only when circuit breaker has tripped.

2.2 CONTROLS AND INDICATION

Coordinate local control and indication requirements with Owner or end users. Most of the indications included in "Status Lights" Paragraph below can be and are accomplished by listed manufacturers through digital displays in their panel-mounted operator stations. However, many operators still prefer the ability to "pass and glance" to determine the status of operating machinery or equipment.

- A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

7. **<Insert condition>**.

- B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.
1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
 2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.
 - a. Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.
- C. Historical Logging Information and Displays:

Retain first subparagraph below if time and date stamping is not accomplished through the BAS. This is an added-cost option with some listed manufacturers.

1. Real-time clock with current time and date.
 2. Running log of total power versus time.
 3. Total run time.
 4. Fault log, maintaining last [**four (4)**] **<Insert number>** faults with time and date stamp for each.
 5. **<Insert information or display>**.
- D. Indicating Devices: Digital display[**and additional readout devices as required,**] mounted flush in VFC door and connected to display VFC parameters including, but not limited to:
1. Output frequency (Hz).
 2. Motor speed (rpm).
 3. Motor status (running, stop, fault).
 4. Motor current (amperes).
 5. Motor torque (percent).
 6. Fault or alarming status (code).
 7. PID feedback signal (percent).
 8. DC-link voltage (V dc).
 9. Set point frequency (Hz).
 10. Motor output voltage (V ac).
 11. **<Insert parameter>**.

Coordinate three "interface" paragraphs below with Section 230900 "Instrumentation and Control for HVAC." Retain paragraphs to suit Project. If retaining more than one paragraph, indicate here or on Drawings where each interface type is required.

- E. Control Signal Interfaces:
1. Electric Input Signal Interface:

In first subparagraph below, some manufacturers offer an operator-selectable "x"- to "y"-mA dc signal input.

- a. A minimum of [two] <Insert number> programmable analog inputs: [0- to 10-V dc] [4- to 20-mA dc] [Operator-selectable "x"- to "y"-mA dc] <Insert signal parameters>.
- b. A minimum of [six] <Insert number> multifunction programmable digital inputs.

Retain "Pneumatic Input Signal Interface" Subparagraph below only if Project includes pneumatic controls in another Section. Several listed manufacturers now treat this feature as an added-cost option because it is so infrequently used anymore.

2. Pneumatic Input Signal Interface: 3 to 15 psig (20 to 104 kPa).
3. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:
 - a. 0- to 10-V dc.
 - b. 4- to 20-mA dc.
 - c. Potentiometer using up/down digital inputs.
 - d. Fixed frequencies using digital inputs.
 - e. <Insert signal input>.
4. Output Signal Interface: A minimum of [one] <Insert number> programmable analog output signal(s) ([0- to 10-V dc] [4- to 20-mA dc] [operator-selectable "x"- to "y"-mA dc] <Insert signal parameters>), which can be configured for any of the following:
 - a. Output frequency (Hz).
 - b. Output current (load).
 - c. DC-link voltage (V dc).
 - d. Motor torque (percent).
 - e. Motor speed (rpm).
 - f. Set point frequency (Hz).
 - g. <Insert indication>.
5. Remote Indication Interface: A minimum of [two] <Insert number> programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
 - a. Motor running.
 - b. Set point speed reached.
 - c. Fault and warning indication (overtemperature or overcurrent).
 - d. PID high- or low-speed limits reached.
 - e. <Insert indication>.

Retain "PID Control Interface" Paragraph below if VFC controls interface directly with local controls and not through a BAS.

- F. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps

for pressure, flow, or temperature regulation.

1. Number of Loops: [**One (1)**] [**Two (2)**] <Insert number>.

Retain "BAS Interface" Paragraph below if VFC controls interface with the BAS. Retain option if BAS is used to monitor and record energy usage for verification of LEED-NC and LEED for Schools Credit EA 5, LEED-CI Credit EA 3, and LEED-CS Credit EA 5.1.

- G. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms[**and energy usage**]. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.
1. Network Communications Ports: Ethernet and [**RS-422/485**] <Insert port type>.
 2. Embedded BAS Protocols for Network Communications: [**ASHRAE 135 BACnet**] [**Echelon LonWorks**] [**Johnson Metasys N2**] [**Modbus/Memobus**] [**Siemens System 600 APOGEE**] <Insert protocol type>; protocols accessible via the communications ports.

2.3 LINE CONDITIONING AND FILTERING

If input current distortion due to harmonic generation in VFCs is a concern, consult manufacturers for options available to mitigate harmonic distortion. Options may include dc bus link reactors, isolation transformers, active and passive harmonic filters, and 12- or 18-pulse phase-shifting input transformers. Retain first or second "Input Line Conditioning" Paragraph below if retaining "Harmonic Analysis Study and Report" Paragraph in "Informational Submittals" Article, if a specific method of mitigation is not important, and if manufacturer is delegated responsibility to incorporate whatever mitigating means are necessary to comply with specified limitations. Otherwise, retain third "Input Line Conditioning" Paragraph and insert specific requirements. See "Harmonic Distortion" Article in the Evaluations for additional guidance.

- A. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD at input terminals of [**all**] [**indicated**] VFCs to less than [**5**] [**8**] <Insert number> percent and THD(V) to [**3**] [**5**] <Insert number> percent.
- B. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD and THD(V) at the defined PCC per [**IEEE 519**] <Insert standard>.
- C. Input Line Conditioning: <Insert requirements>.

Normally if the separation between motor and VFC is less than 100 feet (30 m), the motor is designed for use with VFC, low carrier frequencies are specified, or all three, then output filtering may not be an issue. However, if distances are over 100 feet (30 m) and high carrier frequencies are being used, controller output voltage can exceed motor pulse-withstand capability. Consult motor and VFC manufacturers to determine need for, and options available for, conditioning output voltage. Options may include line inductors, dV/dT filters, output reactors, and motor termination filters. Insert requirements in first paragraph below. See "Motor and VFC Compatibility" Article in the Evaluations for additional guidance.

- D. Output Filtering: <Insert requirements>.

If EMI/RFI generation in VFCs is a concern, consult manufacturers for options available to mitigate it. Specifying compliance with applicable standards and following proper installation methods will usually address EMI/RFI issues. Retain first "EMI/RFI Filtering" Paragraph below if a specific method of mitigation is not important and manufacturer is delegated responsibility to incorporate whatever mitigating means are necessary to comply with specified limitations. Otherwise, retain second "EMI/RFI Filtering" Paragraph and insert specific requirements. See "Electromagnetic Compatibility" Article in the Evaluations for additional guidance.

- E. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for [Category C2] <Insert category>.
- F. EMI/RFI Filtering: <Insert requirements>.

2.4 BYPASS SYSTEMS

Retain this article only if VFCs will require bypass systems. Applying bypass systems to VFCs requires additional consideration of system parameters and code requirements. Additionally, listed manufacturers offer different forms of bypass strategies and different operating characteristics. See "Bypass Systems" Article in the Evaluations for guidance, and coordinate with manufacturers for available selections.

- A. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

Retain one of two "Bypass Mode" paragraphs below, or retain both if required for separate VFCs, and indicate on Drawings where each type is required. First paragraph is for bypass control where the motor must be at zero speed before the bypass function is performed; second paragraph allows for bypass control whether the motor is at rest or running. If retaining second paragraph, also retain "Bidirectional Autospeed Search" Paragraph in "Manufactured Units" Article.

- B. Bypass Mode: Manual operation only; requires local operator selection at VFC. Transfer between power converter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.
- C. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.

Retain one of two "Bypass Controller" paragraphs below. First paragraph is frequently called a "two-contactor-style" bypass - it typically does not allow power converter maintenance while the VFC is operating in bypass, because the power converter input remains energized, unless used with an input isolating switch and barrier. Second paragraph is for a "three-contactor-style" bypass - it allows power converter testing while the motor continues to operate at full speed in bypass, because the power converter is de-energized as well as being isolated from input and output power circuits. Either controller can be operated in manual or manual/automatic mode.

- D. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller[; **with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode**].

In "Bypass Contactor" Subparagraph below, IEC-rated contactors are most often used for the bypass contactor in HVAC applications and for smaller motors, and they are usually smaller and less costly than equivalent NEMA-rated contactors. NEMA-rated contactors are most often used in industrial applications and for larger motors, where they must carry high motor inrush and full-load running currents. IEC-rated contactors are most often used in all applications for the isolating contactors, because they are only used to isolate the power converter and normally do not carry any current. Consult manufacturers for the types used for each.

1. Bypass Contactor: Load-break, [IEC] [NEMA]-rated contactor.
2. Output Isolating Contactor: Non-load-break, [IEC] [NEMA]-rated contactor.

Retain "Isolating Switch" Subparagraph below if retaining option in "Bypass Controller" Paragraph above.

3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

There is some concern among various listed manufacturers that the input isolating contactor of the three-contactor bypass, without an isolating switch and a barrier between the power converter and the bypass, may not comply with NFPA 70 requirements for safe isolation of the power converter during energized maintenance, because the contactor is not a positive, lockable disconnecting means, and lack of a barrier can lead to accidental contact with live parts in the bypass. Consult authorities having jurisdiction if this is a concern and if retaining "Bypass Controller" Paragraph below.

- E. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller[; **with input isolating switch and barrier**] arranged to isolate the power converter input and output and permit safe testing[**and troubleshooting**] of the power converter, both energized and de-energized, while motor is operating in bypass mode.

1. Bypass Contactor: Load-break, [IEC] [NEMA]-rated contactor.
2. Input and Output Isolating Contactors: Non-load-break, [IEC] [NEMA]-rated contactors.

Retain "Isolating Switch" Subparagraph below if retaining first option in last "Bypass Controller" Paragraph above.

3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

First option in "Bypass Contactor Configuration" Paragraph below is for full-voltage starting; second option is for reduced-voltage starting. For large horsepower motors, consider using a reduced-voltage bypass controller instead of a full-voltage controller. Some listed manufacturers also offer reduced-voltage, solid-state controllers as a bypass option; consult manufacturers if this is a preference. See "Reduced-Voltage Bypass Contactors" Article in the Evaluations for additional information.

- F. Bypass Contactor Configuration: [**Full-voltage (across-the-line)**] [**Reduced-voltage (autotransformer)**] <Insert type> type.
 1. NORMAL/BYPASS selector switch.

Retain first subparagraph below only if retaining automatic and manual "Bypass Mode" Paragraph above.

2. HAND/OFF/AUTO selector switch.
3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.
4. Contactor Coils: Pressure-encapsulated type[**with coil transient suppressors**].
 - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
 - b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: [120] <Insert number>-V ac; obtained from [**integral CPT, with primary and secondary fuses**] <Insert source of control power>, with [CPT] [**control power source**] of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.

Retain "CPT Spare Capacity" Subparagraph below if retaining "CPT" option in "Control Circuits" Subparagraph above and spare CPT capacity is required. Spare capacity is normally available in 100-VA increments. Consult manufacturers for maximum spare capacity and for available CPT sizes for different NEMA and enclosure sizes, because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

- a. CPT Spare Capacity: [50] [100] [200] <Insert number> VA.

Manufacturers typically integrate overload functions into the microprocessors of VFCs and use separate thermal or solid-state overload relays only if specifying a bypass system. Retain one or more of first three subparagraphs below if specifying a bypass system. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 6 and "Overload Protection" Article in the Evaluations for additional guidance.

6. Overload Relays: NEMA ICS 2.
 - a. Melting-Alloy Overload Relays:
 - 1) Inverse-time-current characteristic.
 - 2) [**Class 10**] [**Class 20**] [**Class 30**] tripping characteristic.
 - 3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
 - b. Bimetallic Overload Relays:
 - 1) Inverse-time-current characteristic.
 - 2) [**Class 10**] [**Class 20**] [**Class 30**] tripping characteristic.
 - 3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below if applicable. See Editing Instruction No. 7 and "Bimetallic Overload Relays" Article in the Evaluations for guidance and warnings.

- 4) Ambient compensated.

- 5) Automatic resetting.
- c. Solid-State Overload Relays:
- 1) Switch or dial selectable for motor-running overload protection.
 - 2) Sensors in each phase.
 - 3) **[Class 10] [Class 20] [Class 10/20 selectable]** tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable. These are optional, added-cost features.

- 4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
- 5) Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

- d. **[NC] [NO]** isolated overload alarm contact.
- e. External overload reset push button.

2.5 OPTIONAL FEATURES

Optional feature types and quantities vary considerably among VFC manufacturers. Consult manufacturers for availability and limitations. Features vary according to VFC and motor characteristics and the driven-equipment operating criteria. Retain applicable features in this article; insert others to suit Project. Indicate requirements for and quantities of optional features on Drawings if not included here. These features are normally added-cost items. See "Optional Features" Article in the Evaluations for additional guidance, and consult manufacturers for availability of, and limitations on, other options.

Retain "Multiple-Motor Capability" Paragraph below if Project requires multiple motors controlled from a single VFC and controller redundancy is unnecessary.

- A. Multiple-Motor Capability: VFC suitable for variable-speed service to multiple motors. Overload protection shuts down VFC and motors served by it, and generates fault indications, when overload protection activates.

Retain one of three subparagraphs below, or more than one if required for separate VFCs; indicate on Drawings where each type is required. Other multimotor options are available from some listed manufacturers; consult manufacturers if other combinations are required.

1. Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.
2. Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.

Retaining subparagraph below requires retaining and properly revising "Bypass Systems" Article to support this configuration. Consult manufacturers for more information.

3. Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.
- B. Damper control circuit with end of travel feedback capability.
 - C. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
 - D. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
 - E. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from **[the firefighter's control station] [smoke-control fan controller] <Insert location>**, this password-protected input:
 1. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).

Retain one of first two subparagraphs below. First subparagraph is for VFCs without a bypass system; second is for VFCs with a bypass system and the bypass will be used for this function. In first subparagraph, coordinate preset speed with pressure rating of the ventilation system. Consider requiring final speed setting to be determined during commissioning, testing, and balancing of the ventilation system. Ensure that ducted systems are designed to tolerate the higher pressures generated by the full or preset speed settings.

2. Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
3. Forces VFC to transfer to Bypass Mode and operate motor at full speed.
4. Causes display of Override Mode on the VFC display.
5. Reset VFC to normal operation on removal of override signal [**automatically**] [**manually**].

If retaining "Remote Indicating Circuit Terminals" Paragraph below, consider adding Specifications for remote indicating devices.

- F. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
- G. Remote digital operator kit.
- H. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer[**and a notebook computer**].
- I. **<Insert optional feature>**.

2.6 ENCLOSURES

- A. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.

See "Enclosures" Article in the Evaluations for discussion of enclosure types. Coordinate subparagraphs below with Drawings by identifying the designated areas on plans or by including the required enclosure types. Enclosure materials and finishes may be added to the Section Text. Availability of some enclosure types is limited by type and rating of controller; special accommodations and accessories (e.g., powered/filtered ventilation) may be required for some enclosure types. Consult manufacturers for availability of, and limitations on, enclosures other than NEMA 250, Type 1. VFCs are not usually available in explosion-proof enclosures.

1. Dry and Clean Indoor Locations: **[Type 1] <Insert type>**.
2. Outdoor Locations: **[Type 3R] [Type 4X] <Insert type>**.
3. **[Kitchen] [Wash-Down] Areas: [Type 4X] <Insert type>, [stainless steel] <Insert material>**.
4. Other Wet or Damp Indoor Locations: **[Type 4] <Insert type>**.
5. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.
6. **<Insert enclosure requirements>**.

Retain "Plenum Rating" Paragraph below when the VFC will be installed in plenums (e.g., in the air stream inside an air-handling unit) or in a space used for environmental air (e.g., above a suspended ceiling used for return air). Some authorities having jurisdiction require that a label verifying the rating be prominently displayed on the VFC enclosure.

- B. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFC as "Plenum Rated."

2.7 ACCESSORIES

Accessories listed in this article are limited in application by VFC and enclosure types; accessories in the first five paragraphs below apply primarily to VFCs with bypass systems. Retain applicable accessories below. Indicate requirements for and quantities of accessories on Drawings. See "Accessories" Article in the Evaluations for additional guidance; consult manufacturers for availability of, and limitations on, other accessories.

- A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFC enclosure cover unless otherwise indicated.
 1. Push Buttons, Pilot Lights, and Selector Switches: **[Heavy] [Standard]-duty, [oiltight] type**.
 - a. Push Buttons: **[Covered] [Lockable] [Recessed] [Shielded] [Shrouded] [Unguarded] types; [maintained] [momentary]**.
 - b. Pilot Lights: **[Incandescent] [LED] [Neon] [Resistor] [Transformer] types; <Insert color(s)>; push to test**.
 - c. Selector Switches: **[Rotary] <Insert description> type**.

Stop and lockout push-button stations are no longer allowed by NFPA 70 as a means of isolating controllers or motors for personnel safety during maintenance; however, they are still required by some end users and Owners. Retain subparagraph below only if required by the end user or Owner.

- d. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

- B. **[NC] [NO] [Reversible NC/NO]** bypass contactor auxiliary contact(s).
- C. Control Relays: Auxiliary and adjustable **[pneumatic] [solid-state]** time-delay relays.

Features in "Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays" Paragraph below provide one method of protecting against input circuit anomalies while in the bypass mode. They are available in individual relays or combined into a single multipurpose relay, and they would only be required if retaining "Bypass Systems" Article. Because features in paragraph below may not be available from all listed manufacturers, other methods of providing redundant control of motor loads served may be required; consult manufacturers for availability. Consider specifying phase-failure relays for single-phasing protection when fuses are retained with the bypass feature if solid-state overload relays are not specified.

- D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays:
Solid-state sensing circuit with isolated output contacts for hard-wired connections.
Provide adjustable undervoltage, overvoltage, and time-delay settings.
 - 1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.
- E. Supplemental **[Analog] [Digital]** Meters:
 - 1. Elapsed-time meter.
 - 2. Kilowatt meter.
 - 3. Kilowatt-hour meter.
- F. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, **[Type 4] [Type 4X] [Type 12] <Insert type>** enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- G. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, **[Type 3R] [Type 4X] [Type 12] <Insert type>** enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- H. Cooling Fan and Exhaust System: For NEMA 250, **[Type 1] [Type 12] <Insert enclosure type>**; UL 508 component recognized: Supply fan, with **[composite] [stainless steel] <Insert material>** intake and exhaust grills **[and filters]**; **[120] <Insert number>** -V ac; obtained from **[integral CPT] <Insert source of control power>**.
- I. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.

Indicate quantities of spare control-wiring terminal blocks on Drawings.

- J. Spare control-wiring terminal blocks**;** **unwired]** **;** **wired]**.
 - 1. **<Insert accessory>**.

2.8 SOURCE QUALITY CONTROL

NEMA ICS 61800-2 includes acceptance testing by manufacturer of VFCs completely assembled and wired, before shipment from the factory.

- A. Testing: Test and inspect VFCs according to requirements in [**NEMA ICS 61800-2**] <**insert standard**>.
 - 1. Test each VFC while connected to [**its specified motor**] [**a motor that is comparable to that for which the VFC is rated**].
 - 2. Verification of Performance: Rate VFCs according to operation of functions and features specified.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- B. VFCs will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances, <**insert Project-specific conditions**,> and other conditions affecting performance.
- B. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 HARMONIC ANALYSIS STUDY

- A. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze [**possible**] [**designated**] operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) [**at each VFC**] [**at the defined PCC**] to specified levels.
- B. Prepare a harmonic analysis study and report complying with IEEE 399 and NETA Acceptance Testing Specification.

3.3 INSTALLATION

- A. Coordinate layout and installation of VFCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
- B. Contractor shall make all necessary field measurements to verify that equipment shall fit in allocated space in full compliance with minimum required clearances specified in local codes and standards.
- C. Examine installation area to assure there is enough clearance to install equipment.
- D. Verify that equipment is ready to install.
- E. Verify that required utilities are available, in proper location and ready for use.
- F. Beginning of installation means installer accepts conditions.
- G. Wall-Mounting Controllers: Install VFCs on walls with tops at uniform height and with disconnect operating handles not higher than **79 inches (2000 mm)** above finished floor unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems."

Retain "Floor-Mounting Controllers" Paragraph below for equipment supported on slabs-on-grade. If installing VFCs on concrete bases, ensure that their disconnect operating handles will not be higher than **79 inches (2000 mm)** above finished floor.

- H. Floor-Mounting Controllers: Install VFCs on **4-inch (100-mm)** nominal thickness concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on **18-inch (450-mm)** centers around the full perimeter of concrete base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to supported equipment.

Retain first paragraph below for equipment supported on roofs.

- I. Roof-Mounting Controllers: Install VFC on roofs with tops at uniform height and with disconnect operating handles not higher than **79 inches (2000 mm)** above finished roof surface unless otherwise indicated, and by bolting units to curbs or mounting on freestanding, lightweight, structural-steel channels bolted to curbs. Seal roof penetrations after raceways are installed.

1. Curbs and roof penetrations are specified in Section 077200 "Roof Accessories."
2. Structural-steel channels are specified in Section 260529 "Hangers and Supports for Electrical Systems."

Retain "Seismic Bracing" Paragraph below if seismic controls are Project requirement. Coordinate with Drawings and Sections specifying vibration and seismic controls.

- J. Seismic Bracing: Comply with requirements specified in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- K. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

Retain first four paragraphs below, as appropriate, to coincide with retained VFC features and attributes.

- L. Install fuses in each fusible-switch VFC.
- M. Install fuses in control circuits if not factory installed. Comply with requirements in Section 262813 "Fuses."
- N. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.
- O. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
- P. Tighten bus-assembly joints with torque wrench or similar tool recommended by bus assembly manufacturer. Tighten joints again after bus assemblies have been energized for 30 days.
- Q. Connect bus assemblies and components to wiring system and to ground as indicated and instructed by manufacturer.
- R. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those in specified standards.
- S. Submit torque values for all connections with a torque schedule and witness signature.
- T. Comply with NECA 1.

3.4 IDENTIFICATION

- A. Identify VFCs, components, and control wiring. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 2. Label each VFC with engraved nameplate.
 3. Label each enclosure-mounted control and pilot device.

If specific operational procedures are required in emergency situations, specify below. Show specific information to be included in framed instructions on Drawings; retain paragraph below if required.

- B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.5 CONTROL WIRING INSTALLATION

Retain this article if applicable or if remote control or indication is required.

- A. Install wiring between VFCs and remote devices[**and facility's central-control system**]. Comply with requirements in Section 260523 "Control-Voltage Electrical Power Cables."
- B. Bundle, train, and support wiring in enclosures.
- C. Connect selector switches and other automatic control devices where applicable.
 - 1. Connect selector switches to bypass only those manual- and automatic control devices that have no safety functions when switches are in manual-control position.
 - 2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.6 FIELD QUALITY CONTROL

See Editing Instruction No. 10 in the Evaluations for guidance on the level of field quality control that would be appropriate for Project. Retain one of first two paragraphs below to identify who shall perform tests and inspections. Retain and edit "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first two paragraphs below to describe tests and inspections to be performed.

C. Acceptance Testing Preparation:

1. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

D. Tests and Inspections:

1. Inspect VFC, wiring, components, connections, and equipment installation. [**Test and adjust controllers, components, and equipment.**]
2. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.

In first subparagraph below, the 10 percent voltage variation is a functional issue. Where ASHRAE 90.1 is Project's applicable energy code, further restrictions in voltage drop are required.

4. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify DEN Project Manager before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

NETA Acceptance Testing Specification allows three methods to test and inspect bolted electrical connections for high resistance; the infrared (thermographic) method is the most thorough and costly. Retain "Initial Infrared Scanning" Subparagraph below if this method is preferred.

8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFC. Remove front panels so joints and connections are accessible to portable scanner.
 - b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFC 11 months after date of Substantial Completion.
 - c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. VFCs will be considered defective if they do not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

- F. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.7 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor in performing startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. **<Insert startup steps if any>**.

3.8 ADJUSTING

Retain applicable paragraphs below to correspond to selections made in Part 2.

- A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

First two paragraphs below pertain primarily to VFCs with bypass systems. Retain if retaining "Bypass Systems" Article.

- B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
- C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify DEN Project Manager before increasing settings.
- D. Set the taps on reduced-voltage autotransformer controllers.

Retain option in first paragraph below unless settings are included on Drawings.

- E. Set field-adjustable circuit-breaker trip ranges[**as specified in Section 260573 "Overcurrent Protective Device Coordination Study."**]
- F. Set field-adjustable pressure switches.

3.9 PROTECTION

Retain this article if retaining "Delivery, Storage, and Handling" Article and if retaining space heaters in "Accessories" Article.

- A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.
- B. Replace VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.
- C. Provide final protection to ensure that moisture does not enter assembly.

3.10 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.11 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor with training Owner's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.
 - 1. Train Owner's maintenance personnel on procedures and schedules for starting up and shutting down, troubleshooting, servicing, and maintaining equipment and schedules.
- B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

3.12 COMISSIONING

- A. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.
 - 1. Use an infrared scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
 - 2. Perform two follow-up infrared scans of bus assembly, one at four months and the other at 11 months after Substantial Completion.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 262923

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SECTION 263100 - PHOTOVOLTAIC COLLECTORS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. PV laminates (cells laminated into rigid sheets, with connecting cables).
 - 2. PV modules (laminates in mounting frames).
 - 3. Charge controllers.
 - 4. Inverters.
 - 5. Mounting structures.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. CEC: California Energy Commission.

- B. ETFE: Ethylene tetrafluoroethylene.
- C. FEP: Fluorinated ethylene propylene.
- D. IP Code: Required ingress protection to comply with IEC 60529.
- E. MPPT: Maximum power point tracking.
- F. PTC: USA standard conditions for PV.
- G. PV: Photovoltaic.
- H. STC: Standard Test Conditions defined in IEC 61215.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for PV panels.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For PV modules.
 - 1. Include plans, elevations, sections, and mounting details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Detail fabrication and assembly.
 - 4. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
- B. Sample Warranty: For manufacturer's special materials and workmanship warranty and minimum power output warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For PV modules to include in operation and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Manufacturer's Special Materials and Workmanship Warranty: Manufacturer agrees to repair or replace components of PV modules that fail in materials or workmanship within specified warranty period.
 - 1. Manufacturer's materials and workmanship warranties include, but are not limited to, the following:
 - a. Faulty operation of PV modules.
 - b. <Insert failure modes>.

Verify available warranties and warranty periods for modules.

- 2. Warranty Period: Minimum [two (2)] [five (5)] <Insert number> years from date of Substantial Completion.

Verify available warranties and warranty periods for specified minimum power output. The percentage maintained may include two ranges for different time periods.

- B. Manufacturer's Special Minimum Power Output Warranty: Manufacturer agrees to repair or replace components of PV modules that fail to exhibit the minimum power output within specified warranty period. Special warranty, applying to modules only, applies to materials only, on a prorated basis, for period specified.
 - 1. Manufacturer's minimum power output warranties include, but are not limited to, the following warranty periods, from date of Substantial Completion:
 - a. Specified minimum power output to [80] <Insert number> percent or more, for a period of [25] <Insert number> years.
 - b. <Insert additional minimum power output special warranty>.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURED UNITS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aleo Solar.
2. BP Solar USA.
3. Canadian Solar.
4. ET Solar.
5. Evergreen Solar, Inc.
6. GE Energy; General Electric Company.
7. Kaneka Corporation.
8. Kyocera International, Inc.
9. Mitsubishi Electric Corporation.
10. REC Solar US LLC.
11. Sanyo North America Corporation.
12. Schott Solar.
13. Sharp Electronics Corporation.
14. SunPower Corporation.
15. Suntech Power.
16. Trina Solar Limited.
17. United Solar Ovonic LLC.
18. Yingli Green Energy Holding Co., Ltd.
19. **<Insert manufacturer's name>.**
20. or approved equal.

2.2 PERFORMANCE REQUIREMENTS

- A. NRTL (Nationally Recognized Testing Laboratory) Listing: Entire assembly shall be listed and labeled by a qualified testing agency acceptable to authorities having jurisdiction for electrical and fire safety, [**Class A**] [**Class C**], according to UL 1703.
- B. FM approved for NFPA 70, Class 1, Division 2, Group C and Group D hazardous locations.

2.3 SYSTEM DESCRIPTION

Retain "Grid-Tied PV System" Paragraph below if the energy system will be required to be connected to the electrical utility grid. Retain options and delete insert note as required.

A. Grid-Tied PV System:

1. Connected via a utility meter to the electrical utility.
2. An array of [**six (6)**] <Insert number> modules to generate a total nominal [**1000**] <Insert value> rated W.
3. System Components:
 - a. Cell materials.
 - b. PV modules.
 - c. Array frame.
 - d. Charge controller.
 - e. Inverter.
 - f. Overcurrent protection/combiner box.
 - g. Mounting structure.
 - h. Utility meter.
 - i. <Insert component>.

B. Battery-Storage PV System:

1. Connected to a battery bank to provide electricity to Project.
2. An array of [**six (6)**] <Insert number> modules to generate a total nominal [**1000**] <Insert value> rated W.
3. System Components:
 - a. Cell materials.
 - b. PV modules.
 - c. Array frame.
 - d. Charge controller.
 - e. Inverter.
 - f. Overcurrent protection/combiner box.
 - g. Mounting structure.
 - h. Battery charge controller(s).
 - i. Batteries.
 - j. Battery-storage structure.

2.4 MANUFACTURED UNITS

Retain one of six "Cell Materials" paragraphs below. Retain one of first five for thin-film cells; retain sixth for wafer crystalline silicon (c-Si) cells.

- A. Cell Materials: Amorphous silicon (a-Si).
- B. Cell Materials: Copper indium (di)selenide (CIS).
- C. Cell Materials: Copper indium gallium (di)selenide (CIGS).
- D. Cell Materials: Cadmium telluride (CdTe).
- E. Cell Materials: Cadmium sulfide.

- F. Cell Materials: [**Polycrystalline**] [**Monocrystalline**].
 - 1. c-Si.
 - 2. Gallium arsenide (GaAs).
- G. Module Construction:
 - 1. Nominal Size: **32 inches** (800 mm) wide by **64 inches** (1600 mm) long.
 - 2. Weight: **42.8 lb** (19.4 kg).
- H. Insulating Substrate Film: [**Flexible**] [**Rigid**], [**polyester**] [**polyimide**].
- I. Conducting Substrate Film: [**Flexible**] [**Rigid**] [**Fluoropolymer**], [**ETFE**] [**FEP**].
- J. Encapsulant: Ethyl vinyl acetate.

Retain one of six "Front Panel" paragraphs below.

- K. Front Panel: Fully tempered glass.
- L. Front Panel: **0.125-inch-** (3.2-mm-) thick glass.
- M. Front Panel: Low iron glass.
- N. Front Panel: Antireflective coating glass.
- O. Front Panel: Laminating film.
- P. Front Panel: Laminating material.

Retain one of four "Backing Material" paragraphs below.

- Q. Backing Material: Tempered glass.
- R. Backing Material: **0.125-inch-** (3.2-mm-) thick glass; <**Insert color**>.
- S. Backing Material: Polyester film.
 - 1. Layers: <**Insert number**>.
 - 2. Color: [**White**] <**Insert color**>.
- T. Backing Material: PVC film.
 - 1. Layers: <**Insert number**>.
 - 2. Color: [**White**] <**Insert color**>.
- U. Bypass Diode Protection: Internal.
- V. Junction Box:
 - 1. Size: **1.56 by 3.96 by 0.52 inch** (39.6 by 100.6 by 13.2 mm).

2. Fully potted, vandal resistant.
3. IP Code: **[IP65] [IP66] [IP67] <Insert IP code designation>**.
4. Flammability Test: UL 1703.

W. Output Cabling:

1. **[0.158 inch (4 mm)] <Insert dimension>**.
2. Quick, multiconnect, polarized connectors.
3. Two-Conductor Harness: No traditional return wire is needed from the end of a row back to the source combiner.

X. Series Fuse Rating: **<Insert amperage>**.

2.5 CAPACITIES AND CHARACTERISTICS

A. Minimum Electrical Characteristics:

1. Rated Open Circuit Voltage (V_{oc}): **<Insert V dc>**.
2. Maximum System Voltage: **<Insert V dc>**.
3. Maximum Power at Voltage (V_{pm}): **<Insert V dc>**.
4. Short-Circuit Temperature Coefficient: **<Insert mA/deg C>**.
5. Rated Short-Circuit Current (I_{sc}): **<Insert amperage>**.
6. Maximum System: **<Insert V dc>**.
7. Rated Operation Current (I_{mp}): **<Insert amperage>**.
8. Maximum Power at STC (P_{max}): **<Insert watts>**.

B. Additional Electrical Characteristics:

1. PTC Rating: **<Insert watts>**.
2. Peak Power per Unit Area: **<Insert watts>**.
3. Tolerance of Pmax: **<Insert number>** percent.
4. Minimum Peak Power: **<Insert watts>**.
5. Series Fuse Rating: **<Insert amperage>**.
6. Module Efficiency: **<Insert number>** percent.
7. Temperature Cycling Range: **<Insert deg C>**.
8. Humidity, Freeze, Damp Heat Condition: **<Insert number>** percent RH.
9. Wind Loading or Surface Pressure: **<Insert lbf/sq. ft. (N/sq. m)>**.
10. Maximum Distortion Angle: **<Insert degrees>**.
11. Hailstone Impact Withstand: **<Insert inches (mm)>** diameter at **<Insert mph (km/h)>** wind velocity.
12. Series Fuse Rating: **<Insert amperage>**.

C. Normal Operating Temperature Characteristics (NOTC):

1. Temperature at Nominal Operating Cell Temperature: **<Insert deg C>**.
2. Temperature Coefficient (NOTC P_{max}): **<Insert deg C>**.
3. Temperature Coefficient (NOTC V_{oc}): **<Insert deg C>**.
4. Temperature Coefficient (NOTC I_{sc}): **<Insert deg C>**.
5. Temperature Coefficient (NOTC V_{mp}): **<Insert deg C>**.

6. Temperature Coefficient (NOTC I_{mp}): **<Insert deg C>**.

2.6 MODULE FRAMING

- A. PV laminates mounted in anodized extruded-aluminum frames.

1. Entire assembly UL listed for electrical and fire safety, **[Class A] [Class C]**, according to UL 1703, complying with IEC 61215.
2. Frame strength exceeding requirements of certifying agencies in subparagraph above.

Retain one of three "Finish" subparagraphs below.

3. Finish: Anodized aluminum.
 - a. Alloy and temper recommended by framing manufacturer for strength, corrosion resistance, and application of required finish.
 - b. Color: As indicated by manufacturer's designations.
4. Finish: High-performance organic finish.
 - a. Fluoropolymer Two-Coat System: Manufacturer's standard two-coat, thermocured system consisting of specially formulated inhibitive primer and fluoropolymer color topcoat containing not less than 70 percent PVC resin by weight.
 - b. Color: As indicated by manufacturer's designations.
5. Finish: Baked-enamel finish.
 - a. Color: As indicated by manufacturer's designations.

2.7 ARRAY CONSTRUCTION

- A. Framing:

Retain one of three options in "Material" Subparagraph below.

1. Material: **[Extruded aluminum] [Galvanized steel] [Coated steel]**.
2. Maximum System Weight: Less than **4 lb/sq. ft.** (19.53 kg/sq. m).
3. Minimum Distance to Connectors: **<Insert inches (mm)>**.
4. Raceway Cover Plates: **[Plastic] [Aluminum] [Galvanized steel]**.

- B. Flat-Roof Mounting:

1. No roof penetrations.
2. Self-ballasting.
3. Wind-tunnel tested to **110-mph** (160-km/h) wind.
4. Service Life: **[25] <Insert number>** years.
5. Freestanding system.

2.8 CHARGE CONTROLLER

A. Charge Controller Electrical Characteristics:

1. Output Current Rating: **<Insert amperage>**.
2. Nominal Battery Voltage: **<Insert V dc>**.
3. PV Maximum Open Circuit Voltage: **<Insert V dc>**.
4. Equalization Voltage: **<Insert V dc>**.
5. Voltage Step-Down Capability: **<Insert V dc>**.
6. Power Conversion Efficiency: **<Insert number>** percent.

B. Charge controllers shall have the following:

Retain subparagraphs below to suit Project.

1. Digital display.
2. Data logging.
3. Remote interface.
4. External sensors.
5. Temperature compensation.

2.9 INVERTER

Retain one of two "Control Type" paragraphs below.

- A. Control Type: Pulse width modulation control.
- B. Control Type: Maximum power point tracker control.
- C. Inverter Electrical Characteristics:

Retain inverter characteristics below to suit Project.

1. Maximum Recommended PV Input Power: **<Insert kilowatts>**.
2. Maximum Voc: **<Insert V dc>**.
3. PV Start Voltage: **<Insert V dc>**.
4. MPPT Voltage Range: **<Insert V dc>**.
5. Maximum Input Current: **<Insert amperage>**.
6. Number of String Inputs: **<Insert number>**.
7. Number of Independent MPPT Circuits: **<Insert value>**.
8. Nominal Output Voltage: **<Insert V dc>**.
9. CEC Rated Power: **<Insert kilowatts>**.
10. Nominal Output Voltage: **<Insert V ac>**.
11. Maximum Output Current: **<Insert amperage>**.
12. Peak Efficiency: **<Insert number>** percent.
13. CEC Weighted Efficiency: **<Insert number>** percent.
14. CEC Night Tare Loss: **<Insert watts>**.
15. DC/AC Terminal Range (AWG): **<Insert range of AWG values>**.
16. NEMA 250 Enclosure Rating: **<Insert amperage>**.

D. Operating Conditions:

1. Operating Ambient Temperatures: Minus 30 to plus 122 deg F (minus 35 deg C to plus 50 deg C).
2. Storage Temperature: Minus 40 to plus 122 deg F (minus 40 to plus 50 deg C).
3. Relative Humidity: 0 to 95 percent, noncondensing.
4. Altitude: 5500 feet (1677 m) above sea level.

Retain charge controller characteristics below to suit Project.

E. Charge controllers shall have the following:

1. Overcurrent protection.
2. Generator input breaker box.
3. Automatic transfer relay.
4. Digital display.
5. Transformer.
6. Disconnect switch.
7. Shunt controller.
8. Shunt regulator.
9. Surge overload protection.

F. Enclosure:

1. NEMA 250, Type 3R.
2. Enclosure Material: [**Galvanized steel**] [**Steel**].

Retain "Cooling Methods" Subparagraph below.

3. Cooling Methods:
 - a. Fan convection cooling.
 - b. Passive cooling.
4. Protective Functions:
 - a. AC over/under voltage.
 - b. AC over/under frequency.
 - c. Ground over current.
 - d. Overtemperature.
 - e. AC and dc overcurrent.
 - f. DC over voltage.
5. Standard liquid crystal display, four lines, 20 characters, with user display and on/off toggle switch.
6. Weight: 260 lb (118 kg).
7. Dimensions: 54 by 36 by 19 inches (137 by 91 by 48 cm).

Retain disconnection options below to suit Project.

G. Disconnects:

1. Low-voltage disconnect.
2. Low-voltage reconnect.
3. High-temperature disconnect.
4. High-temperature reconnect.

H. Regulatory Approvals:

1. IEEE 1547.1.
2. IEEE 1547.3.
3. UL 1741.

I. Characteristics:

1. Inverter Dimensions: **<Insert inches (mm)>**.
2. Inverter Weight: **<Insert lb (kg)>**.

2.10 SYSTEM OVERCURRENT PROTECTION

A. Combiner Box:

Retain "Fuses" or "Circuit Breakers" Subparagraph below.

1. Fuses: **<Insert amperage>**.
2. Circuit Breakers: **<Insert amperage>**.

2.11 MOUNTING STRUCTURES

- A. Roof Mount: Extruded aluminum, [**two (2)**] [**four (4)**] rails, tilt legs, and roof standoffs.
- B. Pole Mount: [**Top**] [**Panel tops**] [**Side**].
- C. Tracking Mounts: [**One (1)**] [**Two (2)**] axis.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrate areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Do not begin installation until mounting surfaces have been properly prepared.
- C. If preparation of mounting surfaces is the responsibility of another installer, notify DEN Project Manager of unsatisfactory preparation before proceeding.

- D. Examine modules and array frame before installation. Reject modules and arrays that are wet, moisture damaged, or mold damaged.
- E. Examine roofs, supports, and supporting structures for suitable conditions where PV system will be installed.
- F. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 FIELD QUALITY CONTROL

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections with the assistance of a factory-authorized service representative.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- B. PV module will be considered defective if it does not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

- A. METHOD OF PAYMENT
- B. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 263100

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SECTION 263213 - ENGINE GENERATORS

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. The Contractor shall furnish and install all emergency generator system equipment, mounting hardware, etc., as required for complete installation as indicated on the drawings.
- B. Essential electrical system: Connect equipment, lighting and power systems as indicated. These circuits will receive power supply from engine generator unit when normal power fails.
- C. This Section includes packaged engine-generator sets for emergency standby power supply with the following features:

Adjust list below to suit Project.

- 1. **[Gas] [Diesel]** engine.
 - 2. **[Unit-mounted] [Remote-mounting]** cooling system.
 - 3. **[Unit-mounted] [Remote-mounting]** control and monitoring.
 - 4. Performance requirements for sensitive loads.
 - 5. Load banks.
 - 6. Outdoor enclosure.
- D. Related Sections include the following:

List below only products and equipment that the reader might expect to find in this Section but are specified elsewhere.

1. Section 263600 "Transfer Switches" for transfer switches including sensors and relays to initiate automatic-starting and -stopping signals for engine-generator sets.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviation and terms that remain after this Section has been edited.

- A. Operational Bandwidth: The total variation from the lowest to highest value of a parameter over the range of conditions indicated, expressed as a percentage of the nominal value of the parameter.
- B. LP: Liquid petroleum.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of packaged engine generator indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. In addition, include the following:
 1. Technical data on all components.
 2. Specification comparison.
 3. Thermal damage curve for generator.
 4. Time-current characteristic curves for generator protective device.
 5. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 1. Submit all components together to permit checking of entire system, coordination between components and coordination of sensing devices required for local and remote derangement signal annunciator.
 2. Dimensioned outline plan and elevation drawings of engine-generator set and other components specified.
 3. Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting vibration isolators and seismic restraints and

- for designing vibration isolation bases.
4. Vibration Isolation Base Details: Signed and sealed by a qualified professional engineer. Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include base weights.
 5. Wiring Diagrams: Power, signal, and control wiring.

Coordinate requirements for coordination drawings with DEN Project Manager.

C. Coordination Drawings:

1. Include floor plans and sections to show emergency generator system assembly layouts and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurement.

1.5 INFORMATIONAL SUBMITTALS

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Retain option below for diesel-engine generators with day tank.

A. Manufacturer Seismic Qualification Certification: Submit certification that **[day tank,]**engine-generator set, batteries, battery racks, accessories, and components will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. This definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Coordinate paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

B. Qualification Data: For **[installer] [manufacturer] [and] [testing agency]**.

Coordinate paragraph below with Part 2 "Source Quality Control" Article.

C. Source quality-control test reports.

See Editing Instruction No. 3 in the Evaluations for discussion about prototype-unit testing.

1. Certified summary of prototype-unit test report.
2. Certified Test Reports: For components and accessories that are equivalent, but not identical, to those tested on prototype unit.

Retain first subparagraph below for generator sets specified to meet performance requirements and for generator sets serving sensitive loads.

3. Certified Summary of Performance Tests: Certify compliance with specified requirement to meet performance criteria for sensitive loads.
4. Report of factory test on units to be shipped for this Project, showing evidence of compliance with specified requirements.
5. Report of sound generation.

Retain first subparagraph below if required by authorities having jurisdiction. See "Application Considerations" Article in the Evaluations for more information.

6. Report of exhaust emissions showing compliance with applicable regulations.
7. Certified Torsional Vibration Compatibility: Comply with NFPA 110.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

- D. Field quality-control test reports.
- E. Warranty: Special warranty specified in this Section.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For packaged engine generators to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 1. List of tools and replacement items recommended to be stored at Project for ready access. Include part and drawing numbers, current unit prices, and source of supply.
 2. Owner instruction reports.
 3. Prorata warranty for batteries.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Quantities below are examples only.

1. Fuses: One (1) for every ten (10) of each type and rating, but no fewer than one of each.
2. Indicator Lamps: Two (2) for every six (6) of each type used, but no fewer than two (2) of each.
3. Filters: One set each of lubricating oil, fuel, and combustion-air filters.

1.8 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.

Revise subparagraph below to suit Project location.

1. Maintenance Proximity: Not more than **[four (4)] <Insert number>** hours' normal travel time from Installer's place of business to Project site.

Retain subparagraph below if Contractor is required to assume responsibility for engineering.

2. Engineering Responsibility: Preparation of data for vibration isolators and seismic restraints of engine skid mounts, including Shop Drawings, based on testing and engineering analysis of manufacturer's standard units in assemblies similar to those indicated for this Project.

- B. Manufacturer Qualifications: A qualified manufacturer. Maintain, within **[200 miles (321 km)] <Insert number of miles (kilometers)>** of Project site, a service center capable of providing training, parts, and emergency maintenance repairs.

Retain first paragraph below if Contractor selects testing agency or Contractor is required to provide services of an independent testing agency in Part 3 "Field Quality Control" Article. Qualification requirements supplement those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- C. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL), and that is acceptable to authorities having jurisdiction.
1. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.
- D. Source Limitations: Obtain packaged generator sets and auxiliary components through one source from a single manufacturer.

- E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- F. Comply with ASME B15.1.
- G. Comply with NFPA 37.
- H. Comply with NFPA 70.

Retain paragraph below for healthcare facilities.

- I. Comply with NFPA 99.

Retain first paragraph below if generator is automatically started. See Editing Instruction No. 4 in the Evaluations.

- J. Comply with NFPA 110 requirements for Level [1] [2] emergency power supply system.
- K. Comply with UL 2200.

Retain paragraph below for state or local compliance.

- L. Engine Exhaust Emissions: Comply with applicable state and local government requirements.

Retain paragraph below for installations with critical noise-abatement requirements, particularly outdoor generator sets. Coordinate with noise-reduction features in the design, including those relating to cooling-air intake and discharge arrangement and muffler specification and its location and orientation as shown on Drawings.

- M. Noise Emission: Comply with **[applicable state and local government requirements]** <Insert Project criteria> for maximum noise level at **[adjacent property boundaries]** <Insert critical locations> due to sound emitted by generator set including engine, engine exhaust, engine cooling-air intake and discharge, and other components of installation.

1.9 PROJECT CONDITIONS

Delete first paragraph and subparagraphs below if no interruption of existing electrical service is required.

- A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

2. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.
- B. Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:

Retain first option in subparagraph below if generator-set start time must be within NFPA 110 limits. Coordinate with Drawings.

1. Ambient Temperature Range: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).
2. Relative Humidity: 0 to 95 percent.
3. Altitude: 5,500 feet (1677 m) above sea level.

If unusual service conditions for equipment exist and cannot be eliminated, specify them in paragraph below. See Editing Instruction No. 5 in the Evaluations.

- C. Unusual Service Conditions: Engine-generator equipment and installation are required to operate under the following conditions:

Subparagraph below is an example only. Revise to list unusual conditions.

1. <Insert unusual condition>.

1.10 COORDINATION

- A. Coordinate size and location of concrete bases for package engine generators[**and remote radiators mounted on grade**]. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

Retain paragraph below for remote radiators located on roof.

- B. Coordinate size and location of roof curbs, equipment supports, and roof penetrations for remote radiators. These items are specified in Section 077200 "Roof Accessories."

1.11 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this Article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of packaged engine generators and associated auxiliary components that fail in materials or workmanship within specified warranty period.

Verify available warranties for units and components and insert number below.

1. Warranty Period: Minimum [five (5)] <Insert number> years from date of Substantial Completion. Warranty shall cover unlimited replacement of

emergency generator modules during the warranty period.

2. Provide minimum **[three (3)] <Insert number>** year prorata warranty on engine-starting batteries.

1.12 MAINTENANCE SERVICE

Retain this Article for critical installations and consider including a provision for submitting a continuing maintenance agreement proposal. Revise starting date if required. Obtain a copy of maintenance agreement before retaining or editing below. Maintenance contracts may not be allowed for publicly funded projects.

- A. Initial Maintenance Service: Beginning at Substantial Completion, provide **[twelve (12)] <Insert number>** months' full maintenance by skilled employees of manufacturer's designated service organization. Include quarterly exercising to check for proper starting, load transfer, and running under load. Include routine preventive maintenance as recommended by manufacturer and adjusting as required for proper operation. Provide parts and supplies same as those used in the manufacture and installation of original equipment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph below and list of manufacturers in this Article. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Caterpillar; Engine Div.
 2. Onan/Cummins Power Generation; Industrial Business Group.
 3. **<Insert manufacturer>**
 4. or approved equal.

2.2 ENGINE-GENERATOR SET

- A. Factory-assembled and -tested, engine-generator set.

- B. Mounting Frame: Maintain alignment of mounted components without depending on concrete foundation; and have lifting attachments.

Retain subparagraph below if rigging is required.

1. Rigging Diagram: Inscribed on metal plate permanently attached to mounting frame to indicate location and lifting capacity of each lifting attachment and generator-set center of gravity.

Coordinate paragraph and subparagraphs below with prototype test requirements in Part 1 "Informational Submittals" Article and in Part 2 "Source Quality Control" Article.

- C. Capacities and Characteristics:

1. Power Output Ratings: Nominal ratings as indicated[, **with capacity as required to operate as a unit as evidenced by records of prototype testing**].
2. Output Connections: Three-phase, [**three**] [**four**] wire.
3. Nameplates: For each major system component to identify manufacturer's name and address, and model and serial number of component.

Retain paragraph and subparagraphs below for loads involving little or no sensitive electronic equipment, adjustable frequency drives, or uninterruptible power supply systems. See Evaluations.

- D. Generator-Set Performance:

1. Steady-State Voltage Operational Bandwidth: 3 percent of rated output voltage from no load to full load.
2. Transient Voltage Performance: Not more than 20 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within three seconds.
3. Steady-State Frequency Operational Bandwidth: 0.5 percent of rated frequency from no load to full load.
4. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
5. Transient Frequency Performance: Less than 5 percent variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within five seconds.
6. Output Waveform: At no load, harmonic content measured line to line or line to neutral shall not exceed 5 percent total and 3 percent for single harmonics. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
7. Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 250 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to generator system components.

Below requires 10-second maximum start time under specific conditions and includes startup only, not load assumption.

8. Start Time: Comply with NFPA 110, Type 10, system requirements.

Retain paragraph and subparagraphs below for loads involving sensitive electronic equipment, significant nonlinear load elements, or uninterruptible power supply systems. Coordinate with "Governor" Paragraph in "Engine" Article and with "Generator, Exciter, and Voltage Regulator" Article. See Evaluations.

E. Generator-Set Performance for Sensitive Loads:

1. Oversizing generator compared with the rated power output of the engine is permissible to meet specified performance.
 - a. Nameplate Data for Oversized Generator: Show ratings required by the Contract Documents rather than ratings that would normally be applied to generator size installed.
2. Steady-State Voltage Operational Bandwidth: 1 percent of rated output voltage from no load to full load.

Some manufacturers may be required to provide an oversized engine-generator set in order to meet parameters in first subparagraph below. This could impact space, noise, ventilation, cooling, and other parameters. Verify performance of products if specific manufacturers are listed at the beginning of Part 2. Edit requirements below to suit actual Project load characteristics.

3. Transient Voltage Performance: Not more than 10 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within 0.5 second.
4. Steady-State Frequency Operational Bandwidth: Plus or minus 0.25 percent of rated frequency from no load to full load.
5. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
6. Transient Frequency Performance: Less than 2-Hz variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within three seconds.
7. Output Waveform: At no load, harmonic content measured line to neutral shall not exceed 2 percent total with no slot ripple. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
8. Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 300 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to winding insulation or other generator system components.
9. Excitation System: Performance shall be unaffected by voltage distortion caused by nonlinear load.

Permanent magnet excitation in subparagraph below is a standard feature of some manufacturers' engine-generator sets larger than 200 kW.

- a. Provide permanent magnet excitation for power source to voltage regulator.

Retain subparagraph below if required start time is 10 seconds or less.

10. Start Time: Comply with NFPA 110, Type 10, system requirements.

2.3 ENGINE

Depending on NFPA 110 class and local codes, LP-gas standby may not be required for natural gas-fueled systems. Verify requirements with authorities having jurisdiction.

- A. Fuel: **[Fuel oil, Grade DF-2] [Natural gas with automatic LP-gas standby] [Natural gas]**.
 - 1. **<Insert specific fuel grade requirements.>**
- B. Rated Engine Speed: 1800 rpm.
- C. Maximum Piston Speed for Four-Cycle Engines: **2250 fpm** (11.4 m/s).
- D. Capable of operating at idle or light loads for extended periods of time.
- E. Lubrication System: The following items are mounted on engine or skid:
 - 1. Filter and Strainer: Rated to remove 90 percent of particles 5 micrometers and smaller while passing full flow.
 - 2. Thermostatic Control Valve: Control flow in system to maintain optimum oil temperature. Unit shall be capable of full flow and is designed to be fail-safe.
 - 3. Crankcase Drain: Arranged for complete gravity drainage to an easily removable container with no disassembly and without use of pumps, siphons, special tools, or appliances.
- F. Engine Fuel System:

Retain first two subparagraphs below for diesel-fueled engine; retain third subparagraph and associated subparagraphs for natural-gas- and LP-gas-fueled engine.

- 1. Main Fuel Pump: Mounted on engine. Pump ensures adequate primary fuel flow under starting and load conditions.
- 2. Relief-Bypass Valve: Automatically regulates pressure in fuel line and returns excess fuel to source.
- 3. Dual Natural Gas with LP-Gas Backup (Vapor-Withdrawal) System:
 - a. Carburetor.
 - b. Secondary Gas Regulators: One for each fuel type.
 - c. Fuel-Shutoff Solenoid Valves: One for each fuel source.
 - d. Flexible Fuel Connectors: One for each fuel source.
- 4. Equip fuel system with replaceable fuel filter elements arranged for easy removal without breaking any fuel line connections or disturbing fuel pumps or any other part of engine.
- 5. Locate all fuel filters in one accessible housing, ahead of injection pumps to thoroughly filter fuel before it reaches pumps.
- 6. Use no screens or filters requiring cleaning or replacement of injection pumps or valve assemblies.

Retain paragraph below where required by NFPA 110, which prescribes engine water-jacket temperature requirements. Coordinate with Drawings for electrical supply.

- G. Coolant Jacket Heater: Electric-immersion type, factory installed in coolant jacket system. Comply with NFPA 110 requirements for Level 1 equipment for heater capacity.

Retain option in paragraph below that is consistent with steady-state tolerances and transient frequency tolerances of loads supplied. Retain second option for systems with sensitive loads. Coordinate with "Engine-Generator Set" Article.

- H. Governor: Fully enclosed electronic type governor with actuator capable of providing accurate speed control within 1 percent of rated speed, complete with panel-mounted electronic assembly with ramp generator, speed-sensing modules, and load-sharing features.

Retain one of two paragraphs and associated subparagraphs below. Coordinate with Drawings. See Editing Instruction No. 6 in the Evaluations.

- I. Cooling System: Closed loop, liquid cooled, with radiator factory mounted on engine-generator-set mounting frame and integral engine-driven coolant pump.
1. Coolant: Solution of 50 percent ethylene-glycol-based antifreeze and 50 percent water, with anticorrosion additives as recommended by engine manufacturer.

Retain one of first two subparagraphs below. Retain second if containment of coolant expansion by radiator is marginal or inadequate. Coordinate with Drawings.

2. Size of Radiator: Adequate to contain expansion of total system coolant from cold start to 110 percent load condition.
 3. Expansion Tank: Constructed of welded steel plate and rated to withstand maximum closed-loop coolant system pressure for engine used. Equip with gage glass and petcock.
 4. Temperature Control: Self-contained, thermostatic-control valve modulates coolant flow automatically to maintain optimum constant coolant temperature as recommended by engine manufacturer.
 5. Coolant Hose: Flexible assembly with inside surface of nonporous rubber and outer covering of aging-, ultraviolet-, and abrasion-resistant fabric.
 - a. Rating: **50-psig** (345-kPa) maximum working pressure with coolant at **180 deg F** (82 deg C), and noncollapsible under vacuum.
 - b. End Fittings: Flanges or steel pipe nipples with clamps to suit piping and equipment connections.
- J. Cooling System: Closed loop, liquid cooled, with remote radiator and integral engine-driven coolant pump.
1. Configuration: **[Vertical]** **[Horizontal]** air discharge.
 2. Frame fabricated of heavy-gauge, hot-rolled steel.
 3. Capable of withstanding wind loads of 140 km/h 85 mph and high temperature changes.
 4. Radiator Core Tubes: Core constructed of non-corrosive materials consisting of

- brass tubes, copper fins and headers made of heavy-gauge brass with brass reinforcement plates.
5. Headers bolted to tanks with full neoprene cork gasketing to assure positive sealing.
 6. All exposed surfaces shall be metal treated for protection against corrosion with a zinc chromate prime coat prior to final painting.
 7. Provide venturi-type fan shroud.
 8. TEFC motor.
 9. Provide site glass mounted in top tank for vertical core. Provide surge tank with sight glass mounted horizontal core.

Retain one of first two subparagraphs below. Retain second if containment of coolant expansion by radiator is marginal or inadequate. Coordinate with Drawings.

10. Size of Radiator: Adequate to contain expansion of total system coolant from cold start to 110 percent load condition.
11. Expansion Tank: Constructed of welded steel plate and rated to withstand maximum closed-loop coolant system pressure for engine used. Equip with gage glass and petcock.
12. Fan: Driven by **[multiple belts from engine shaft] [totally enclosed electric motor with sealed bearings]**.
13. Coolant: Solution of 50 percent ethylene-glycol-based antifreeze and 50 percent water, with anticorrosion additives as recommended by engine manufacturer.
14. Temperature Control: Self-contained, thermostatic-control valve modulates coolant flow automatically to maintain optimum constant coolant temperature as recommended by engine manufacturer.
15. Provide heavy duty core and fan guards.
16. Fill system with solution of 50-50 water and ethylene glycol anti-freeze to prevent freezing at temperatures as low as minus 30 degrees F (minus 35 degrees C).

Retain one of three "Muffler/Silencer" paragraphs below. Modify dBA requirement in second subparagraph to accommodate environment in which engine-generator set is operating. If unit is specified with an enclosure, consider specifying sound level requirements at specified distance from enclosure on each of four sides.

- K. Muffler/Silencer: Critical type, sized as recommended by engine manufacturer and selected with exhaust piping system to not exceed engine manufacturer's engine backpressure requirements. Seamless, stainless steel, flexible, exhaust adapter for exhaust outlet to silencer.
1. Minimum sound attenuation of 25 dB at 500 Hz.
 2. Sound level measured at a distance of 10 feet (3 m) from exhaust discharge after installation is complete shall be **[85] <Insert number>** dBA or less.

Retain second option in paragraph below if filters may not be serviced as often as recommended. If air contaminant level is excessive, consult manufacturers to determine if special filtration of combustion air is needed.

- L. Air-Intake Filter: Heavy-duty, engine-mounted air cleaner with replaceable dry-filter element and "blocked filter" indicator.

Select first option in paragraph below for smaller engine-generator sets. Retain second option for units 175 kW and larger.

M. Starting System: [12] [24]-V electric, with negative ground.

1. Components: Sized so they will not be damaged during a full engine-cranking cycle with ambient temperature at maximum specified in Part 1 "Project Conditions" Article.
2. Cranking Motor: Heavy-duty unit that automatically engages and releases from engine flywheel without binding.

Retain first option in subparagraph below if system description in Part 1 "Quality Assurance" Article specifies NFPA 110, Level 1 or 2; otherwise, retain second. See Editing Instruction No. 7 in the Evaluations.

3. Cranking Cycle: As required by NFPA 110 for system level specified.

First option in subparagraph below complies with NFPA 110 requirements. Second is a more conservative rule used for some industrial applications.

4. Battery: Adequate capacity within ambient temperature range specified in Part 1 "Project Conditions" Article to provide specified cranking cycle at least three times without recharging.

Coordinate subparagraph below with Drawings.

5. Battery Cable: Size as recommended by engine manufacturer for cable length indicated. Include required interconnecting conductors and connection accessories.

Retain first subparagraph below if compartment is required.

6. Battery Compartment: Factory fabricated of metal with acid-resistant finish and thermal insulation. Thermostatically controlled heater shall be arranged to maintain battery above 10 deg C regardless of external ambient temperature within range specified in Part 1 "Project Conditions" Article. Include accessories required to support and fasten batteries in place.
7. Battery-Charging Alternator: Factory mounted on engine with solid-state voltage regulation and 35-A minimum continuous rating.

Coordinate first subparagraph below with Section 263600 "Transfer Switches." Retain if battery charger is not specified to be integral with transfer switch.

8. Battery Charger: Current-limiting, automatic-equalizing and float-charging type. Unit shall comply with UL 1236 and include the following features:
 - a. Operation: Equalizing-charging rate of 10 A shall be initiated automatically after battery has lost charge until an adjustable equalizing voltage is achieved at battery terminals. Unit shall then be automatically switched to a lower float-charging mode and shall continue to operate in that mode until battery is discharged again.
 - b. Automatic Temperature Compensation: Adjust float and equalize voltages for variations in ambient temperature from minus 40 deg C to plus 60 deg C to prevent overcharging at high temperatures and undercharging at low temperatures.

- c. Automatic Voltage Regulation: Maintain constant output voltage regardless of input voltage variations up to plus or minus 10 percent.
- d. Ammeter and Voltmeter: Flush mounted in door. Meters shall indicate charging rates.

First subparagraph below covers sensing for safety indications on control and monitoring panel. NFPA 110 requires sensing for Level 1 systems and makes sensing optional for Level 2 systems. See Editing Instruction No. 4 in the Evaluations.

- e. Safety Functions: Sense abnormally low battery voltage and close contacts providing low battery voltage indication on control and monitoring panel. Sense high battery voltage and loss of ac input or dc output of battery charger. Either condition shall close contacts that provide a battery-charger malfunction indication at system control and monitoring panel.
- f. Enclosure and Mounting: NEMA 250, Type 1, wall-mounted cabinet.

2.4 FUEL OIL STORAGE

Retain this Article for diesel-engine units.

- A. Comply with NFPA 30.
- B. Day Tank: Comply with UL 142, freestanding, factory-fabricated fuel tank assembly, with integral, float-controlled transfer pump and the following features:
 - 1. Containment: Integral rupture basin with a capacity of 150 percent of nominal capacity of day tank.
 - a. Leak Detector: Locate in rupture basin and connect to provide audible and visual alarm in the event of day-tank leak.

Revise hours in first subparagraph below or delete subparagraph and indicate capacity on Drawings. Coordinate with Drawings and NFPA 110 requirements.

- 2. Tank Capacity: **[As recommended by engine manufacturer for an uninterrupted period of 4 hours' operation at 100 percent of rated power output of engine-generator system without being refilled]** <Insert gallons (liters)>.
- 3. Fuel level gauge.
- 4. Float switch and solenoid valve to allow tank to fill when level drops below predetermined level.
- 5. Pump: Package unit with duplex fuel pump to provide automatic, self-refilling fuel supply system.
- 6. Pump Capacity: Exceeds maximum flow of fuel drawn by engine-mounted fuel supply pump at 110 percent of rated capacity, including fuel returned from engine.
- 7. Low-Level Alarm Sensor: Liquid-level device operates alarm contacts at 25 percent of normal fuel level.

Revise first subparagraph below or delete if not required. Coordinate with Part 2 "Control and Monitoring" Article.

8. High-Level Alarm Sensor: Liquid-level device operates alarm and redundant fuel shutoff contacts at midpoint between overflow level and 100 percent of normal fuel level.
9. Critical low level shutoff.
10. Piping Connections: Factory-installed fuel supply and return lines from tank to engine; local fuel fill, vent line, overflow line; and tank drain line with shutoff valve.

Subparagraph below is not in NFPA 110 minimum requirements.

11. Redundant High-Level Fuel Shutoff: Actuated by high-level alarm sensor in day tank to operate a separate motor device that disconnects day-tank pump motor. Sensor shall signal solenoid valve, located in fuel suction line between fuel storage tank and day tank, to close. Both actions shall remain in shutoff state until manually reset. Shutoff action shall initiate an alarm signal to control panel but shall not shut down engine-generator set.
12. Day tank construction: All welded steel atmospheric tank built in accordance with local codes and applicable standards.
 - a. Pipe thread connections:
 - 1) Supply to prime mover.
 - 2) Return from prime mover.
 - 3) Vent and drain with ball valve.
 - b. Provide a weatherproof, screened vent cap for field installation.
 - c. Provide inspection port on top.
 - d. Provide with a welded steel channel base.
 - e. Provide a removable steel protection cover for all day tank system components.
 - f. Factory leak test day tank at 5 PSI.
 - g. Steel containment basin:
 - 1) Minimum capacity: 110 percent of day tank.
 - 2) Provide leak detector that shall activate rupture alarm.
 - 3) Provide drain with ball valve.
 - 4) Provide with a welded steel channel base suitable for bolt attachment to concrete pad.
 - h. Provide interior corrosion protection consisting of an epoxy coating.
 - i. Provide exterior of day tank and interior and exterior of containment basin with a heavy duty industrial anti-corrosion coating and finish coat.
13. Solenoid valve, day tank:
 - a. 1 IN NPT, 100 PSI, normally closed, under control of level controller.
 - b. Provide an inlet shutoff valve.
14. Level controller, day tank: Self contained unit within a NEMA 1 box mounted on top of day tank.

- a. Electronic liquid level controller/indicator with functions to include:
 - 1) Adjustable differential pump/valve level control.
 - 2) Tank level indication.
 - 3) System alarms and manual operating controls.
 - b. Provide following control functions:
 - 1) "Auto-Off-Manual" fill control mode switch.
 - 2) "Press to test" fill control pushbutton.
 - 3) Adjustable differential pump/valve level control with output contacts for control of on-board solenoid valve and remote delivery system.
 - 4) Overflow cutout.
 - c. Provide following indication functions:
 - 1) Electric level gauge and condition indicator scaled in percent level and color coded and placarded to indicate system condition verses level.
 - d. LED lamp indicators for:
 - 1) Power available.
 - 2) Fill control not in auto.
 - 3) Tank filling.
 - 4) Low level alarm.
 - 5) High level alarm.
 - 6) Tank rupture.
 - e. Provide following outputs:
 - 1) Fill control start-stop.
 - 2) Low level alarm.
 - 3) High level alarm.
 - 4) Not-in auto.
 - 5) Tank rupture.
15. Duplex pump system: Automatic duplex pump controller and duplex pumps.
- a. Duplex pumps: Consist of two pumps, motors and accessories.
 - 1) Direct drive, positive displacement, hydraulic gear type with pressure loaded mechanical shaft seal.

Insert appropriate pump and motor data.

- 2) Motors: Dripproof, NEMA type B, continuous duty at 40 degC, 1800 RPM.
- 3) Pump pressure relief valve, adjustable type, vented back to tank.
- 4) Pump inlet fuel strainer, 60 mesh.
- 5) Pump shutoff ball valve.
- 6) Pump motor starter, full voltage type, non-reversing, with overload

- 7) relay and circuit breaker.
- 7) Control relays and control power transformer as required to operate pump motor starter from day tank control contacts.
- b. Duplex pump controller: Function to alternate operation of each pump on successive starts.
 - 1) Provide pump running indicators for each pump.
 - 2) Provide pump fail alarm indicator and output contacts.
 - 3) Provide mode control switch and control logic for automatic operation as:
 - 4) Pump 1 lead/pump 2 lag.
 - 5) Pump 2 lead/pump 1 lag.
 - 6) Both run.

Review day tank manufacturer's catalogs for additional accessories that may be necessary for your specific project.

16. Accessories:

- a. Provide 1 GPM hand operated pump with isolation ball valves on inlet and outlet and in-line check valve.
- b. Air cooled fuel oil cooler:
- c. Capacity: Coordinate requirements with Emergency Generator Manufacturer.

C. Base-Mounted Fuel Oil Tank: Factory installed and piped, complying with UL 142 fuel oil tank. Features include the following:

- 1. Tank level indicator.

Consult tank manufacturers about capacities available for size of set in Project.

- 2. Capacity: Fuel for [eight (8)] <Insert number> hours' continuous operation at 100 percent rated power output.
- 3. Vandal-resistant fill cap.

Determine applicable codes and regulations, and coordinate subparagraph below with Drawings.

- 4. Containment Provisions: Comply with requirements of authorities having jurisdiction.
- 5. Heavy gauge steel with top and bottom baffles.
- 6. Heavy gauge steel channel side supports.
- 7. Primer and enamel exterior to match engine generator unit.
- 8. Vent sized to tank. Withstand pressure of day tank shall exceed total developed static head imposed by vent.
- 9. 0.44 L/s 7 gpm pump and motor and float switches to control pump.
- 10. Double wall with alarm contact for rupture basin alarm. Provide contacts for remote alarm.
- 11. Solenoid valve to interface with remote transfer pumps.
- 12. Low level alarm float switch to indicate when operating supply is under 3 hours. Provide contacts for remote monitoring.

13. Provide control wiring in conduit from sub-base tank low level alarm to generator mounted control panel and remote derangement annunciator.

2.5 CONTROL AND MONITORING

This Article specifies the subsystem that monitors, protects, and controls the engine generator. See Editing Instruction No. 8 in the Evaluations.

Retain first paragraph below for automatically starting systems; retain second paragraph for manually starting systems.

- A. Automatic Starting System Sequence of Operation: When mode-selector switch on the control and monitoring panel is in the automatic position, remote-control contacts in one or more separate automatic transfer switches initiate starting and stopping of generator set. When mode-selector switch is switched to the on position, generator set starts. The off position of same switch initiates generator-set shutdown. When generator set is running, specified system or equipment failures or derangements automatically shut down generator set and initiate alarms. Operation of a remote emergency-stop switch also shuts down generator set.
- B. Manual Starting System Sequence of Operation: Switching on-off switch on the generator control panel to the on position starts generator set. The off position of same switch initiates generator-set shutdown. When generator set is running, specified system or equipment failures or derangements automatically shut down generator set and initiate alarms. Operation of a remote emergency-stop switch also shuts down generator set.

Retain one of three paragraphs below to describe control and monitoring unit configuration. Coordinate retained paragraph with Drawings. Retain first paragraph unless special requirements justify significant extra cost of one of the other two configurations. See Evaluations.

- C. Configuration: Operating and safety indications, protective devices, basic system controls, and engine gages shall be grouped in a common control and monitoring panel mounted on the generator set. Mounting method shall isolate the control panel from generator-set vibration.
- D. Configuration: Operating and safety indications, protective devices, basic system controls, and engine gages shall be grouped in a common wall-mounted control and monitoring panel.
- E. Configuration: Operating and safety indications, protective devices, basic system controls, engine gages, instrument transformers, generator disconnect switch or circuit breaker, and other indicated components shall be grouped in a combination control and power panel. Control and monitoring section of panel shall be isolated from power sections by steel barriers. Panel features shall include the following:

Retain one of first two subparagraphs below to further define control and power panel in last paragraph above.

1. Wall-Mounting Cabinet Construction: Rigid, self-supporting steel unit complying

- with NEMA ICS 6. Power bus shall be copper. Bus, bus supports, control wiring, and temperature rise shall comply with UL 891.
2. Switchboard Construction: Freestanding unit complying with Section 262413 "Switchboards."
 3. Switchgear Construction: Freestanding unit complying with Section 262300 "Low-Voltage Switchgear."
 4. Current and Potential Transformers: Instrument accuracy class.

Retain first paragraph and associated subparagraphs below to specify minimum control and monitoring panel features. First is for standardized panels for automatically starting units. Coordinate with Drawings. See Editing Instruction No. 9 in the Evaluations.

- F. Indicating and Protective Devices and Controls: As required by NFPA 110 for Level [1] [2] system, and the following:

1. AC voltmeter.
2. AC ammeter.
3. AC frequency meter.
4. DC voltmeter (alternator battery charging).
5. Engine-coolant temperature gage.
6. Engine lubricating-oil pressure gage.
7. Running-time meter.
8. Ammeter-voltmeter, phase-selector switch(es).
9. Generator-voltage adjusting rheostat.

Two subparagraphs below are optional devices.

10. Fuel tank derangement alarm.
11. Fuel tank high-level shutdown of fuel supply alarm.
12. Fuel pressure gauge.

Retain subparagraph below for units with "generator-protector" feature.

13. Generator overload.

- G. Supporting Items: Include sensors, transducers, terminals, relays, and other devices and include wiring required to support specified items. Locate sensors and other supporting items on engine or generator, unless otherwise indicated.

Feature in paragraph below facilitates connection to building automation system or building control and monitoring system. Coordinate with Drawings and Section covering data transmission and data terminals.

- H. Connection to Data Link: A separate terminal block, factory wired to Form C dry contacts, for each alarm and status indication is reserved for connections for data-link transmission of indications to remote data terminals. Data system connections to terminals are covered in Section 260913 "Electrical Power Monitoring and Control."

Retain one of first two paragraphs and associated subparagraphs below or delete all. The Evaluations discuss what will be obtained by selecting first paragraph and subparagraphs. Coordinate with Drawings.

- I. Common Remote Audible Alarm: Comply with NFPA 110 requirements for Level 1 systems. Include necessary contacts and terminals in control and monitoring panel.

1. Overcrank shutdown.
2. Coolant low-temperature alarm.
3. Control switch not in auto position.
4. Battery-charger malfunction alarm.
5. Battery low-voltage alarm.

Retain paragraph and subparagraphs below and coordinate with Drawings for manually starting systems or for automatically starting systems not specified to comply with NFPA 110, Level 1, but where some remote alarm functions are needed.

- J. Common Remote Audible Alarm: Signal the occurrence of any events listed below without differentiating between event types. Connect so that after an alarm is silenced, clearing of initiating condition will reactivate alarm until silencing switch is reset.
1. Engine high-temperature shutdown.
 2. Lube-oil, low-pressure shutdown.
 3. Overspeed shutdown.
 4. Remote emergency-stop shutdown.
 5. Engine high-temperature prealarm.
 6. Lube-oil, low-pressure prealarm.
 7. Fuel tank, low-fuel level.
 8. Low coolant level.

Retain paragraph below and coordinate with Drawings for systems required to comply with NFPA 99 or where otherwise needed. Revise if all indications required by NFPA 99 are not needed.

2.6 GENERATOR REMOTE DERANGEMENT SIGNAL ANNUNCIATOR:

- A. Comply with NFPA 99. An LED labeled with proper alarm conditions shall identify each alarm event and a common audible signal shall sound for each alarm condition. Silencing switch in face of panel shall silence signal without altering visual indication. Connect so that after an alarm is silenced, clearing of initiating condition will reactivate alarm until silencing switch is reset. Cabinet and faceplate are surface- or flush-mounting type to suit mounting conditions indicated.
- B. Generator remote derangement signal annunciator:
1. Flush mounted, with flush plate of No.4 finish, stainless steel, 20 x 20 IN x 4-1/4 IN deep.
 2. Circuits: 24 volts DC powered from starting batteries. Verify circuit voltage to match battery voltage.
 3. Provide red and green signal lamps, buzzer, silencing switch, lamp test switch, relays, solid-state components, and engraved function identifications.
- C. Annunciator functions:
1. Green light "ON" to indicate generator is operating to supply power to load.
 2. Separate red light for each shutdown or alarm condition and amber light for each prealarm condition and common buzzer with silence/ acknowledge switch.
 3. Shut down indicating lights as follows:

- a. Overcrank.
 - b. Overspeed.
 - c. Low lubricating oil pressure.
 - d. High engine water temperature.
4. Alarm indicator lights as follows:
- a. Low engine water temperature (less than 70 °F).

Coordinate fuel level monitoring requirements with mechanical.

- b. Low fuel in main storage tank.
 - c. Low fuel in day tank.
 - d. Control switch not in auto position.
 - e. Battery charger malfunctioning.
 - f. Low battery voltage.
 - g. Fuel in day tank rupture basin.
5. Prealarm indicator lights as follows:
- a. High engine water temperature.
 - b. Low lubricating oil pressure.

Delete paragraph c. when paralleling gear is provided.

- c. When generator "main breaker" is open.
- d. When main or feeder breaker in essential power switchboard is open (common light).

Delete if generator main breaker is rated less than 1000 amp.

- e. To indicate that an excessive ground fault has been detected on the generator main breaker.

Add the following if main derangement panel is not located at a 24 hour manned location.

6. Generator remote derangement signal annunciator sub-panel:
- a. Flush mounted, with flush plate of No.4 finish, 16 gauge stainless steel, 6 x 6 IN x 4 IN deep maximum.
 - b. Circuits: 24 volts DC powered from generator starting batteries. Verify circuit voltage to match battery voltage.
 - c. Provide signal lamps, buzzer, NORMAL/OFF/TEST silencing switch, relays, solid-state components, and engraved function identifications.
7. Sub-panel functions:
- a. Green light to indicate that generator is supplying load. Label light "STANDBY POWER GENERATION SYSTEM SUPPLYING LOAD".
 - b. Common amber or yellow light to indicate alarm or prealarm condition. Label light "STANDBY POWER GENERATION SYSTEM ALARM OR PREALARM".
 - c. Common red light to indicate shut down. Label light "STANDBY POWER GENERATION SYSTEM SHUTDOWN".

- d. Common buzzer for all conditions.

Indicate sub-panel location if not indicated on plans.

- e. Locate sub-panel at <Insert location>.

Coordinate paragraph below with Drawings.

- D. Remote Emergency-Stop Switch: Flush; wall mounted, unless otherwise indicated; and labeled. Push button shall be protected from accidental operation.

2.7 GENERATOR OVERCURRENT AND FAULT PROTECTION

Retain one or more paragraphs in this Article to specify disconnect switch(es) and protective devices for the generator (alternator) component of generator set. Revise as required to accommodate multiple output devices. See Editing Instruction No. 10 in the Evaluations.

Retain one of first four paragraphs and associated subparagraphs below. Retain first for units smaller than 200 kW where initial cost is a concern. Device provides little or no generator protection and no selectivity with downstream circuit protective devices.

- A. Generator Circuit Breaker: Molded-case, thermal-magnetic type; 100 percent rated; complying with NEMA AB 1 and UL 489.
 - 1. Tripping Characteristic: Designed specifically for generator protection.
 - 2. Trip Rating: Matched to generator rating.
 - 3. Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
 - 4. Mounting: Adjacent to or integrated with control and monitoring panel.
- B. Generator Circuit Breaker: Molded-case, electronic-trip type; 100 percent rated; complying with UL 489.
 - 1. Tripping Characteristics: Adjustable long-time and short-time delay and instantaneous.
 - 2. Trip Settings: Selected to coordinate with generator thermal damage curve.
 - 3. Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
 - 4. Mounting: Adjacent to or integrated with control and monitoring panel.
- C. Generator Circuit Breaker: Insulated-case, electronic-trip type; 100 percent rated; complying with UL 489.
 - 1. Tripping Characteristics: Adjustable long-time and short-time delay and instantaneous.
 - 2. Trip Settings: Selected to coordinate with generator thermal damage curve.
 - 3. Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
 - 4. Mounting: Adjacent to or integrated with control and monitoring panel.

Retain paragraph and subparagraphs below if generator is protected by "generator-protector" feature.

- D. Generator Disconnect Switch: Molded-case type, 100 percent rated.
1. Rating: Matched to generator output rating.
 2. Shunt Trip: Connected to trip switch when signaled by generator protector or by other protective devices.

Protection scheme specified in paragraph and subparagraphs below may be proprietary. Consult manufacturers.

- E. Generator Protector: Microprocessor-based unit shall continuously monitor current level in each phase of generator output, integrate generator heating effect over time, and predict when thermal damage of alternator will occur. When signaled by generator protector or other generator-set protective devices, a shunt-trip device in the generator disconnect switch shall open the switch to disconnect the generator from load circuits. Protector shall perform the following functions:
1. Initiates a generator overload alarm when generator has operated at an overload equivalent to 110 percent of full-rated load for 60 seconds. Indication for this alarm is integrated with other generator-set malfunction alarms.
 2. Under single or three-phase fault conditions, regulates generator to 300 percent of rated full-load current for up to 10 seconds.
 3. As overcurrent heating effect on the generator approaches the thermal damage point of the unit, protector switches the excitation system off, opens the generator disconnect device, and shuts down the generator set.
 4. Senses clearing of a fault by other overcurrent devices and controls recovery of rated voltage to avoid overshoot.

Retain paragraph below and coordinate with Drawings for legally required emergency generator sets rated 1000 A and more at 277/480 V.

- F. Ground-Fault Indication: Comply with NFPA 70, "Emergency System" signals for ground-fault. Integrate ground-fault alarm indication with other generator-set alarm indications.

2.8 GENERATOR, EXCITER, AND VOLTAGE REGULATOR

- A. Comply with NEMA MG 1.
- B. Generator: 4-pole or 6-pole revolving field type with permanent magnet exciter and magnetic amplifier or SCR voltage regulator. No commutator or commutator brushes allowed.
1. Minimum continuous standby ratings: As indicated, substantiated by manufacturer's standard published curves and conform to NEMA MG-1 specification. Special ratings or maximum ratings are not acceptable.

Increase the percentage of non-linear load if required.

- a. Generator shall be rated to serve up to 50 percent non-linear load without exceeding standard NEMA temperature rise.

- C. Minimum efficiency: 92 percent at 50 to 110 percent of nominal standby rating, less than 30 percent instantaneous voltage dip at full load and rated power factor and suitable for simultaneous operation with other future units connected in parallel.
- D. Drive: Generator shaft shall be directly connected to engine shaft. Exciter shall be rotated integrally with generator rotor.
- E. Electrical Insulation: Class F.
- F. Stator-Winding Leads: Brought out to terminal box to permit future reconnection for other voltages if required.
- G. Stator and rotor: Class F insulated with 100 percent epoxy impregnation and overcoat of resilient insulating material to reduce possible fungus and/or abrasive deterioration.
- H. Directly connect stator to engine flywheel housing.
- I. Drive rotor through semiflexible driving flange to ensure permanent alignment.
- J. Self ventilating with suitable blower, air inlet and outlet openings.
- K. Provide terminal box of adequate size for entrance of flexible conduit for generator leads out bottom from either side.
- L. Generator drive free from critical torsional vibration within operating range.

Delete circuit breaker for generator if provided in essential power switchboard or paralleling gear and essential power switchboard or paralleling gear is in eng-gen. room or near-by.

- M. Provide generator mounted main circuit breaker: Solid state molded case type, rating as indicated.

Delete following if generator main breaker is rated less than 1000a.

- 1. Provide integral ground fault sensor
- 2. Indicate when there is a ground fault on the main breaker.
- 3. Ground fault shall not trip main breaker but shall be indicated at generator remote derangement signal annunciator.
- 4. Include the following:
 - a. Test circuit with cut-off switch.
 - b. Fail safe indicating lamp.
 - c. Terminals for remote alarm.
 - d. Reset controls.
 - e. Adjustable sensitivity from 200 to 1200A; set at 200A.
 - f. Adjustable time delay 3.5 to 30 cycles; set at 3.5 cycles.
 - g. Post a sign at main breaker stating course of action in the event of a ground fault. Verify contents of statement with Owner.
- N. Construction shall prevent mechanical, electrical, and thermal damage due to vibration, overspeed up to 125 percent of rating, and heat during operation at 110

percent of rated capacity.

- O. Enclosure: Dripproof.

Delete first paragraph below if instrument transformers are housed in control and power panel.

- P. Instrument Transformers: Mounted within generator enclosure.

- Q. Voltage Regulator: Voltage regulator: SCR type, to maintain 2 percent voltage regulation from 0 to full load with steady state modulation not exceeding plus 1/2 percent including cross-current compensation to provide maximum of 5 percent unbalance in kva load sharing between this unit and possible future generators.

1. Provide automatic protection against short circuits on system.
2. Permit unit to operate at no load below rated frequency for engine start up and shut down procedures.
3. Provide voltage level and gain controls for normal operating adjustments.
4. Provide voltage level control with minimum range of plus or minus 5 percent from rated voltage.
5. Mount regulator, volts per hertz type, in generator housing on suitable vibration isolators.
6. Provide "series boost" type short-circuit current sustaining attachment to allow downstream circuit breakers to trip sequentially.

Retain paragraph below for high-humidity environments to limit condensation in alternator windings.

- R. Strip Heater: Thermostatically controlled unit arranged to maintain stator windings above dew point.

Retain both paragraphs below for units specified for "critical" performance. Coordinate with generator-set performance Paragraph selected in "Engine-Generator Set" Article. See "Specifying Considerations" Article in the Evaluations for discussions on sensitive electronic equipment and nonlinear generator loads and on supplying significant harmonic currents.

- S. Windings: Two-thirds pitch stator winding and fully linked amortisseur winding.

- T. Subtransient Reactance: [12] <Insert number> percent, maximum.

2.9 LOAD BANK

Retain this Article and revise for resistive load elements only or for another type of load bank. See Editing Instruction No. 11 in the Evaluations. Coordinate with Drawings.

- A. Description: Permanent, outdoor, weatherproof, remote-controlled, forced-air-cooled, [resistive] [resistive and reactive] unit capable of providing a balanced 3-phase, delta-connected load to generator set at [100] <Insert number> percent rated-system capacity, at [80] <Insert number> percent power factor, lagging. Unit may be composed of separate resistive and reactive load banks controlled by a common control panel. Unit shall be capable of selective control of load in 25 percent steps and with minimum step changes of approximately 5 and 10 percent available.

- B. Resistive Load Elements: Corrosion-resistant chromium alloy with ceramic and steel supports. Elements shall be double insulated and designed for repetitive on-off cycling. Elements shall be mounted in removable aluminized-steel heater cases.
- C. Reactive Load Elements: Epoxy-encapsulated reactor coils.
- D. Load-Bank Heat Dissipation: Integral fan with totally enclosed motor shall provide uniform cooling airflow through load elements. Airflow and coil operating current shall be such that, at maximum load, with ambient temperature at the upper end of specified range, load-bank elements operate at not more than 50 percent of maximum continuous temperature rating of resistance elements.
- E. Load Element Switching: Remote-controlled contactors switch groups of load elements. Contactor coils are rated 120 V. Contactors shall be located in a separate NEMA 250, Type 3R enclosure within load-bank enclosure, accessible from exterior through hinged doors with tumbler locks.
- F. Contactor Enclosures: Heated by thermostatically controlled strip heaters to prevent condensation.
- G. Load-Bank Enclosures: NEMA 250, Type 3R, complying with NEMA ICS 6. Louvers at cooling-air intake and discharge openings shall prevent entry of rain and snow. Openings for airflow shall be screened with 1/2-inch- (13-mm-) square, galvanized-steel mesh. Reactive load bank shall include automatic shutters at air intake and discharge.
- H. Protective Devices: Power input circuits to load banks shall be fused, and fuses shall be selected to coordinate with generator circuit breaker. Fuse blocks shall be located in contactor enclosure. Cooling airflow and overtemperature sensors shall automatically shut down and lock out load bank until manually reset. Safety interlocks on access panels and doors shall disconnect load power, control, and heater circuits. Fan motor shall be separately protected by overload and short-circuit devices. Short-circuit devices shall be noninterchangeable fuses with 200,000-A interrupting capacity.

Coordinate two paragraphs below with Drawings.

- I. Remote-Control Panel: Separate from load bank in NEMA 250, Type 1 enclosure with a control power switch and pilot light, and switches controlling groups of load elements.

Retain paragraph below if load bank is used in automatic exercising of generator. Coordinate with Section covering remote-controlled switch, contactor, or electrically operated circuit breaker used to switch load bank to generator output. Switching device is typically not part of equipment specified in this Section.

- J. Control Sequence: Control panel may be preset for adjustable single-step loading of generator during automatic exercising.

2.10 OUTDOOR GENERATOR-SET ENCLOSURE

Retain first paragraph and associated subparagraphs below and coordinate with Drawings to define basic outdoor-enclosure type. Edit to specify enclosure features required.

- A. Description: Vandal-resistant, sound-attenuating, weatherproof steel housing, wind resistant up to 115 mph (184 km/h) with gust factor of 1.3. Multiple panels shall be lockable and provide adequate access to components requiring maintenance. Panels shall be removable by one person without tools. Instruments and control shall be mounted within enclosure. Provide prefabricated or preengineered walk-in enclosure with the following features:
1. Construction: Galvanized-steel, metal-clad, integral structural-steel-framed building erected on concrete foundation.
 - a. Support roof load of 1915 Pa 40 PSF.
 - b. Fiberglass or mineral wool insulation to provide minimum R11 insulation in side walls and roof for thermal transmission, sound attenuation material can be in addition to or include the thermal insulation.

Revise wind speed in first subparagraph below to suit local conditions.

2. Structural Design and Anchorage: Comply with ASCE 7 for wind loads.
3. Space Heater: Thermostatically controlled and sized to prevent condensation to maintain internal temperature at 50 degrees F (10 degrees C). Interlock so unit heaters shut off when generators are running.
4. Louvers: Equipped with bird screen and filter arranged to permit air circulation when engine is not running while excluding exterior dust, birds, and rodents.
5. Hinged Doors: With padlocking provisions.

Revise first subparagraph below if forced ventilation rather than convection ventilation is required.

6. Ventilation: Louvers equipped with bird screen and filter arranged to permit air circulation while excluding exterior dust, birds, and rodents.
7. Thermal Insulation: Manufacturer's standard materials and thickness selected in coordination with space heater to maintain winter interior temperature within operating limits required by engine-generator-set components.
8. Muffler Location: **[Within]** **[External to]** enclosure.
9. Attenuate engine-generator produced sound to an A-weighted sound level of 85 dB(A) at 3 FT (915 mm) from enclosure.
10. Space for routine maintenance and service shall be provided on all four sides of generator.
11. Exterior shall be factory finished in color selected by DEN Project Manager. Provide touch-up paint in finish color.
12. Provide anchor bolts for casting into concrete base for attaching enclosure to pad.
13. Provide one 36 IN (915 mm) wide man door in one side and provide either a pair of 36 IN (915 mm) wide doors in one side or removable air intake and louver assembly for removal of large assemblies.
14. Provide space for mounting electrical panel for serving loads inside enclosure to include but not be limited to lights, unit heaters, engine block heaters, battery chargers, ventilation fans, etc.

15. Provision for exit of exhaust stack in roof, flashed and sealed to prevent entry of moisture. Support for critical silencer on roof.
 16. Coordinate enclosure supplied with concrete pad and foundations.
 17. Provide ventilation fan with gravity damper, thermostatically controlled to operate continuously at internal temperatures adjustable from 60 to 90 degrees F. Interlock ventilation fans to prevent them from running when the engine generators are running. Interlock ventilation fan with motorized inlet dampers.
 18. Field test installation under load. Use a precision sound measuring instrument meeting ANSI-S1.4 type 1. Provide measurements to DEN Project Manager.
 19. Enclosure shall be approved for installation in local seismic zone.
- B. Engine Cooling Airflow through Enclosure: Maintain temperature rise of system components within required limits when unit operates at 110 percent of rated load for 2 hours with ambient temperature at top of range specified in system service conditions.
1. Louvers: Fixed-engine, cooling-air inlet and discharge. Storm-proof and drainable louvers prevent entry of rain and snow.
 2. Automatic Dampers: At engine cooling-air inlet and discharge. Dampers shall be closed to reduce enclosure heat loss in cold weather when unit is not operating.

Coordinate two paragraphs and associated subparagraphs below with Drawings for lighting types and location, and supply circuits.

- C. Interior Lights with Switch: Factory-wired, vaporproof-type fixtures within housing; arranged to illuminate controls and accessible interior. Arrange for external electrical connection.
1. AC lighting system and connection point for operation when remote source is available.
 2. DC lighting system for operation when remote source and generator are both unavailable.
- D. Convenience Outlets: Factory wired GFCI. Arrange for external electrical connection.

2.11 MOTORS

Retain this Article for generator sets with remote radiators.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert additional requirements below.

- A. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in electrical Sections.

2.12 VIBRATION ISOLATION DEVICES

Coordinate paragraph and subparagraphs below with Drawings and with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

- A. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic restraint to control both high and low frequency vibrations between major components, subbase and structural foundation.
 - 1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, elastomeric isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
 - 2. Outside Spring Diameter: Not less than 80 percent of compressed height of the spring at rated load.
 - 3. Minimum Additional Travel: 50 percent of required deflection at rated load.
 - 4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 - 5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
 - 6. Spring isolators shall be designed for seismic zone 1.

2.13 FINISHES

- A. Indoor and Outdoor Enclosures and Components: Manufacturer's standard finish over corrosion-resistant pretreatment and compatible primer, in color as selected by DEN Project Manager.

2.14 SOURCE QUALITY CONTROL

- A. Prototype Testing: Factory test engine-generator set using same engine model, constructed of identical or equivalent components and equipped with identical or equivalent accessories.

Consider requiring Level 1 compliance in subparagraph below for other than Level 1 installations to obtain benefits of specific standard requirements.

- 1. Tests: Comply with NFPA 110, Level 1 Energy Converters and with IEEE 115.
- B. Project-Specific Equipment Tests: Before shipment, factory test engine-generator set and other system components and accessories manufactured specifically for this Project. Perform tests at rated load and power factor. Include the following tests:
 - 1. Test components and accessories furnished with installed unit that are not identical to those on tested prototype to demonstrate compatibility and reliability.
 - 2. Full load run.
 - 3. Maximum power.
 - 4. Voltage regulation.
 - 5. Transient and steady-state governing.

6. Single-step load pickup.
7. Safety shutdown.

Retain subparagraph below if factory tests will be witnessed by Owner's representative.

8. Provide fourteen (14) days' advance notice of tests and opportunity for observation of tests by DEN Project Manager.

Coordinate subparagraph below with Part 1 "Informational Submittals" Article.

9. Report factory test results within ten (10) days of completion of test.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas, equipment bases, and conditions, with Installer present, for compliance with requirements for installation and other conditions affecting packaged engine-generator performance.
- B. Examine roughing-in of piping systems and electrical connections. Verify actual locations of connections before packaged engine-generator installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Power Outages: Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
- B. Comply with packaged engine-generator manufacturers' written installation and alignment instructions and with NFPA 110.
- C. Install packaged engine generator to provide access, without removing connections or accessories, for periodic maintenance.
- D. Install packaged engine generator with restrained spring isolators having a minimum deflection of [1 inch (25 mm)] <Insert static deflection> on 4-inch- (100-mm-) high concrete base. Secure sets to anchor bolts installed in concrete bases. Concrete base construction is specified in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- E. Install remote radiator with restrained spring isolators having a minimum deflection of [1 inch (25 mm)] <Insert static deflection> on [concrete base on grade] [roof equipment supports on roof].

Delete first paragraph below if radiator is engine mounted.

- F. Install Schedule 40, black steel piping with welded joints for cooling water piping between engine-generator set and **[heat exchanger] [remote radiator]**. Piping materials and installation requirements are specified in Section 232113 "Hydronic Piping."
- G. Install Schedule 40, black steel piping with welded joints and connect to engine muffler. Install thimble at wall. Piping shall be same diameter as muffler outlet. Flexible connectors and steel piping materials and installation requirements are specified in Section 232113 "Hydronic Piping."

Coordinate subparagraph below with Drawings.

- 1. Install condensate drain piping to muffler drain outlet full size of drain connection with a shutoff valve, stainless-steel flexible connector, and Schedule 40, black steel pipe with welded joints. Flexible connectors and piping materials and installation requirements are specified in Section 232113 "Hydronic Piping."
- H. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not specified to be factory mounted.

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping and specialties.
- B. Connect fuel, cooling-system, and exhaust-system piping adjacent to packaged engine generator to allow service and maintenance.

Coordinate first paragraph below with Section 232113 "Hydronic Piping."

- C. Connect cooling-system water piping to engine-generator set and **[remote radiator] [heat exchanger]** with flexible connectors.
- D. Connect engine exhaust pipe to engine with flexible connector.
- E. Connect fuel piping to engines with a gate valve and union and flexible connector.
 - 1. Diesel storage tanks, tank accessories, piping, valves, and specialties for fuel systems are specified in Section 231113 "Facility Fuel-Oil Piping."
 - 2. Natural-gas piping, valves, and specialties for gas distribution are specified in Section 231123 "Facility Natural-Gas Piping."
 - 3. LP-gas piping, valves, and specialties for gas piping are specified in Section 231126 "Facility Liquefied-Petroleum Gas Piping."
- F. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

- G. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 IDENTIFICATION

- A. Identify system components according to Section 230553 "Identification for HVAC Piping and Equipment" and Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

Retain one of first two paragraphs below, which identify who shall perform tests and inspections. Retain requirement for field quality-control test reports in Part 1 "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections and prepare test reports.

Retain paragraph and subparagraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections and prepare test reports.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph and subparagraphs below to describe tests and inspections to be performed by any of the entities in three paragraphs above.

- C. Tests and Inspections:

NETA and other testing requirements indicated in subparagraphs below may be in excess of those required for Project. Review NETA and other tests listed and revise subparagraphs below to retain only those tests deemed necessary.

1. Perform tests recommended by manufacturer and each electrical test and visual and mechanical inspection[**(except those indicated to be optional)**] for "AC Generators and for Emergency Systems" specified in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. NFPA 110 Acceptance Tests: Perform tests required by NFPA 110 that are additional to those specified here including, but not limited to, single-step full-load pickup test.
3. Battery Tests: Equalize charging of battery cells according to manufacturer's written instructions. Record individual cell voltages.
 - a. Measure charging voltage and voltages between available battery terminals for full-charging and float-charging conditions. Check electrolyte level and

- specific gravity under both conditions.
 - b. Test for contact integrity of all connectors. Perform an integrity load test and a capacity load test for the battery.
 - c. Verify acceptance of charge for each element of the battery after discharge.
 - d. Verify that measurements are within manufacturer's specifications.
4. Battery-Charger Tests: Verify specified rates of charge for both equalizing and float-charging conditions.
5. System Integrity Tests: Methodically verify proper installation, connection, and integrity of each element of engine-generator system before and during system operation. Check for air, exhaust, and fluid leaks.

Retain subparagraph below for long, restricted exhaust systems.

6. Exhaust-System Back-Pressure Test: Use a manometer with a scale exceeding 40-inch wg (120 kPa). Connect to exhaust line close to engine exhaust manifold. Verify that back pressure at full-rated load is within manufacturer's written allowable limits for the engine.

Verify local requirements and delete first subparagraph below for most projects. Few jurisdictions require this test for emergency or standby generator sets.

7. Exhaust Emissions Test: Comply with applicable government test criteria.
8. Voltage and Frequency Transient Stability Tests: Use recording oscilloscope to measure voltage and frequency transients for 50 and 100 percent step-load increases and decreases, and verify that performance is as specified.
9. Harmonic-Content Tests: Measure harmonic content of output voltage under 25 percent and at 100 percent of rated linear load. Verify that harmonic content is within specified limits.

Retain subparagraph below for projects subject to unwanted or illegal generator-set noise intrusion into adjacent properties or activities. Coordinate with Drawings and with requirements in Part 1 "Action Submittals" and "Quality Assurance" articles and in Part 2 "Engine" Article.

10. Noise Level Tests: Measure A-weighted level of noise emanating from generator-set installation, including engine exhaust and cooling-air intake and discharge, at [four] <Insert number> locations [on the property line] <Insert location for measurement>, and compare measured levels with required values.
- D. Coordinate tests with tests for transfer switches and run them concurrently.
- E. Test instruments shall have been calibrated within the last 12 months, traceable to standards of NIST, and adequate for making positive observation of test results. Make calibration records available for examination on request.
- F. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
- G. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
- H. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

- I. Remove and replace malfunctioning units and [retest] [reinspect] as specified above.
- J. Retest: Correct deficiencies identified by tests and observations and retest until specified requirements are met.
- K. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation resistances, time delays, and other values and observations. Attach a label or tag to each tested component indicating satisfactory completion of tests.
- L. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each power wiring termination and each bus connection. Remove all access panels so terminations and connections are accessible to portable scanner.
 - 1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan 11 months after date of Substantial Completion.
 - 2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
 - 3. Record of Infrared Scanning: Prepare a certified report that identifies terminations and connections checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain packaged engine generators. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 263213

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SECTION 263323 - CENTRAL BATTERY EQUIPMENT

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Retain one or more options in paragraph below.

- A. This Section includes [**slow-transfer**] [**and**] [**fast-transfer**] UPS central battery inverters with the following features:

Edit to suit Project.

1. Output distribution section.
2. Internal maintenance bypass/isolation switch.
3. External maintenance bypass/isolation switch.
4. Multiple output voltages.
5. Emergency-only circuits.
6. Remote monitoring provisions.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain abbreviations that remain after this Section has been edited.

- A. LCD: Liquid-crystal display.

- B. LED: Light-emitting diode.
- C. THD: Total harmonic distortion.
- D. UPS: Uninterruptible power supply.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For the following:
 - 1. Electrical ratings, including the following:
 - a. Capacity to provide power during failure of normal ac.
 - b. Inverter voltage regulation and THD of output current.
 - c. Rectifier data.
 - d. Transfer time of transfer switch.
 - e. Data for specified optional features.
 - 2. Transfer switch.
 - 3. Inverter.
 - 4. Battery charger.
 - 5. Batteries.
 - 6. Battery monitoring.
 - 7. Battery-cycle warranty monitor.
 - 8. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, components, and location and identification of each field connection. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.
 - 1. Wiring Diagrams: Detail internal and interconnecting wiring; and power, signal, and control wiring.
 - 2. Elevation and details of control and indication displays.
 - 3. Output distribution section.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For testing agency.

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems."

Coordinate seismic requirements with DEN Project Manager.

- B. Manufacturer Seismic Qualification Certification: Submit certification that central battery inverter equipment will withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain first paragraph below if Contractor is responsible for field quality-control testing.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For central battery inverter equipment to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Extra materials may not be allowed for publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents. Deliver extra materials to Owner.

Quantities in subparagraphs below are examples only.

1. Fuses: One for every 10 of each type and rating, but no fewer than **<Insert quantity>** of each.
2. Cabinet Ventilation Filters: One complete set.
3. One spare circuit board for each critical circuit.

1.8 QUALITY ASSURANCE

Retain first paragraph below if Contractor selects testing agency or is required to provide services of an independent testing agency in Part 3 "Field Quality Control" Article. Qualification requirements supplement those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory). Retain option below if Part 3 "Field Quality Control" Article specifies tests with life-safety consequences.

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

Select paragraph above or first paragraph below. See Editing Instruction No. 3 in the Evaluations for discussion of testing laboratory listing of central battery inverter. UL 1778 listing applies only to on-line, UPS central battery inverters.

- B. Central Battery Inverter System: UL 924[**and UL 1778**] listed.
- C. Comply with NFPA 70 and NFPA 101.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver equipment in fully enclosed vehicles.
- B. Store equipment in spaces having environments controlled within manufacturers' written instructions for ambient temperature and humidity conditions for non-operating equipment.

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this Article are not less than remedies available to Owner under prevailing local laws. Coordinate with Section 016000 "Product Requirements."

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace batteries that fail in materials or workmanship within specified warranty period. Special warranty, applying to batteries only, applies to materials only, on a prorated basis, for period specified.
 1. Warranty Period: Include the following warranty periods, from date of Substantial Completion:

Retain subparagraphs and associated subparagraphs below to match battery types retained in Part 2. See the Alternative Battery Types for Central Battery Inverters Table in the Evaluations for typical warranty periods for battery types listed in this Section. Verify availability of warranties with selected manufacturers.

- a. Premium, Valve-Regulated, Recombinant, Lead-Calcium Batteries:
 - 1) Full Warranty: Minimum [**one (1) year**] [<Insert number>years].
 - 2) Pro Rata: Minimum [**nineteen (19)**] <Insert number> years.
- b. Standard, Valve-Regulated, Recombinant, Lead-Calcium Batteries:
 - 1) Full Warranty: Minimum [**one (1) year**] [<Insert number> years].
 - 2) Pro Rata: Minimum [**nine (9)**] <Insert number> years.
- c. Nickel-Cadmium, Wet-Cell Batteries:
 - 1) Full Warranty: Minimum [**five (5)**] <Insert number> years.
 - 2) Pro Rata: Minimum [**fifteen (15)**] <Insert number> years.
- d. Lead-Calcium, Wet-Cell Batteries:
 - 1) Full Warranty: Minimum [**one (1) year**] [<Insert number> years].
 - 2) Pro Rata: Minimum [**nine (9)**] <Insert number> years.
- e. Lead-Antimony, Wet-Cell Batteries:
 - 1) Full Warranty: Minimum [**one (1) year**] [<Insert number> years].
 - 2) Pro Rata: Minimum [**nine (9)**] <Insert number> years.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. Retain paragraph and list of manufacturers in this Article. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Bigbeam Emergency Systems, Inc.; Siltron Division.

2. Chloride Systems.
3. Cooper Industries, Inc.; Sure-Lites Division.
4. Crucial Power Products.
5. Dual-Lite.
6. Hubbell Incorporated; Hubbell Lighting.
7. Lightguard/Chloride Systems.
8. Lithonia Lighting; Emergency Lighting Systems.
9. Thomas & Betts Corporation; Emergi-Lite Division.
10. Thomas & Betts Corporation; Lightalarms Division.
11. **<Insert manufacturer>**
12. or approved equal.

2.2 INVERTER PERFORMANCE REQUIREMENTS

Inverters for lighting and power are categorized by the speed at which power is restored to the load. Retain paragraphs in this Article that describe basic type of unit required. See Editing Instruction No. 2 in the Evaluations for discussion of transfer time.

- A. Slow-Transfer Central Battery Inverters: Automatically sense loss of normal ac supply and use an electromechanical switch to transfer loads. Transfer in one second or less from normal supply to battery-inverter supply.
 1. Operation: Unit supplies power to output circuits from a single, external, normal supply source. Unit automatically transfers load from normal source to internal battery/inverter source. Retransfer to normal is automatic when normal power is restored.
- B. Fast-Transfer Central Battery Inverters: Automatically sense loss of normal ac supply and use a solid-state switch to transfer loads. Transfer in **[0.004]** **<Insert number>** second or less from normal supply to battery-inverter supply.
 1. Operation: Unit supplies power to output circuits from a single, external, normal supply source. Unit automatically transfers load from normal source to internal battery/inverter source. Retransfer to normal is automatic when normal power is restored.
- C. UPS-Type Central Battery Inverters: Continuously provide ac power to connected electrical system.
 1. Automatic Operation:
 - a. Normal Conditions: Supply the load with ac power flowing from normal ac power input terminals, through rectifier-charger and inverter, with battery connected in parallel with rectifier-charger output.
 - b. Abnormal Supply Conditions: If normal ac supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, battery supplies constant, regulated, inverter ac power output to the load without switching or disturbance.
 - c. If normal power fails, battery continues supply-regulated ac power through the inverter to the load without switching or disturbance.

- d. When power is restored at normal supply terminals of system, controls automatically synchronize inverter with the external source before transferring the load. Rectifier-charger then supplies power to the load through the inverter and simultaneously recharges battery.
- e. If battery becomes discharged and normal supply is available, rectifier-charger charges battery. When battery is fully charged, rectifier-charger automatically shifts to float-charge mode.
- f. If any element of central battery inverter system fails and power is available at normal supply terminals of system, static bypass transfer switch transfers the load to normal ac supply circuit without disturbance or interruption of supply.
- g. If a fault occurs in system supplied by central battery inverter and current flows in excess of the overload rating of central battery inverter system, static bypass transfer switch operates to bypass fault current to normal ac supply circuit for fault clearing.
- h. When fault has cleared, static bypass transfer switch returns the load to central battery inverter system.
- i. If battery is disconnected, central battery inverter continues to supply power to the load with no degradation of its regulation of voltage and frequency of output bus.

2. Manual Operation:

Revise functional descriptions in both subparagraphs below to suit Project.

- a. Turning inverter off causes static bypass transfer switch to transfer the load directly to normal ac supply circuit without disturbance or interruption.
- b. Turning inverter on causes static bypass transfer switch to transfer the load to inverter.

Insert noise values in paragraph below that are consistent with rated capacity of UPS units specified in this Section. See the Nominal Overall UPS Audible Noise Ratings Table in Editing Instruction No. 8 in the Evaluations.

- D. Maximum Acoustical Noise: <Insert value> dB, "A" weighting, emanating from any UPS component under any condition of normal operation, measured [39 inches (990 mm)] <Insert distance> from nearest surface of component enclosure.

2.3 SERVICE CONDITIONS

- A. Environmental Conditions: Inverter system shall be capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability:

Conditions in subparagraphs below are standard for most central battery inverters. If unusual service conditions for central battery inverter equipment exist and cannot be eliminated, specify them here by revising below. See Editing Instruction No. 5 in the Evaluations for discussion of environments.

1. Ambient Temperature for Electronic Components: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).

2. Relative Humidity: [0 to 95] <Insert value> percent, noncondensing.
3. Altitude: Sea level to 5500 feet (1677 m).

2.4 INVERTERS

A. Description: Solid-state type, with the following operational features:

1. Automatically regulate output voltage to within plus or minus 5 percent.
2. Automatically regulate output frequency to within plus or minus 1 Hz, from no load to full load at unit power factor over the operating range of battery voltage.

Delete subparagraph below if units only serve incandescent lights. See Editing Instruction No. 4 in the Evaluations for discussion of THD.

3. Output Voltage Waveform of Unit: Sine wave with maximum 10 percent THD throughout battery operating-voltage range, from no load to full load.

Retain first subparagraph below for units serving loads that are sensitive to harmonic distortion.

- a. THD may not exceed 5 percent when serving a resistive load of 100 percent of unit rating.
4. Output Protection: Current-limiting and short-circuit protection.

Select subparagraph above or first subparagraph below. See Editing Instruction No. 6 in the Evaluations for discussion of output protection.

5. Output Protection: Ferroresonant transformer to provide inherent overload and short-circuit protection.
6. Surge Protection: [Panelboard] [Auxiliary panel] suppressors specified in Section 264313 "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits."

Delete optional features in subparagraphs below that are not required for Project.

7. Overload Capability: 125 percent for 10 minutes; 150 percent surge.
8. Brownout Protection: Produces rated power without draining batteries when input voltage is down to 75 percent of normal.

2.5 BATTERY CHARGER

A. Description: Solid-state, automatically maintaining batteries in fully charged condition when normal power is available. With LED indicators for "float" and "high-charge" modes.

2.6 BATTERIES

Select one of five options in paragraph below. Coordinate with "Special Warranty" Paragraph in Part 1 "Warranty" Article. See Editing Instruction No. 7 in the Evaluations for discussion of types of storage batteries.

A. Description: Premium, valve-regulated, recombinant, lead-calcium Standard,

valve-regulated, recombinant, lead-calcium Nickel-cadmium, wet-cell Lead-calcium, wet-cell Lead-antimony, wet-cell batteries.

1. Capable of sustaining full-capacity output of inverter unit for minimum of **[90 minutes]** <Insert duration>.

2.7 ENCLOSURES

Enclosure in this Article is suitable for indoor use to provide a degree of protection to personnel against incidental contact with enclosed equipment and to provide a degree of protection against falling dirt. See Editing Instruction No. 5 in the Evaluations for discussion of unusual service conditions.

Central battery inverters are available in multiple cabinets. Large units may use more than one cabinet to house batteries, electronics, and output equipment.

- A. NEMA 250, Type 1 steel cabinets with access to components through hinged doors with flush tumbler lock and latch.
- B. Finish: Manufacturer's standard baked-enamel finish over corrosion-resistant prime treatment.

2.8 SEISMIC REQUIREMENTS

- A. Central battery inverter assemblies, subassemblies, components, fastenings, supports, and mounting and anchorage devices shall be designed and fabricated to withstand seismic forces. The term "withstand" is defined in the "Manufacturer Seismic Qualification Certification" Paragraph in Part 1 "Informational Submittals" Article.

2.9 CONTROL AND INDICATION

- A. Description: Group displays, indications, and basic system controls on common control panel on front of central battery inverter enclosure.
- B. Minimum displays, indicating devices, and controls shall include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms shall include an audible signal and a visual display.

LCD messaging in paragraph below may not be available for many models rated 10 kVA and less.

- C. Indications: **[Labeled LED]** **[Plain-language messages on a digital LCD or LED]**.

Delete items in four subparagraphs and associated subparagraphs below that are not required. Coordinate with remote monitoring and alarm functions and with monitoring and alarm functions specified for central battery inverters in other articles in this Section. Consider deleting items that are nonstandard with leading manufacturers in class or size of central battery inverter indicated. Some features may be proprietary. Many features may not be available on units at low end of capacity range covered by this Section. Revise list to suit Project.

1. Quantitative Indications:

- a. Input voltage, each phase, line to line.
 - b. Input current, each phase, line to line.
 - c. System output voltage, each phase, line to line.
 - d. System output current, each phase.
 - e. System output frequency.
 - f. DC bus voltage.
 - g. Battery current and direction (charge/discharge).
 - h. Elapsed time-discharging battery.
2. Basic Status Condition Indications:
- a. Normal operation.
 - b. Load-on bypass.
 - c. Load-on battery.
 - d. Inverter off.
 - e. Alarm condition exists.
3. Alarm Indications:
- a. Battery system alarm.
 - b. Control power failure.
 - c. Fan failure.
 - d. Overload.
 - e. Battery-charging control faulty.
 - f. Input overvoltage or undervoltage.
 - g. Approaching end of battery operation.
 - h. Battery undervoltage shutdown.
 - i. Inverter fuse blown.
 - j. Inverter transformer overtemperature.
 - k. Inverter overtemperature.
 - l. Static bypass transfer switch overtemperature.
 - m. Inverter power supply fault.
 - n. Inverter output overvoltage or undervoltage.
 - o. System overload shutdown.
 - p. Inverter output contactor open.
 - q. Inverter current limit.
4. Controls:
- a. Inverter on-off.
 - b. Start.
 - c. Battery test.
 - d. Alarm silence/reset.
 - e. Output-voltage adjustment.

Retain first paragraph and subparagraphs below, if required, to allow for present or possible future remote inverter system status and alarm panel.

- D. Dry-form "C" contacts shall be available for remote indication of the following conditions:

1. Inverter on battery.
2. Inverter on-line.
3. Inverter load-on bypass.
4. Inverter in alarm condition.
5. Inverter off (maintenance bypass closed).

E. Include the following minimum array:

1. Ready, normal-power on light.
2. Charge light.
3. Inverter supply load light.
4. Battery voltmeter.
5. AC output voltmeter with minimum accuracy of 2 percent of full scale.
6. Load ammeter.
7. Test switch to simulate ac failure.

Generally, enclosures are indoor, ventilated type. Small units (15 kVA and less) are available for outdoor installation from a few manufacturers. Revise paragraph below to suit environment.

F. Enclosure: Steel, with hinged lockable doors, suitable for [wall] [floor] mounting. Manufacturer's standard corrosion-resistant finish.

2.10 OPTIONAL FEATURES

In this Article, delete optional features not required and coordinate those retained with Drawings. See Evaluations for discussion of these items.

- A. Multiple Output Voltages: Supply unit branch circuits at different voltage levels if required. Transform voltages internally as required to produce indicated output voltages.
- B. Emergency-Only Circuits: Automatically energize only when normal supply has failed. Disconnect emergency-only circuits when normal power is restored.
- C. Maintenance Bypass/Isolation Switch: Load is supplied, bypassing central battery inverter system. Normal supply, electromechanical transfer switch, and system load terminals are completely disconnected from external circuits.

Retain paragraph above for slow-transfer systems; retain paragraph and subparagraphs below for fast-transfer and UPS-type systems. See Editing Instruction No. 10 in the Evaluations for a discussion of maintenance bypass/isolation switches.

- D. Maintenance Bypass/Isolation Switch: Switch is interlocked so it cannot be operated unless static bypass transfer switch is in bypass mode. Switch provides manual selection among the following three conditions without interrupting supply to the load during switching:
 1. Full Isolation: Load is supplied, bypassing central battery inverter system. Normal ac input circuit, static bypass transfer switch, and central battery inverter load terminals are completely disconnected from external circuits.

2. Maintenance Bypass: Load is supplied, bypassing central battery inverter system. Central battery inverter ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.
3. Normal: Normal central battery inverter ac supply terminals are energized and the load is supplied either through static bypass transfer switch and central battery inverter rectifier-charger and inverter or through battery and inverter.

2.11 OUTPUT DISTRIBUTION SECTION

- A. Panelboard: Comply with Section 262416 "Panelboards" except provide assembly integral to equipment cabinet.

2.12 SYSTEM MONITORING AND ALARMS

Delete paragraph and subparagraph below if optional inverter system monitoring by remote monitoring panel is not required. Coordinate with Part 2 "Control and Indication" Article and with Drawings.

- A. Remote Status and Alarm Panel: Labeled LEDs on panel faceplate shall indicate [**five (5)**] <Insert quantity> basic status conditions. Audible signal indicates alarm conditions. Silencing switch in face of panel silences signal without altering visual indication.
 1. Cabinet and Faceplate: Surface or flush mounted to suit mounting conditions indicated.

Coordinate paragraph and subparagraphs below with Section 260913 "Electrical Power Monitoring and Control." See Evaluations.

Remote computer in paragraph below permits inverter system to communicate with computers to provide capability for remote monitoring and diagnosis and to initiate human and automated responses to inverter system events. Revise to suit Project.

- B. Provisions for Remote Computer Monitoring: Communication module in unit control panel provides capability for remote monitoring of status, parameters, and alarms specified in Part 2 "Control and Indication" Article. Remote computer and connecting signal wiring will be provided by Owner. Include the following features:
 1. Connectors and network interface units or modems for data transmission via RS-232 link.
 2. Software shall be designed to control and monitor inverter system functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of reports. Include capability for storage and analysis of power-line transient records. Software shall be compatible with requirements in Section 260913 "Electrical Power Monitoring and Control" and the operating system and configuration of Owner-furnished computers.

Paragraph and subparagraph below specify alternatives for optional monitoring of inverter system batteries and cover monitoring for abnormal conditions within battery compartments of cabinet-type housings for sealed batteries.

- C. Battery Ground-Fault Detector: Initiates alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.
1. Annunciation of Alarms: At inverter system control panel.

Retain paragraph and subparagraphs below if inverter system battery is covered by warranty specified in Part 1 that is in excess of one year and if warranty offered by specified manufacturer(s) requires continuous monitoring of battery cycling.

- D. Battery-Cycle Warranty Monitoring: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring charge-discharge cycle history of batteries covered by cycle-life warranty.
1. Basic Functional Performance: Automatically measures and records each discharge event, classifies it according to duration category, and totals discharges according to warranty criteria, displaying remaining warranted battery life on integral LCD.

Functions in subparagraph and associated subparagraphs below are optional features available for battery-cycle monitors. Delete those that are not required or that are provided by separate inverter-system battery-monitoring features specified in this Section.

2. Additional monitoring functions and features shall include the following:
 - a. Measuring and recording of total voltage at battery terminals; providing alarm for excursions outside proper float voltage level.
 - b. Monitoring of ambient temperature at battery and initiating an alarm if temperature deviates from normally acceptable range.
 - c. Keypad on device front panel provides access to monitored data using front panel display.
 - d. Alarm contacts arranged to provide [**local**] [**remote**] alarm for [**battery discharge events**] [**abnormal temperature**] [**abnormal battery voltage or temperature**].
 - e. Memory device to store recorded data in nonvolatile electronic memory.
 - f. RS-232 port to permit downloading of data to a portable personal computer.
 - g. Modem to make measurements and recorded data accessible to remote personal computer via telephone line. Computer will be provided by Owner.

2.13 SOURCE QUALITY CONTROL

Retain factory tests in this Article to suit Project.

- A. Factory test complete inverter system[, **including battery,**] before shipment. Include the following:
1. Functional test and demonstration of all functions, controls, indicators, sensors, and protective devices.

2. Full-load test.
 3. Transient-load response test.
 4. Overload test.
 5. Power failure test.
- B. Observation of Test: Give fourteen (14) days' advance notice of tests and provide access for Owner's representative to observe tests at Owner's option.
- C. Report test results. Include the following data:
1. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.
 2. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.
 3. List of instruments and equipment used in factory tests.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for ventilation, temperature, humidity, and other conditions affecting performance.
1. Verify that manufacturer's written instructions for environmental conditions have been permanently established in spaces where equipment will be installed, before installation begins.
- B. Examine roughing-in for electrical connections to verify actual locations of connections before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

Coordinate this Article with Drawings and with seismic-restraint requirements if applicable. If cabinets are to be supported by casters, alternative seismic restraints must be designed.

- A. Install system components on **[floor] [concrete base]** and attach by bolting.

Retain subparagraph below if Project is in seismic area.

1. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 260548 "Vibration and Seismic Controls for Electrical Systems" for seismic-restraint requirements.

Retain first subparagraph below to suit Project. Coordinate with Drawings.

2. Concrete Bases: **4 inches** (100 mm) high, reinforced, with chamfered edges. Extend base no more than **3 inches** (75 mm) in all directions beyond the maximum dimensions of switchgear unless otherwise indicated or unless required for seismic anchor support. Construct concrete bases according to Section 260529 "Hangers and Supports for Electrical Systems."
3. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
5. Use [**3000-psi** (20.7-MPa)] <Insert value>, 28-day compressive-strength concrete and reinforcement as specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]

- B. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

3.3 CONNECTIONS

- A. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer's wiring diagrams, unless otherwise indicated.
- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
1. Separately Derived Systems: Make grounding connections to grounding electrodes and bonding connections to metallic piping systems as indicated; comply with NFPA 70.
- C. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 IDENTIFICATION

- A. Identify equipment and components according to Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

Retain paragraph and subparagraph below to require Contractor to perform tests and inspections.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Perform tests and inspections and prepare test reports.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain paragraph and subparagraphs below to describe tests and inspections to be performed by any of the entities in three paragraphs above. See Editing Instruction No. 9 in the Evaluations for discussion of NETA tests.

B. Tests and Inspections:

1. Inspect interiors of enclosures for integrity of mechanical and electrical connections, component type and labeling verification, and ratings of installed components.
2. Test manual and automatic operational features and system protective and alarm functions.

Delete first subparagraph below if not applicable.

3. Test communication of status and alarms to remote monitoring equipment.
4. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specifications. Certify compliance with test parameters.
5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace malfunctioning units and retest as specified above.

3.6 STARTUP SERVICE

Delete first paragraph below if factory-authorized service representative is not required.

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
- B. Verify that central battery inverter is installed and connected according to the Contract Documents.
- C. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
- D. Complete installation and startup checks according to manufacturer's written instructions.

3.7 ADJUSTING AND CLEANING

Coordinate first paragraph below with Drawings.

- A. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- B. Install new filters in each equipment cabinet within fourteen (14) days from date of Substantial Completion.

3.8 DEMONSTRATION

Delete this Article if not required.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain central battery inverters. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 263323

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SECTION 263353 - STATIC UNINTERRUPTIBLE POWER SUPPLY

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Revise this article to describe basic UPS features for this Project. Coordinate these features with corresponding paragraphs in Part 2. See Evaluations and editor's notes in Part 2 for applicability of various items. Some features are not available in lower-rated UPS units, and different manufacturers may treat features differently; an item may be standard with one manufacturer, optional with some, and not offered by others. UPS technology and marketing approaches are constantly changing. Additional information is available on manufacturers' Web sites. Consult two or more manufacturers after revising this Section. Make a preliminary tabulation of UPS loads and draw a single-line diagram of the planned distribution of those loads.

- A. Section Includes:

Edit to suit Project.

1. Three-phase, on-line, double-conversion, static-type, UPS units with the following features:
 - a. Surge suppression.
 - b. Input harmonics reduction.
 - c. Rectifier-charger.
 - d. Inverter.
 - e. Static bypass transfer switch.

- f. Battery and battery disconnect device.
- g. **[Internal] [External]** maintenance bypass/isolation switch.
- h. Output isolation transformer.
- i. Remote UPS monitoring provisions.
- j. Battery monitoring.
- k. Remote monitoring.
- l. **<Insert required major features>**.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. EMI: Electromagnetic interference.
- B. LCD: Liquid-crystal display.
- C. LED: Light-emitting diode.
- D. PC: Personal computer.
- E. THD: Total harmonic distortion.
- F. UPS: Uninterruptible power supply.

1.4 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: UPS shall withstand the effects of earthquake motions determined according to **[ASCE/SEI 7] <Insert requirement>**.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

- 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified **[and the unit will be fully operational after the seismic event].**"

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include data on features, components, ratings, and performance.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For UPS. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, components, and location and identification of each field connection. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.

Retain subparagraph below if UPS installation includes field-installed wiring that is sufficiently extensive to warrant preparation of Shop Drawings.

- 2. Wiring Diagrams: For power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified [**power quality specialist**] [**testing agency**].

Retain first paragraph below if required by seismic criteria applicable to Project. Coordinate with Sections specifying mechanical vibration, supports, electrical supports, and seismic controls. See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For UPS equipment, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Manufacturer Certificates: For each product, from manufacturer.
- D. Factory Test Reports: Comply with specified requirements.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- E. Field quality-control reports.

Retain first paragraph below if retaining "Performance Testing" Article. See "Performance Testing Considerations" Article in the Evaluations for detailed discussion.

- F. Performance Test Reports: Indicate test results compared with specified performance requirements, and provide justification and resolution of differences if values do not agree.
- G. Warranties: Sample of special warranties.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For UPS units to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

If maintenance contract is specified, delete this article.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Quantities in subparagraphs below are examples only.

1. Fuses: **[One (1)]** <Insert number> for every **[ten (10)]** <Insert number> of each type and rating, but no fewer than **[one (1)]** <Insert number> of each.
2. Cabinet Ventilation Filters: **[One (1)]** <Insert number> complete set(s).

1.9 QUALITY ASSURANCE

Retain first paragraph below if Contractor is required in "Performance Testing" Article to provide the services of a power quality specialist. See "Performance Testing Considerations" Article in the Evaluations for detailed discussion.

- A. Power Quality Specialist Qualifications: A registered professional electrical engineer or engineering technician, currently certified by the National Institute for Certification in Engineering Technologies, NICET Level 4, minimum, experienced in performance testing UPS installations and in performing power quality surveys similar to that required in "Performance Testing" Article.

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in

addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- B. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. UL Compliance: Listed and labeled under UL 1778 by an NRTL.

Retain paragraph below if UPS components for this Project are installed in computer rooms.

- E. NFPA Compliance: Mark UPS components as suitable for installation in computer rooms according to NFPA 75.

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Battery Warranties: Specified form in which manufacturer and Installer agree to repair or replace UPS system storage batteries that fail in materials or workmanship within specified warranty period.

Retain one of three subparagraphs below to specify typical industry UPS battery-life warranty for type of battery specified in Part 2. Consult manufacturers' literature and revise, if applicable, to suit Project. See "Warranties" Article in the Evaluations for detailed discussion.

- 1. Warranted Cycle Life for Valve-Regulated, Lead-Calcium Batteries: Equal to or greater than that represented in manufacturer's published table, including figures corresponding to the following, based on annual average battery temperature of 77 deg F (25 deg C):

Discharge Rate:	Discharge Duration:	Discharge End Voltage:	Cycle Life:
8 hours	8 hours	1.67	6 cycles
30 minutes	30 minutes	1.67	20 cycles
15 minutes	45 seconds	1.67	120 cycles

- 2. Warranted Cycle Life for Premium Valve-Regulated, Lead-calcium Batteries: Equal to or greater than that represented in manufacturer's published table, including figures corresponding to the following, based on annual average battery temperature of 77 deg F (25 deg C):

Discharge Rate:	Discharge Duration:	Discharge End Voltage:	Cycle Life:
8 hours	8 hours	1.67	40 cycles
30 minutes	30 minutes	1.67	125 cycles
15 minutes	1.5 minutes	1.67	750 cycles

3. Warranted Cycle Life for Flooded Batteries: Equal to or greater than that represented in manufacturer's published table, including figures corresponding to the following, based on annual average battery temperature of 77 deg F (25 deg C):

Discharge Rate:	Discharge Duration:	Discharge End Voltage:	Cycle Life:
8 hours	8 hours	1.75	40 cycles
1 hour	1 hour	1.75	80 cycles
15 minutes	45 seconds	1.67	2700 cycles

Retain paragraph below unless standard one-year correction period for overall UPS installation is adequate or if a service contract or other extended service arrangement is required. Consider specifying that Contractor present Owner with a proposal, signed by a factory-authorized service representative, for a full-service contract for a period beginning at the end of the one-year correction period.

- B. Special UPS Warranties: Specified form in which manufacturer and Installer agree to repair or replace components that fail in materials or workmanship within special warranty period.

Verify that manufacturers will honor either option in subparagraph below.

1. Special Warranty Period: Minimum [two (2)] [three (3)] <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 OPERATIONAL REQUIREMENTS

- A. Automatic operation includes the following:
1. Normal Conditions: Load is supplied with power flowing from the normal power input terminals, through the rectifier-charger and inverter, with the battery connected in parallel with the rectifier-charger output.

2. Abnormal Supply Conditions: If normal supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, the battery supplies energy to maintain constant, regulated inverter power output to the load without switching or disturbance.
3. If normal power fails, energy supplied by the battery through the inverter continues supply-regulated power to the load without switching or disturbance.
4. When power is restored at the normal supply terminals of the system, controls automatically synchronize the inverter with the external source before transferring the load. The rectifier-charger then supplies power to the load through the inverter and simultaneously recharges the battery.
5. If the battery becomes discharged and normal supply is available, the rectifier-charger charges the battery. On reaching full charge, the rectifier-charger automatically shifts to float-charge mode.
6. If any element of the UPS system fails and power is available at the normal supply terminals of the system, the static bypass transfer switch switches the load to the normal ac supply circuit without disturbance or interruption.
7. If a fault occurs in the system supplied by the UPS, and current flows in excess of the overload rating of the UPS system, the static bypass transfer switch operates to bypass the fault current to the normal ac supply circuit for fault clearing.
8. When the fault has cleared, the static bypass transfer switch returns the load to the UPS system.
9. If the battery is disconnected, the UPS continues to supply power to the load with no degradation of its regulation of voltage and frequency of the output bus.

B. Manual operation includes the following:

Revise performance descriptions in both subparagraphs below to suit Project.

1. Turning the inverter off causes the static bypass transfer switch to transfer the load directly to the normal ac supply circuit without disturbance or interruption.
2. Turning the inverter on causes the static bypass transfer switch to transfer the load to the inverter.

Retain first paragraph below if specifying maintenance bypass/isolation switch for UPS units.

C. Maintenance Bypass/Isolation Switch Operation: Switch is interlocked so it cannot be operated unless the static bypass transfer switch is in the bypass mode. Device provides manual selection among the three conditions in subparagraphs below without interrupting supply to the load during switching:

1. Full Isolation: Load is supplied, bypassing the UPS. Normal UPS ac input circuit, static bypass transfer switch, and UPS load terminals are completely disconnected from external circuits.
2. Maintenance Bypass: Load is supplied, bypassing the UPS. UPS ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.
3. Normal: Normal UPS ac supply terminals are energized and the load is supplied through either the static bypass transfer switch and the UPS rectifier-charger and inverter, or the battery and the inverter.

- D. Environmental Conditions: The UPS shall be capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability, except battery performance.

Conditions in four subparagraphs below are standard for commercial UPS equipment. A separate ambient temperature range applies for the UPS battery, and the range of temperature conditions for the battery environment stated here is greater than that allowed by typical special battery warranties. If unusual service conditions for UPS equipment exist and cannot be eliminated, specify them here by revising subparagraphs below. See Editing Instruction No. 2 in the Evaluations.

1. Ambient Temperature for Electronic Components: **32 to 104 deg F** (0 to 40 deg C).

If the battery must operate within the temperature range specified in first subparagraph below rather than in the environment specified in the special battery warranty, special battery selection requirements may apply. Consult battery manufacturers.

2. Ambient Temperature for Battery: **41 to 95 deg F** (5 to 35 deg C).
3. Optimum battery temperature: **68 deg F** (20 deg C)
4. Relative Humidity: 0 to 95 percent, noncondensing.
5. Altitude: **5500 feet** (1677 m) with no derating.

2.2 PERFORMANCE REQUIREMENTS

Revise first paragraph below to specify duration of system supply. See Editing Instruction No. 3 in the Evaluations.

- A. The UPS shall perform as specified in this article while supplying rated full-load current, composed of any combination of linear and nonlinear load, up to 100 percent nonlinear load with a load crest factor of 3.0, under the following conditions or combinations of the following conditions:
1. Inverter is switched to battery source.
 2. Steady-state ac input voltage deviates up to plus or minus 10 percent from nominal voltage.
 3. Steady-state input frequency deviates up to plus or minus 5 percent from nominal frequency.
 4. THD of input voltage is 15 percent or more with a minimum crest factor of 3.0, and the largest single harmonic component is a minimum of 5 percent of the fundamental value.

Choice of alternative performance figure in subparagraph below affects ability of the UPS to maintain specified performance capability under continuous unbalanced load conditions. Retaining a high figure may limit competition and increase cost. Retain lowest percentage of continuous load unbalance reasonably expected to occur for this Project.

5. Load is **[30] [50] [100]** percent unbalanced continuously.
- B. Minimum Duration of Supply: If battery is sole energy source supplying rated full UPS load current at 80 percent power factor, duration of supply is **[five] [10] [15] <Insert duration>** minutes.

- C. Input Voltage Tolerance: System steady-state and transient output performance remains within specified tolerances when steady-state ac input voltage varies plus 10, minus [15] [20] [30] percent from nominal voltage.

Insert efficiency percentages in first paragraph below that are consistent with rated capacity of the UPS unit specified in this Section. See Editing Instruction No. 5 in the Evaluations for table of typical values.

- D. Overall UPS Efficiency: Equal to or greater than <Insert number> percent at 100 percent load, <Insert number> percent at 75 percent load, and <Insert number> percent at 50 percent load.

Insert noise values in first paragraph below that are consistent with rated capacity of UPS units specified in this Section. See Editing Instruction No. 6 in the Evaluations for table of typical values.

- E. Maximum Acoustical Noise: <Insert value>, "A" weighting, emanating from any UPS component under any condition of normal operation, measured <Insert distance> from nearest surface of component enclosure.

Retaining first option in first paragraph below may make it easier to provide good, well-coordinated overcurrent protection for the UPS feeder but may also require manufacturer to add series reactors in input circuit for some models, and it may increase cost.

- F. Maximum Energizing Inrush Current: [Six] [Eight] times the full-load current.
- G. Maximum AC Output-Voltage Regulation for Loads up to 50 Percent Unbalanced: Plus or minus 2 percent over the full range of battery voltage.
- H. Output Frequency: 60 Hz, plus or minus 0.5 percent over the full range of input voltage, load, and battery voltage.
- I. Limitation of harmonic distortion of input current to the UPS shall be as follows:

Retain one of two subparagraphs below to establish maximum harmonic distortion permitted for current drawn by the UPS from its input power source. First subparagraph is desirable for most applications, is vital for many, and commands a cost premium. See Evaluations for discussion.

1. Description: Either a tuned harmonic filter or an arrangement of rectifier-charger circuits shall limit THD to [5] [10] percent, maximum, at rated full UPS load current, for power sources with X/R ratio between 2 and 30.

Delete subparagraph below for a UPS with an engine-generator-set source or for a UPS with a utility source if it may result in excessive distortion of generator load current or in higher harmonic content of current drawn by facility service than is allowed by electric utility according to IEEE 519. See Evaluations.

2. Description: THD is limited to a maximum of 32 percent, at rated full UPS load current, for power sources with X/R ratio between 2 and 30.

Retain first paragraph below for UPS systems with more-sensitive loads; retain second paragraph for systems with less-sensitive loads. First paragraph may command a cost premium; it may also restrict competition or force some manufacturers to use an output isolation transformer with low forward transfer impedance. See Evaluations. Consult manufacturers.

- J. Maximum Harmonic Content of Output-Voltage Waveform: 5 percent rms total and 3 percent rms for any single harmonic, for 100 percent rated nonlinear load current with a load crest factor of 3.0.
- K. Maximum Harmonic Content of Output-Voltage Waveform: 5 percent rms total and 3 percent rms for any single harmonic, for rated full load with THD up to 50 percent, with a load crest factor of 3.0.

First paragraph below is one way of specifying UPS overload performance. Other methods may be used. Consult manufacturers' data and revise paragraph to suit Project. Retain if overload performance is required.

- L. Minimum Overload Capacity of UPS at Rated Voltage: 125 percent of rated full load for 10 minutes, and 150 percent for 30 seconds in all operating modes.
- M. Maximum Output-Voltage Transient Excursions from Rated Value: For the following instantaneous load changes, stated as percentages of rated full UPS load, voltage shall remain within stated percentages of rated value and recover to, and remain within, plus or minus 2 percent of that value within 100 ms:
 - 1. 50 Percent: Plus or minus 5 percent.
 - 2. 100 Percent: Plus or minus 5 percent.
 - 3. Loss of AC Input Power: Plus or minus 1 percent.
 - 4. Restoration of AC Input Power: Plus or minus 1 percent.

For units rated less than 15 kVA, manufacturer's input power factor rating is normally lower. Retain second option in first paragraph below on larger units to maintain adequate battery standby power.

- N. Input Power Factor: A minimum of **[0.70] [0.85]** lagging when supply voltage and current are at nominal rated values and the UPS is supplying rated full-load current.
- O. EMI Emissions: Comply with FCC Rules and Regulations and with 47 CFR 15 for Class A equipment.

2.3 UPS SYSTEMS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Eaton Corporation](#).
 - 2. [Liebert Corporation](#).
 - 3. [MGE UPS SYSTEMS](#).
 - 4. [Mitsubishi Electric Automation, Inc.](#)
 - 5. [Toshiba Corporation](#); Industrial Systems.
 - 6. **<Insert manufacturer's name>**.
 - 7. or approved equal.

- B. Electronic Equipment: Solid-state devices using hermetically sealed, semiconductor elements. Devices include rectifier-charger, inverter, static bypass transfer switch, and system controls.
- C. Enclosures: Comply with NEMA 250, Type 1, unless otherwise indicated.
 - 1. The rectifier/charger, inverter, static transfer switch, input, output, battery, maintenance bypass switches, output isolation transformer and customer load connections shall be housed in a freestanding enclosure. The standard run time battery shall be housed in a separate enclosure. Cabinet doors and covers shall be removable for expedient servicing, adjustments, and installation. Cabinets shall be equipped with casters and leveling feet.
- D. Control Assemblies: Mount on modular plug-ins, readily accessible for maintenance.
- E. Surge Suppression: Protect internal UPS components from surges that enter at each ac power input connection including main disconnect switch, static bypass transfer switch[, and maintenance bypass/isolation switch]. Protect rectifier-charger, inverter, controls, and output components.

For guidance on surge suppressor selection in first subparagraph below, see the Evaluations in Section 264313 "Surge Protection for Low-Voltage Electrical Power Circuits." Most UPS installations will be in Category B situations, but each should be evaluated independently.

- 1. Use factory-installed surge suppressors tested according to IEEE C62.41.1 and IEEE C62.41.2, [**Category B**] [**Category C**].

Subparagraph above specifies surge protection typically available for all three-phase, on-line UPS units. Surge suppressors that comply with this subparagraph are effective against high-voltage, fast surges (quick, sharp, power-line high-voltage spikes). They do not, however, protect against low-frequency, high-energy surges that may be even more damaging to UPS components than high-voltage spikes. For important mission-critical applications approximately 15- to 20-kVA rating and above, include the capability for handling surges in the 300-cycle, minus 180 percent voltage range specified in subparagraph below. See Evaluations.

- 2. Additional Surge Protection: Protect internal UPS components from low-frequency, high-energy voltage surges described in IEEE C62.41.1 and IEEE C62.41.2. Design the circuits connecting with external power sources and select circuit elements, conductors, conventional surge suppressors, and rectifier components and controls so input assemblies will have adequate mechanical strength and thermal and current-carrying capacity to withstand stresses imposed by 40-Hz, 180 percent voltage surges described in IEEE C62.41.1 and IEEE C62.41.2.

Retain first paragraph below for units rated more than approximately 100 kVA. Consult manufacturers.

- F. Maintainability Features:
 - 1. Mount rectifier-charger and inverter sections and the static bypass transfer switch on modular plug-ins, readily accessible for maintenance.
 - 2. The UPS shall be constructed of replaceable subassemblies. The main control printed circuit board shall be interchangeable across the entire single-phase

product range.

Upgrading existing UPS systems to add capacity is rare. Retain first paragraph below if this method of providing future UPS capacity is applicable. Retaining paragraph may limit competition and increase initial cost; if retaining, consider increasing sizes of conduit, wire, and overcurrent protective devices to accommodate future increased capacity. Additional space may also be required for future equipment cabinets.

- G. Capacity Upgrade Capability: Arrange wiring, controls, and modular component plug-in provisions to permit future [25] <Insert number> percent increase in UPS capacity.

Retain first paragraph below if required by seismic criteria applicable to Project. See "Seismic Considerations" Article in the Evaluations.

- H. Seismic-Restraint Design: UPS assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces.

Locating UPS cabinets on raised flooring in computer rooms is no longer common due to the high cost of computer room space. However, if locating units on raised flooring, revise first paragraph below to ensure that bottom plane of cabinets is closed. This action prevents the potential of unwanted imbalance in air systems supplying underfloor areas.

- I. UPS Cabinet Ventilation: Redundant fans or blowers draw in ambient air near the bottom of cabinet and discharge it near the top rear.

Retain paragraph below for a UPS with heavy nonlinear loading.

- J. Output Circuit Neutral Bus, Conductor, and Terminal Ampacity: Rated phase current times a multiple of 1.73, minimum.

2.4 RECTIFIER-CHARGER

- A. Capacity: Adequate to supply the inverter during rated full output load conditions and simultaneously recharge the battery from fully discharged condition to 95 percent of full charge within 10 times the rated discharge time for duration of supply under battery power at full load.

Feature in first paragraph below is important for optimum battery life.

- B. Output Ripple: Limited by output filtration to less than 0.5 percent of rated current, peak to peak.
- C. Control Circuits: Immune to frequency variations within rated frequency ranges of normal and emergency power sources.
1. Response Time: Field adjustable for maximum compatibility with local generator-set power source.

- D. Battery Float-Charging Conditions: Comply with battery manufacturer's written instructions for battery terminal voltage and charging current required for maximum battery life.
- E. Automatic Restart: Upon restoration of utility AC power after a power outage, the rectifier/charger shall automatically restart, "walk-in", and gradually assume the inverter and battery recharge loads.
- F. Rectifier/Charger Input Current Limit: The rectifier/charger shall have an "on generator" function, which when activated by an external dry contact opening (user supplied), shall reduce the input current limit to 100%.
- G. Rectifier/Charger Battery Test: The rectifier/charger shall run a weekly diagnostic test of the batteries by briefly placing them under load, this shall be done by reducing the output voltage of the rectifier/charger. The rectifier shall remain on and in the circuit should the battery fail to meet criteria. If any fault is detected an alarm will flash on the diagnostic panel. Measurements taken will be compared with the diagnostic algorithm in the microprocessor to confirm the integrity of the battery.

2.5 INVERTER

Retain one of two paragraphs in this article. Retain second paragraph if the UPS may be supplied power from a standby engine-generator set.

- A. Description: Pulse-width modulated, with sinusoidal output.
- B. Description: Pulse-width modulated, with sinusoidal output. Include a bypass phase synchronization window adjustment to optimize compatibility with local engine-generator-set power source.
- C. Inverter Start-Up: The inverter shall automatically startup when a start command is generated and shall be stable and ready to deliver power to the load within 2 seconds.
- D. Inverter Protection: Inverter transistors shall be protected by fast acting, current limiting fuses and current limiting circuits. The inverter shall be capable of running indefinitely with the batteries disconnected. For rapid removal of the inverter from the critical load, the inverter control electronics shall instantaneously turn off the inverter transistors when the inverters capacity is exceeded. Simultaneously, the static transfer switch shall transfer the load to utility power without interruption to maintain continuous power to the critical load.
- E. Inverter Oscillator: The inverter shall contain an oscillator capable of operating and maintaining the output frequency of the inverter within specified limits. The inverter oscillator shall be capable of frequency synchronization and phase locking to the utility power source frequency. When operating as a slave to the utility power and a failure occurs in the slaving signal, the inverter oscillator shall automatically revert to a free running state and maintain the specified limits. The oscillator shall not drift more than 0.1% while operating at maximum rated operating temperature.
- F. Inverter DC Protection: The inverter shall be automatically protected at the following

DC voltage levels, which shall be independently adjustable for UPS application flexibility.

1. DC Over voltage Shutdown = 2.40 V/cell.
2. DC Under voltage Shutdown = 1.65 V/cell.
3. The DC under voltage shutdown shall be automatically increased when the backup time is longer than one hour to 1.75 V/cell to avoid deep discharge to the battery due to light load.

G. Phase Balance: Electronic controls shall be provided to regulate each phase so that an unbalanced load will not cause the output voltage to go outside of the specified voltage unbalance or phase displacement limits.

H. Inverter performance criteria:

1. Power Rating: UPS ratings are shown at 0.8 pf lagging, other power factor loads can be supported.
2. Input: Shall operate within specification over the nominal rectifier/charger output range and minimum battery voltage of 1.65 volts per cell.
3. Output Voltage: 480 or 208 VAC-60HZ, 3 Phase, 4 wire (plus ground), adjustable by $\pm 5\%$ of nominal.
4. Output Regulation: Balanced Loads: $\pm 1\%$ balanced load - Phase Angle $120^\circ \pm 1^\circ$, Unbalanced Loads: $\pm 3\%$ 100% unbalanced load - Phase Angle $120^\circ \pm 3^\circ$.
5. Output Waveform: Sinusoidal.
6. Frequency Stability: Normally synchronized to utility line over frequency range of $\pm 0.75\%$ or optionally $\pm 1.5\%$, $\pm 3\%$, $\pm 6\%$; free running $\pm 0.05\%$. Slew rate $\square 1.0$ Hz/Sec.
7. Output Dynamic Response: $< \pm 5\%$ maximum deviation, recovering to within 2% of (sudden 100% load steady state in less than 20ms; application or removal).
8. Overload Rating: 150% for 1 minute, 125% for 10 minutes.
9. Harmonic Content: Linear loads: Max. voltage THD $< 3\%$, 100% non-linear load: Max. voltage THD $< 5\%$.

I. Efficiency (AC-AC): Minimum: 90-93% at Full Load.

2.6 STATIC BYPASS TRANSFER SWITCH

A. Description: Solid-state switching device providing uninterrupted transfer. A contactor or electrically operated circuit breaker automatically provides electrical isolation for the switch.

B. Switch Rating: Continuous duty at the rated full UPS load current, minimum.

C. The static switch shall be naturally commutated high speed static devices (SCR) rated to conduct full load current continuously while on inverter or bypass power (reserve source). The reserve portion of the static switch shall be designed to avoid backfeed into the mains. Failure of one SCR shall not effect the operation of the UPS and the failure shall be shown on the LCD display. Over current protection in the bypass mode will be through fuses. The bypass power source can be other than rectifier/charger

input utility source.

- D. Overload Ratings: Continuous 125%, 1 Minute 150%, 30 cycles 1000%, 5 cycles 1500%.
- E. Transfer Characteristics: Transfer time from inverter shall be less than 0.5ms to utility power when both sources are in phase lock, and vice versa and automatic 5 second delay before allowing retransfer from utility power to inverter after transferring from inverter to utility power. Transfer time from inverter to utility when both sources are not in phase lock shall be 20 ms (To prevent damage by phase reversal to the load.)
- F. Separate Reserve Feed: The UPS shall be supplied with a separate reserve feed. This feed eliminates the single point of failure of the primary input by offering two (2) separate paths for the power flow. This feature also allows two or more UPS's to be installed in an isolated redundant configuration.
- G. Reserve Transfer: The static switch shall automatically and successfully transfer the critical load from the inverter to the bypass source (reserve) under the following conditions:
1. DC voltage out-of-limits failure.
 2. Inverter failure.
 3. Critical load current exceeds inverter overload rating.
 4. Over-temperature develops within the inverter.
 5. Manual command is given.
 6. Reserve Transfer shall be automatically inhibited, whenever bypass source conditions are outside predetermined (adjustable) limits, or UPS output and bypass are not synchronized and phase locked.
 7. Retransfer: The static switch shall automatically and successfully retransfer the critical load from the bypass source to the inverter under the following conditions:
 - a. Inverter output voltage returns to within specified limits.
 - b. Critical load current reduces to within inverter overload rating.
- H. Synchronizing Equipment: The static switch shall include all necessary logic circuitry for fully automatic frequency synchronization and phase locking of the UPS inverter output to the bypass/reserve power source.

2.7 BATTERY

Retain one of three "Description" paragraphs in this article. Revise retained paragraph to suit Project requirements for cell type and rack or housing mounting configuration. See Editing Instruction No. 4 and "UPS Batteries" Article in the Evaluations for discussions of battery alternatives. Coordinate with "Warranty" Article and with Drawings.

- A. Description: Valve-regulated, recombinant, lead-calcium units, factory assembled in an isolated compartment of UPS cabinet, complete with battery disconnect switch.

Optional feature in subparagraph below is available from some manufacturers; retain if budget allows, enhanced maintainability is required, and the possibility of reduced competition is acceptable.

1. Arrange for drawout removal of battery assembly from cabinet for testing and inspecting.
- B. Description: Valve-regulated, premium, heavy-duty, recombinant, lead-calcium units; factory assembled in an isolated compartment or in a separate matching cabinet, complete with battery disconnect switch.

Optional feature in subparagraph below is available from some manufacturers; retain if budget allows, enhanced maintainability is required, and the possibility of reduced competition is acceptable.

1. Arrange for drawout removal of battery assembly from cabinet for testing and inspecting.
- C. Description: Flooded, lead-calcium, heavy-duty industrial units in styrene acrylonitrile containers mounted on[**three-tier,**] acid-resistant, painted steel racks. Assembly includes battery disconnect switch, intercell connectors, hydrometer syringe, and thermometer with specific gravity-correction scales.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- D. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [C&D Technologies, Inc.](#)
 2. [Eaton Corporation.](#)
 3. [EnerSys.](#)
 4. [Panasonic Corporation of North America](#); Panasonic Industrial Company.
 5. **<Insert manufacturer's name>**.
 6. or approved equal.

Retain paragraph below if required by seismic criteria applicable to Project. See "Seismic Considerations" Article in the Evaluations.

- E. Seismic-Restraint Design: Battery racks, cabinets, assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces.

2.8 CONTROLS AND INDICATIONS

- A. Description: Group displays, indications, and basic system controls on a common control panel on front of UPS enclosure.
- B. Minimum displays, indicating devices, and controls include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms include audible signals and visual displays.

LCD messaging in first paragraph below may not be available for many models rated 10 kVA and less.

- C. Indications: [**Labeled LED**] [**Plain-language messages on a digital LCD or LED**].

Retain lists in subparagraphs below or revise to suit Project. Coordinate with remote monitoring and alarm functions and with monitoring and alarm functions specified for the UPS battery in other articles in this Section. Consider deleting all items that are nonstandard with leading manufacturers in the UPS class or size indicated. Some may be proprietary. Many may not be available on units at low end of capacity range covered by this Section.

1. Quantitative indications shall include the following:
 - a. Input voltage, each phase, line to line.
 - b. Input current, each phase, line to line.
 - c. Bypass input voltage, each phase, line to line.
 - d. Bypass input frequency.
 - e. System output voltage, each phase, line to line.
 - f. System output current, each phase.
 - g. System output frequency.
 - h. DC bus voltage.
 - i. Battery current and direction (charge/discharge).
 - j. Elapsed time discharging battery.

2. Basic status condition indications shall include the following:
 - a. Normal operation.
 - b. Load-on bypass.
 - c. Load-on battery.
 - d. Inverter off.
 - e. Alarm condition.

3. Alarm indications shall include the following:
 - a. Bypass ac input overvoltage or undervoltage.
 - b. Bypass ac input overfrequency or underfrequency.
 - c. Bypass ac input and inverter out of synchronization.
 - d. Bypass ac input wrong-phase rotation.
 - e. Bypass ac input single-phase condition.
 - f. Bypass ac input filter fuse blown.
 - g. Internal frequency standard in use.
 - h. Battery system alarm.
 - i. Control power failure.
 - j. Fan failure.
 - k. UPS overload.
 - l. Battery-charging control faulty.
 - m. Input overvoltage or undervoltage.
 - n. Input transformer overtemperature.
 - o. Input circuit breaker tripped.
 - p. Input wrong-phase rotation.
 - q. Input single-phase condition.
 - r. Approaching end of battery operation.
 - s. Battery undervoltage shutdown.
 - t. Maximum battery voltage.
 - u. Inverter fuse blown.
 - v. Inverter transformer overtemperature.

- w. Inverter overtemperature.
 - x. Static bypass transfer switch overtemperature.
 - y. Inverter power supply fault.
 - z. Inverter transistors out of saturation.
 - aa. Identification of faulty inverter section/leg.
 - bb. Inverter output overvoltage or undervoltage.
 - cc. UPS overload shutdown.
 - dd. Inverter current sensor fault.
 - ee. Inverter output contactor open.
 - ff. Inverter current limit.
4. Controls shall include the following:
- a. Inverter on-off.
 - b. UPS start.
 - c. Battery test.
 - d. Alarm silence/reset.
 - e. Output-voltage adjustment.

Retain first paragraph below if required to allow for present or possible future remote UPS status and alarm panel.

- D. Dry-form "C" contacts shall be available for remote indication of the following conditions:
- 1. UPS on battery.
 - 2. UPS on-line.
 - 3. UPS load-on bypass.
 - 4. UPS in alarm condition.
 - 5. UPS off (maintenance bypass closed).
- E. Emergency Power Off Switch: Capable of local operation and operation by means of activation by external dry contacts.

Of components and features listed in first eight articles below, some are optional and some are standard, depending on manufacturer, model, and rating. For some, a single component functions as two. See Evaluations. Retain those components required for Project.

2.9 MAINTENANCE BYPASS/ISOLATION SWITCH

Many UPS units in the 5- to 125-kVA range do not have devices specified in this article as standard features. Loads of UPS units without these devices must be shut down if UPS units are de-energized for maintenance or repair. See Evaluations.

- A. Description: Manually operated switch or arrangement of switching devices with mechanically actuated contact mechanism arranged to route the flow of power to the load around the rectifier-charger, inverter, and static bypass transfer switch.
- 1. Switch shall be electrically and mechanically interlocked to prevent interrupting power to the load when switching to bypass mode.

2. Switch shall electrically isolate other UPS components to permit safe servicing.

Retain first paragraph below for systems approximately 150 kVA and larger, where this component is often housed in a floor-mounted cabinet.

- B. Comply with NEMA PB 2 and UL 891.
- C. Switch Rating: Continuous duty at rated full UPS load current.

Retain first paragraph below if Drawings do not indicate mounting and location of switch. Coordinate with Drawings.

- D. Mounting Provisions: **[Internal to system cabinet] [Separate wall- or floor-mounted unit]**.

Retain paragraph below for externally mounted switch.

- E. Key interlock requires unlocking maintenance bypass/isolation switch before switching from normal position with key that is released only when the UPS is bypassed by the static bypass transfer switch. Lock is designed specifically for mechanical and electrical component interlocking.

2.10 OUTPUT ISOLATION TRANSFORMER

This article specifies an important feature for UPS units serving loads susceptible to conducted EMI if there are no other provisions for adequate attenuation of EMI. Output isolation transformers have other functions besides mitigation of EMI and may be standard on certain models by some manufacturers. In some applications, a UPS serves loads through one or more power distribution units that contain shielded isolation transformers. In such cases, the output isolation transformer in the UPS does not need to comply with shielding requirements in this article. See Evaluations.

- A. Description: **[Shielded unit] [Unit]** with low forward transfer impedance up to 3 kHz, minimum. Include the following features:

Retain K-factor in first subparagraph below that is appropriate for UPS load in this Project. Consider harmonic diversity and avoid overestimating the K-factor.

1. Comply with applicable portions of UL 1561, including requirements for nonlinear load current-handling capability for a K-factor of approximately **[4] [9] [13] [20]**.
2. Output Impedance at Fundamental Frequency: Between 3 and 4 percent.
3. Regulation: 5 percent, maximum, at rated nonlinear load current.
4. Full-Load Efficiency at Rated Nonlinear Load Current: 96 percent, minimum.
5. Electrostatic Shielding of Windings: Independent for each winding.
6. Coil Leads: Physically arranged for minimum interlead capacitance.
7. Shield Grounding Terminal: Separately mounted; labeled "Shield Ground."
8. Capacitive Coupling between Primary and Secondary: 33 picofarads, maximum, over a frequency range of 20 Hz to 1 MHz.

2.11 OUTPUT DISTRIBUTION SECTION

Retain this article if distribution panels are required to be integral with UPS system cabinets. Coordinate with Drawings and panelboard schedules.

- A. Panelboards: Comply with Section 262416 "Panelboards" except provide assembly integral to UPS cabinet.

2.12 MONITORING BY REMOTE STATUS AND ALARM PANEL

Retain this article if optional UPS monitoring by remote monitoring panel is required. Coordinate with "Controls and Indications" Article and with Drawings.

- A. Description: Labeled LEDs on panel faceplate indicate **[five (5)] <Insert quantity>** basic status conditions. Audible signal indicates alarm conditions. Silencing switch in face of panel silences signal without altering visual indication.
 - 1. Cabinet and Faceplate: Surface or flush mounted to suit mounting conditions indicated.

2.13 MONITORING BY REMOTE COMPUTER

Coordinate this article with "Basic Battery Monitoring" Article if battery monitoring is included. Coordinate with Section 260913 "Electrical Power Monitoring and Control." See Evaluations.

Feature in this article permits the UPS to communicate with computers to provide capability for remote monitoring and diagnosis and to initiate human and automated responses to UPS system events.

- A. Description: Communication module in unit control panel provides capability for remote monitoring of status, parameters, and alarms specified in "Controls and Indications" Article. The remote computer and the connecting signal wiring are not included in this Section. Include the following features:
 - 1. Connectors and network interface units or modems for data transmission via RS-232 link.
 - 2. Software designed for control and monitoring of UPS functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of meaningful reports. Permit storage and analysis of power-line transient records. Designs for Windows applications, software, and computer are not included in this Section.

Retain subparagraph below if cited Section is included.

- 3. Software and Hardware: Compatible with that specified in Section 260913 "Electrical Power Monitoring and Control."

2.14 BASIC BATTERY MONITORING

This article specifies alternatives for optional monitoring of UPS batteries.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [BTECH, Inc.](#)
 2. [Eaton Corporation.](#)
 3. **<Insert manufacturer's name>**.
 4. or approved equal.

First two paragraphs below cover monitoring for abnormal conditions within battery compartments of cabinet-type housings for sealed batteries. Feature in second paragraph is unavailable from most manufacturers.

- B. Battery Ground-Fault Detector: Initiates alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.
- C. Battery compartment smoke/high-temperature detector initiates an alarm when smoke or a temperature greater than 75 deg C occurs within the compartment.
- D. Annunciation of Alarms: At UPS control panel.

2.15 ADDITIONAL BATTERY MONITORING

Retain this article in special situations for large, compartment-mounted, valve-regulated batteries or for rack-mounted, station-type, flooded batteries. Retain only if detailed computerized analysis of battery performance is likely to be used. Do not retain unless separate provision is made for signal transmission to an appropriate computer and budget includes allowance for these costly features. Coordinate with Drawings. See Evaluations.

- A. Monitoring features and components shall include the following:
1. Factory-wired sensing leads to cell and battery terminals and cell temperature sensors.
 2. Connections for data transmission via RS-232 link, [**network interface and**] [**modem and**] external signal wiring to [**computer**] [**electrical power monitoring and control equipment**]. External signal wiring and computer are not specified in this Section.

Revise subparagraph below to include specific computer operating system if required.

3. PC-based software designed to store and analyze battery data. Software compiles reports on individual-cell parameters and total battery performance trends, and provides data for scheduling and prioritizing battery maintenance.
- B. Performance: Automatically measures and electronically records the following parameters on a routine schedule and during battery discharge events. During discharge events, records measurements timed to nearest second; includes measurements of the following parameters:
1. Total battery voltage and ambient temperature.

Retain first subparagraph below if complexity of wiring required for intercell monitoring makes it practical or acceptable.

2. Individual-cell voltage, impedance, and temperature. During battery-discharging events such as utility outages, measures battery and cell voltages timed to nearest second.

Retain subparagraph below for flooded-type battery if frequent visual monitoring of electrolyte levels is not acceptable.

3. Individual-cell electrolyte levels.

2.16 BATTERY-CYCLE WARRANTY MONITORING

Retain this article if UPS battery is covered by a cycle-life warranty specified in Part 1 and warranty requires continuous monitoring of battery cycling.

- A. Description: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring of charge-discharge cycle history of batteries covered by cycle-life warranties.
- B. Performance: Automatically measures and records each discharge event, classifies it according to duration category, and totals discharges according to warranty criteria, displaying remaining warranted battery life on front panel display.
- C. Additional monitoring functions and features shall include the following:

Functions in seven subparagraphs below represent optional features available for battery-cycle monitors. Retain those required or those that are not provided by separate UPS battery-monitoring features specified in previous articles in this Section.

1. Measuring and Recording: Total voltage at battery terminals; initiates alarm for excursions outside the proper float-voltage level.
2. Monitors: Ambient temperature at battery; initiates alarm if temperature deviates from normally acceptable range.
3. Keypad on Device Front Panel: Provides access to monitored data using front panel display.
4. Alarm Contacts: Arranged to initiate [**local**] [**remote**] alarm for [**battery discharge events**] [**abnormal temperature**] [**abnormal battery voltage or temperature**].
5. Memory: Stores recorded data in nonvolatile electronic memory.
6. RS-232 Port: Permits downloading of data to a portable PC.
7. Modem: Makes measurements and recorded data accessible to a remote PC via telephone line. Computer is not specified in this Section.

2.17 SYSTEM RELIABILITY

- A. The UPS Mean Time Between Failures (MTBF) shall not be less than 35,000 hours for the inverter and 200,000 hours for the load.

2.18 SOURCE QUALITY CONTROL

Simulated battery tests are standard. Consider cost before specifying factory testing with actual batteries that are to be part of final installation.

- A. Factory test complete UPS system before shipment. Use **[actual batteries that are part of final installation] [simulated battery testing]**. Include the following:
1. Test and demonstration of all functions, controls, indicators, sensors, and protective devices.
 2. Full-load test.
 3. Transient-load response test.
 4. Overload test.
 5. Power failure test.

Retain first paragraph below if required.

- B. Observation of Test: Give 14 days' advance notice of tests and provide opportunity for DEN Project Manager to observe tests at DEN Project Manager's choice.

Retain paragraph below if factory test reports are required. Coordinate with Part 1.

- C. Report test results. Include the following data:
1. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.
 2. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.
 3. List of instruments and equipment used in factory tests.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for conditions affecting performance of the UPS.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

Retain first paragraph below if required. Coordinate with Drawings and with seismic-restraint requirements if applicable.

- A. Equipment Mounting: Install UPS on concrete base. Comply with requirements for concrete base specified in [**Section 033000 "Cast-in-Place Concrete."**] [**Section 033053 "Miscellaneous Cast-in-Place Concrete."**]
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- B. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.
- C. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer's wiring diagrams unless otherwise indicated.

3.3 GROUNDING

See Evaluations for discussion of grounding for separately derived systems created by isolation transformers. Coordinate this article with Drawings.

- A. Separately Derived Systems: If not part of a listed power supply for a data-processing room, comply with NFPA 70 requirements for connecting to grounding electrodes and for bonding to metallic piping near isolation transformer.

3.4 IDENTIFICATION

- A. Identify components and wiring according to Section 260553 "Identification for Electrical Systems."

Retain subparagraph below for rack-mounted, wet-cell batteries.

- 1. Identify each battery cell individually.

3.5 BATTERY EQUALIZATION

- A. Equalize charging of battery cells according to manufacturer's written instructions. Record individual-cell voltages.

3.6 FIELD QUALITY CONTROL

Retain one of first two paragraphs below to identify who shall perform tests and inspections. Retain first paragraph for units rated 150 kVA or more or that are considered mission critical. Coordinate with Part 1.

If retaining either option retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- C. Tests and Inspections:

1. Comply with manufacturer's written instructions.
2. Inspect interiors of enclosures, including the following:
 - a. Integrity of mechanical and electrical connections.
 - b. Component type and labeling verification.
 - c. Ratings of installed components.

Retain first subparagraph below for flooded lead-calcium and valve-regulated, lead-calcium batteries only.

3. Inspect batteries and chargers according to requirements in NETA Acceptance Testing Specifications.
4. Test manual and automatic operational features and system protective and alarm functions.

Retain first subparagraph below if battery monitoring is required.

5. Test communication of status and alarms to remote monitoring equipment.

Retain subparagraph below for critical units rated 150 to 250 kVA and units rated 300 kVA and more.

6. Load the system using a variable-load bank to simulate kilovolt amperes, kilowatts, and power factor of loads for unit's rating. Use instruments calibrated within the previous [six months] <Insert time> according to NIST standards.

Retain tests in seven subparagraphs below if factory-test results for these items are not adequate.

- a. Simulate malfunctions to verify protective device operation.
- b. Test duration of supply on emergency, low-battery voltage shutdown, and transfers and restoration due to normal source failure.
- c. Test harmonic content of input and output current less than 25, 50, and 100 percent of rated loads.
- d. Test output voltage under specified transient-load conditions.

- e. Test efficiency at 50, 75, and 100 percent of rated loads.

Retain both subparagraphs below if features are specified.

- f. Test remote status and alarm panel functions.
- g. Test battery-monitoring system functions.

Retain first paragraph below for projects subject to seismic criteria.

- D. Seismic-restraint tests and inspections shall include the following:

- 1. Inspect type, size, quantity, arrangement, and proper installation of mounting or anchorage devices.

Retain subparagraph below for projects where anchorage device testing is required by Section 260548.16 "Seismic Controls for Electrical Systems."

- 2. Test mounting and anchorage devices according to requirements in Section 260548.16 "Seismic Controls for Electrical Systems."

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. The UPS system will be considered defective if it does not pass tests and inspections.
- F. Record of Tests and Inspections: Maintain and submit documentation of tests and inspections, including references to manufacturers' written instructions and other test and inspection criteria. Include results of tests, inspections, and retests.
- G. Prepare test and inspection reports.

3.7 PERFORMANCE TESTING

Retain this article if performance testing of UPS installation is required. See "Performance Testing Considerations" Article in the Evaluations for detailed discussion.

- A. Engage the services of a qualified power quality specialist to perform tests and activities indicated[**for each UPS system**].

Revise first paragraph below to specify extent and basic schedule for performance testing required for Project. Schedule below provides opportunity to specify single or multiple monitoring periods. Multiple monitoring periods are preferable to increase opportunity for observing UPS performance under conditions that occur randomly or are influenced by seasonal load conditions or by such phenomena as lightning storms.

- B. Monitoring and Testing Schedule: Perform monitoring and testing in [**a single 10-day period**] [**four 10-day periods, each in a different season of the year**] <Insert period>.
 - 1. Schedule monitoring and testing activity with Owner, through DEN Project Manager, with at least 14 days' advance notice.
 - 2. Schedule monitoring and testing after Substantial Completion, when the UPS is supplying power to its intended load.

Coordinate first paragraph below with Drawings.

- C. Monitoring and Testing Instruments: Three-phase, recording, power monitors. Instruments shall provide continuous simultaneous monitoring of electrical parameters at UPS input terminals and at input terminals of loads served by the UPS. Instruments shall monitor, measure, and graph voltage current and frequency simultaneously and provide full-graphic recordings of the values of those parameters before and during power-line disturbances that cause the values to deviate from normal beyond the adjustable threshold values. Instruments shall be capable of recording either on paper or on magnetic media and have a minimum accuracy of plus or minus 2 percent for electrical parameters. Parameters to be monitored include the following:
1. Current: Each phase and neutral and grounding conductors.
 2. Voltage: Phase to phase, phase to neutral, phase to ground, and neutral to ground.
 3. Frequency transients.
 4. Voltage swells and sags.
 5. Voltage Impulses: Phase to phase, phase to neutral, phase to ground, and neutral to ground.
 6. High-frequency noise.
 7. Radio-frequency interference.
 8. THD of the above currents and voltages.
 9. Harmonic content of currents and voltages above.
- D. Monitoring and Testing Procedures[**for Each Test Period**]:
1. Exploratory Period: For the first **[two (2)] <Insert number>** days[**of the first scheduled monitoring and testing period**], make recordings at various circuit locations and with various parameter-threshold and sampling-interval settings. Make these measurements with the objective of identifying optimum UPS, power system, load, and instrumentation setup conditions for subsequent test and monitoring operations.
 2. Remainder of Test Period: Perform continuous monitoring of at least two circuit locations selected on the basis of data obtained during exploratory period.
 - a. Set thresholds and sampling intervals for recording data at values selected to optimize data on performance of the UPS for values indicated, and to highlight the need to adjust, repair, or modify the UPS, distribution system, or load component that may influence its performance or that may require better power quality.
 - b. Perform load and UPS power source switching and operate the UPS on generator power during portions of test period according to directions of Owner's power quality specialist.
 - c. Operate the UPS and its loads in each mode of operation permitted by UPS controls and by the power distribution system design.

Retain one of first two subparagraphs below. Substantial cost is involved in using temporary equipment. Using temporary generator sets may not be necessary if installed power system includes a standby or emergency set. However, because tests are performed when the facility is occupied and operating, tests must be carefully planned to avoid compromising life safety and operational integrity. In many cases, the

need to ensure successful performance testing of vital UPS systems will override other concerns. This is the time to verify that the UPS will perform as required in the Project's unique environment.

- d. Using loads and devices available as part of the facility's installed systems and equipment[**and a temporarily connected portable generator set**], create and simulate unusual operating conditions, including outages, voltage swells and sags, and voltage, current, and frequency transients. Maintain normal operating loads in operation on system to maximum extent possible during tests.
- e. Using temporarily connected resistive/inductive load banks[**and a temporarily connected portable generator set**], create and simulate unusual operating conditions, including outages, voltage swells and sags, and voltage, current, and frequency transients. Maintain normal operating loads in operation on system to maximum extent possible during tests.
- f. Make adjustments and repairs to UPS, distribution, and load equipment to correct deficiencies disclosed by monitoring and testing and repeat appropriate monitoring and testing to verify success of corrective action.

Retain first paragraph below if computerized monitoring is specified for the UPS or its battery in Part 2.

- E. Coordination with Specified UPS Monitoring Functions: Obtain printouts of built-in monitoring functions specified for the UPS and its components in this Section that are simultaneously recorded with portable instruments in this article.
 1. Provide the temporary use of an appropriate PC and printer equipped with required connections and software for recording and printing if such units are not available on-site.
 2. Coordinate printouts with recordings for monitoring performed according to this article, and resolve and report any anomalies in and discrepancies between the two sets of records.
- F. Monitoring and Testing Assistance by Contractor:
 1. Open UPS and electrical distribution and load equipment and wiring enclosures to make monitoring and testing points accessible for temporary monitoring probe and sensor placement and removal as requested.
 2. Observe monitoring and testing operations; ensure that UPS and distribution and load equipment warranties are not compromised.
 3. Perform switching and control of various UPS units, electrical distribution systems, and load components as directed by power quality specialist. Specialist shall design this portion of monitoring and testing operations to expose the UPS to various operating environments, conditions, and events while response is observed, electrical parameters are monitored, and system and equipment deficiencies are identified.
 4. Make repairs and adjustments to the UPS and to electrical distribution system and load components, and retest and repeat monitoring as needed to verify validity of results and correction of deficiencies.
 5. Engage the services of the UPS manufacturer's factory-authorized service representative periodically during performance testing operations for repairs, adjustments, and consultations.

- G. Documentation: Record test point and sensor locations, instrument settings, and circuit and load conditions for each monitoring summary and power disturbance recording. Coordinate simultaneous recordings made on UPS input and load circuits.
- H. Analysis of Recorded Data and Report: Review and analyze test observations and recorded data and submit a detailed written report. Include the following in [each] report:
1. Description of corrective actions performed during monitoring and survey work and their results.
 2. Recommendations for further action to provide optimum performance by the UPS and appropriate power quality for non-UPS loads. Include a statement of priority ranking and a cost estimate for each recommendation that involves system or equipment revisions.
 3. Copies of monitoring summary graphics and graphics illustrating harmonic content of significant voltages and currents.
 4. Copies of graphics of power disturbance recordings that illustrate findings, conclusions, and recommendations.
 5. Recommendations for operating, adjusting, or revising UPS controls.
 6. Recommendation for alterations to the UPS installation.
 7. Recommendations for adjusting or revising generator-set or automatic transfer switch installations or their controls.
 8. Recommendations for power distribution system revisions.
 9. Recommendations for adjusting or revising electrical loads, their connections, or controls.

Retain paragraph below if multiple test periods are specified.

- I. Interim and Final Reports: Provide an interim report at the end of each test period and a final comprehensive report at the end of final test and analysis period.

3.8 DEMONSTRATION

Retain this article if formal training is required.

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the UPS.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 263353

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SECTION 263533 - POWER FACTOR CORRECTION EQUIPMENT

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes automatic power factor correction equipment rated 600 V and less.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 PERFORMANCE REQUIREMENTS

Retain this article with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design for associated electrical equipment such as motor-control center, switchboard, or switchgear. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Verify requirements of authorities having jurisdiction.

- A. Seismic Performance: Power factor correction equipment shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include[**dimensions, operating characteristics of multiple capacitor cells or elements, and**] data on features, ratings, and performance.

1. Include data substantiating that materials comply with requirements.

- B. Shop Drawings: For automatic power factor correction units.

1. Detail equipment assemblies and indicate dimensions, weights, method of field assembly, components, and location and size of each field connection. Show access and workspace requirements and required clearances.

Retain subparagraph below if equipment includes wiring.

2. Wiring Diagrams: For power, signal, and control wiring. Detail internal and interconnecting wiring and differentiate between manufacturer-installed and field-installed wiring.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified testing agency.

Retain first paragraph below if required by seismic criteria applicable to Project. Coordinate with Sections specifying mechanical vibration, supports, electrical supports, and seismic controls. See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For capacitors, accessories, and components, from manufacturer.

1. Basis of Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1. Indicate and interpret test results for compliance with performance requirements, present written documentation to DEN Project Manager.

D. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For equipment to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

1. Lists of spare parts and replacement components recommended for storage at Project site.
2. Detailed instructions covering operation under both normal and abnormal conditions.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses: **[One (1)]** <Insert number> for every **[three (3)]** <Insert number> of each type and rating, but no fewer than three of each.

1.8 QUALITY ASSURANCE

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

A. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with IEEE 18 and NEMA CP 1.
- D. Comply with NFPA 70.

1.9 COORDINATION

Retain this article if automatic power factor correction units are to be monitored by equipment specified in Section 260913 "Electrical Power Monitoring and Control."

- A. Coordinate sensor-communication module package with data network and with monitoring equipment specified in Section 260913 "Electrical Power Monitoring and Control" for successful transmission and remote readout of remote monitoring data specified in this Section.
- B. Coordinate with all construction trades and equipment manufacturers the location and installation of equipment supplied under this Section.

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

See Editing Instruction No. 6 in the Evaluations for guidance about specifying special warranty.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace capacitor-bank components that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for capacitor cells with manufacturers listed in Part 2 articles.

- 1. Warranty Period: Minimum **[five (5)] <Insert number>** years from date of Substantial Completion.
- B. General Warranty: Special warranty specified in this Article shall not deprive Owner of other rights Owner may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by Contractor under requirements of the Contract Documents.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 CAPACITORS, GENERAL

This article specifies the requirements for each cell and which are common to fixed and automatic capacitor banks.

- A. Comply with UL 810.

Retain first paragraph below if unusual service conditions for this equipment exist and cannot be eliminated. See Editing Instruction No. 2 in the Evaluations for environmental conditions that might be inserted below.

- B. Service Conditions: Capacitor equipment suitable for the following conditions:

1. Operating Temperature: **Minus 30 to plus 120 deg F** (Minus 35 to plus 49 deg C).
2. Maximum Altitude: **5500 feet** (1677 m).
3. Humidity: 0 to 95 percent, noncondensing.
4. **<Insert conditions>**.

- C. Construction: Multiple capacitor cells or elements, factory wired in three-phase groups and mounted in metal enclosures.

Most capacitor cells for power factor correction on low-voltage power systems are type described in first paragraph below, but other types are available. See Editing Instruction No. 3 in the Evaluations.

- D. Cells: Dry metallized-dielectric, self-healing type. Each cell shall be encapsulated in thermosetting resin inside plastic container.

- E. Rupture Protection: Pressure-sensitive circuit interrupter for each cell.

2.2 FIXED CAPACITORS

Retain this article for shunt capacitors that provide a fixed value of reactive power.

- A. Description: Factory wired, ready for field connection to external circuits at a single set of pressure terminals. Comply with UL 810. Integrally fused, unless otherwise indicated.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

B. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. ABB.
2. Aerovox Corp.
3. ARCO Electric Products.
4. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
5. RONK Electrical Industries, Inc.
6. Square D; a brand of Schneider Electric.
7. Staco Energy Products Co.
8. Steelman Industries, Inc.
9. **<Insert manufacturer's name>.**
10. or approved equal.

Coordinate first paragraph below with Drawings. Retain references to fuses if all fixed capacitors are fused.

C. **Fuses:** Current-limiting, noninterchangeable type; factory installed in each phase and located within the equipment enclosure. Features include the following:

1. Interrupting Capacity: 200,000 A
2. Fuse Ratings and Characteristics: As recommended by capacitor manufacturer.
3. Neon Indicator Lamp for Each Fuse: Connect to illuminate when fuse has opened, but is still in place, and locate so it is visible from outside the enclosure.

Retain first paragraph below for factory-installed discharge resistors. See Editing Instruction No. 7 in the Evaluations for conditions when resistors should be installed.

D. **Discharge Resistors:** Factory installed and wired.

Coordinate paragraph below with the Three-Phase Capacitor-Bank Schedule in the Evaluations. See Editing Instruction No. 4 in the Evaluations.

E. **Enclosure:** NEMA 250, steel or aluminum, arranged to contain the fluid leakage from capacitor cells; factory equipped with mounting brackets suitable for type of mounting indicated.

Retain one of three subparagraphs below, or delete all if enclosure type is indicated in the Three-Phase Capacitor-Bank Schedule in the Evaluations. See Editing Instruction No. 2 in the Evaluations for environmental conditions that might be inserted below.

1. Indoor Enclosures: NEMA 250, Type 12 or as indicated.
2. Outdoor Enclosures: NEMA 250, Type 3R or as indicated.
3. Outdoor Enclosures: NEMA 250, Type 4, equipped with watertight conduit connections.

2.3 AUTOMATIC POWER FACTOR CORRECTION UNITS

A. **Description:** Capacitors, contactors, controls, and accessories factory installed in **[independent enclosures] [motor-control center, with a connection to**

motor-control center bus] complying with NEMA ICS 2. Comply with UL 810. Units include a separately mounted current transformer to sense current in the power circuit being corrected and to provide input to unit controls.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- B. **Manufacturers: Subject to compliance with requirements, provide products by one of the following:**
1. ABB.
 2. ARCO Electric Products.
 3. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 4. Square D; a brand of Schneider Electric.
 5. Staco Energy Products Co.
 6. Steelman Industries, Inc.
 7. **<Insert manufacturer's name>.**
 8. or approved equal.
- C. Performance Requirements: Controls permit selection of a target power factor, adjustable to any value between unity and 0.80 lagging. Controls continuously sense the power factor on circuits being corrected and, when the power factor differs from the target setting for more than 10 seconds, operate a contractor to switch a capacitor bank into or out of the circuit. Contactors are opened or closed as required to bring the corrected circuit power factor closer to the target setting. Provide number of switching steps indicated on the Three-Phase Capacitor-Bank Schedule.
- D. Current Transformer: Type, configuration, and ratio to suit sensing and mounting conditions.
- E. Main Circuit Breaker: Thermal-magnetic, inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger. Operable from outside the enclosure to disconnect the unit.
- F. Controls: Solid-state, microprocessor-based controls, including the following:
1. Undervoltage relay that interrupts capacitor switching and disconnects capacitors for power-supply interruptions longer than 15 minutes.
 2. "Advance" and "Retard" push buttons on the control panel to permit manually controlled capacitor-bank switching.
- G. Contactors: Three pole; rated for the repetitive high-inrush-switching duty in the capacitor application.
- For fault-current considerations, see Editing Instruction No. 5 in the Evaluations. Indicate on Drawings maximum fault current at capacitor input terminals.
- H. Fuses for Protection of Capacitor Banks: Rated to protect contactor, interconnecting wiring, and capacitors.

1. Spare-Fuse Cabinet: Identified [**and compartmented steel box**] [**cabinet with hinged lockable door**].

Retain first paragraph below for factory-installed discharge resistors. See Editing Instruction No. 7 in the Evaluations for conditions when resistors should be installed.

- I. Discharge Resistors: Factory installed and wired.

Retain one of first two paragraphs below to limit voltage spikes when switching capacitors on or off line.

- J. Inductors: Air-core type, connected in capacitor circuits; rated to limit switching surges to within contactor ratings.

- K. Precharge Capacitor Circuit: Resistive, precharge circuit to charge capacitors prior to switching and to limit switching surges to within contactor ratings.

- L. Enclosure: NEMA 250, [**Type 1**] [**Type 3R**] [**Type 12**], steel or aluminum, with hinged door and hand-operated catch. Door shall be interlocked with controls or main circuit breaker to de-energize capacitors when door is opened.

1. Factory Finish: Manufacturer's standard enamel over corrosion-resistant treatment or primer coat.

- M. Local Display: LED or liquid-crystal digital type, mounted in door of enclosure, indicating the following:

1. Target and actual power factors accurate to plus or minus 1 percent of reading.
2. Steps energized.
3. Step reconnection delay.
4. Real and reactive currents.
5. Voltage total harmonic distortion.
6. Alarm codes.

- N. System Alarms: Alarm relay and local display indication of the following conditions:

1. Low power factor.
2. Leading power factor.
3. Frequency not detected.
4. Overcurrent.
5. Overvoltage.
6. Overtemperature.
7. Excessive voltage total harmonic distortion.
8. Capacitor overload.
9. Loss of capacitance.

Coordinate paragraph below with Drawings and with Section 260913 "Electrical Power Monitoring and Control." Revise to suit Project and to reflect capability of electrical power monitoring and control system specified.

- O. Remote Monitoring Components: Sensors, associated communication modules, and network interface units, matched to and compatible with electrical power monitoring

and control network. Communication module shall have capability to transmit the following data to remote monitoring devices:

1. System in alarm.
2. Power factor set point.
3. Corrected power factor.
4. Number of capacitor steps activated.

P. Buses: Plated copper.

Q. Mechanical Bracing for Current-Carrying Parts: Adequate to withstand the maximum fault current to which they may be exposed.

2.4 SOURCE QUALITY CONTROL

A. Factory test power factor correction equipment before shipment. Comply with NEMA CP 1. Include the following:

1. Routine capacitor production tests, including short-time overvoltage, capacitance, leak, and dissipation-factor tests.

Retain subparagraph below if specifying an automatic system.

2. Functional test of all operations, controls, indicators, sensors, and protective devices.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install freestanding equipment on concrete bases. Cast-in-place concrete is specified in Section 033000 "Cast-In-Place Concrete."

Retain first paragraph below if seismic criteria apply.

B. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

C. Maintain minimum workspace according to manufacturer's written instructions.

Retain first paragraph below if specifying remote monitoring in Part 2.

D. Connect remote monitoring communication module to electrical power monitoring and control data network through appropriate network interface unit.

E. Tighten bus-assembly joints with torque wrench or similar tool recommended by bus assembly manufacturer. Tighten joints again after bus assemblies have been energized for 30 days.

- F. Identify components according to Section 260553 "Identification for Electrical Systems."

3.2 FIELD QUALITY CONTROL

Retain first or second paragraph below to identify who shall perform tests and inspections. If retaining option, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing. Report results in writing to DEN Project Manager. Include the following:
 - a. Operational Test: After electrical circuits have been energized, connect and observe units to confirm proper operation.
 - b. Replace damaged and malfunctioning controls and equipment.
2. Inspection: Perform external and internal inspections of capacitor equipment for damage and for compliance with the Contract Documents and manufacturer's documentation. Check electrical and mechanical bolted connections for bolt torquing requirements.
3. Inspection of Seismic Controls: Check type, size, quantity, arrangement, and installation of equipment mounting and anchorage devices against requirements indicated in manufacturer's certification.
4. Testing: Perform the following and certify compliance with test parameters:
 - a. Test mounting and anchorage devices according to requirements in Section 260548 "Vibration and Seismic Controls for Electrical Work."
 - b. Test insulation resistance between capacitor terminals and case. Follow manufacturer's written instructions or those below:
 - c. Use test voltages 500 V minimum, for equipment rated 250 V and less, and 1000 V minimum, for equipment rated more than 250 V.
 - d. Apply test voltage for 60 seconds.
 - e. Investigate, report, and resolve insulation resistance less than that stated by manufacturer's literature or less than allowable 25 megohms for equipment rated 250 V and less and 100 megohms for equipment rated more than 250 V.
 - f. Measure capacitance of pole-to-pole capacitor combinations and compare with manufacturer's published values. Report readings, and investigate and

- resolve discrepancies more than 10 percent of manufacturer's nominal values.
- g. Energize circuits and demonstrate electrical operating features of automatic power factor correction units according to manufacturer's written instructions.
 - h. Verify accuracy of remotely monitored parameters transmitted from automatic power factor correction units by communication module.
- 5. Correct deficiencies shown by inspections and tests on site where possible, and retest; otherwise, remove and replace with new units and retest.
 - 6. Report of Tests and Inspections: Written record of test results including adjustment settings shall be submitted to DEN Project Manager.

Retain first paragraph below to describe tests and inspections to be performed.

- C. Tests and Inspections: Perform each visual and mechanical inspection and electrical test stated in the following Sections, except optional tests, in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 1. Current Transformers.
 - 2. Capacitors and Reactors, Capacitors.

3.3 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.
 - 2. Connect and run installed motors and equipment to verify the automatic switching of the capacitors. Verification shall include automatic switching of the total capacity of installed capacitors.

Retain subparagraph below if there is insufficient permanent capacity to fully test automatic operation.

- a. Provide sufficient inductive/reactive load banks, in combination with resistive load banks, for the test.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain automatic power factor correction units.
 - 1. Demonstrate method of determining optimum settings for system controls.
 - 2. Train Owner's maintenance personnel on procedures and schedules for starting up and shutting down, troubleshooting, servicing, and maintaining equipment and schedules.
 - 3. Review data in maintenance manuals in conformance with Division 01.

4. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days' advance notice.
5. Conduct a minimum of two (2) hours' training in conformance with Division 01.

3.5 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.
- B. Clean components internally, on completion of installation, according to manufacturer's written instructions.

3.6 PROTECTION

- A. Provide final protection to ensure that moisture does not enter bus assembly.

3.7 COMMISSIONING

- A. Infrared Scanning: Two (2) months after Substantial Completion, perform an infrared scan of power factor capacitor assemblies.
 1. Use an infrared scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
 2. Perform two (2) follow-up infrared scans of power factor correction equipment, one (1) at four (4) months and the other at eleven (11) months after Substantial Completion.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 263533

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SECTION 263544 - AIRCRAFT GROUND POWER UNITS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Designer of Record (DOR)" Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

DEN PROJECT MANAGER SHALL APPROVE DELETION OF ALL NOTES/COMMENTS FOLLOWING DOR FINAL DESIGN REVIEW.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
- B. Division 26 Technical Specifications.

Retain or delete section references below as applicable to the project. Do not include references to sections that are not included in the project.

- C. Section 055000 – "Metal Fabrications."
- D. Section 147300 - "Over the Wing Passenger Loading Bridges."
- E. Section 147310 - "Apron Drive Passenger Loading Bridges."
- F. Section 147320 - "Radial Drive Passenger Loading Bridges."

1.2 REFERENCE STANDARDS

- A. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents or the Authority Having Jurisdiction.

Insert reference standards as applicable to the Project. Do not relax adherence to the listed standards unless approved in writing by the DEN Project Manager.

- B. SAE ARP-5015: Requirements for Ground Power Equipment that Supplies 115/200V,

3-Phase, 400Hz Output.

- C. SAE ARP-1940: Solid-State Frequency Converters.
- D. NEMA ST-20: Dry-type Transformers for General Applications.
- E. IEEE 127: Aerospace Equipment and Frequency Rating.
- F. IEC 146: Semiconductor Converters.
- G. ISO-1540: Aerospace Characteristics of Aircraft Electrical Systems.
- H. ATA-101: Ground Equipment Technical Data.
- I. NFPA-70: National Electrical Code.
- J. NFPA-415: Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways.
- K. UL 1012: Standard for Power Units Other Than Class 2.

1.3 DEFINITIONS

- A. GPU: Aircraft Ground Power Unit.
- B. PLB: Passenger Loading Bridge.

1.4 SUMMARY

- A. This Section specifies the requirements for manufacture, installation, and testing of 400Hz Aircraft Power Distribution Equipment.
- B. Section Includes:
 - 1. Portable Aircraft Ground Power Units.
 - 2. Fixed (Bridge- or stand-mounted) Aircraft Ground Power Units.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated, include the following
 - 1. Product dimensions and weight.
 - 2. Electrical performance and characteristics.
 - 3. Input power requirements.
 - 4. Output ratings.
 - 5. Finishes and enclosure materials.
 - 6. Operating parameters, limitations, and ambient conditions.

- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Wiring Diagrams: Include basic system architecture, input power connections and protection requirements, output cable connection and rating requirements.
 - 2. Include maintenance requirements and a listing of serviceable internal components.
 - 3. Provide details for all assemblies (cables, rack systems, etc.) and components which are to be field assembled or fabricated.

- C. Coordination Drawings: Provide scaled plans indicating coordinated locations and installation details for each GPU.
 - 1. Include location of each passenger loading bridge and associated GPU.
 - 2. Include wiring details with the loading bridge rotunda control room.
 - 3. Include installation details of GPU output cable, including cable type, quantity of conductors, cable length, installation/connection, and storage.
 - 4. Include details for interface/connection with any related equipment.

1.6 INFORMATIONAL SUBMITTALS

Coordinate requirements with the DEN Project Manager.

- A. Product Certificates: Signed by component manufacturers, certifying that the products furnished comply with project requirements.
- B. Qualification Data: For testing agency.
- C. Source quality-control test reports.
- D. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of GPU to include in emergency, operation, and maintenance manuals.
 - 1. Include complete operation and maintenance manual for equipment.
 - 2. Include any factory corrections made to the supplied equipment upon completion of factory testing.
 - 3. Instruction manual shall include, but not be limited to, the following:
 - a. Calibration data curves, wiring diagrams and other pertinent information on each component.
 - b. Operation procedures for both manual and automatic operation.
 - c. Recommended preventative maintenance procedures and schedules.
 - d. Supplied spare parts list.
 - e. Recommended spare parts list.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Edit list of spare parts below to suit project. Add or delete items, and modify quantities to suit project.

- 1. Control PCB: No fewer than **[one (1)] <insert number>**.
 - 2. Fuse and Output Contactor: No fewer than **[one (1)] <insert number>**.
 - 3. Fans: Equal to **[five (5)] <insert number>** percent of quantity installed for each size and type, but no fewer than **[two (2)] <insert number>** of each size and type.
 - 4. Software: No fewer than **[one (1)] <insert number>** copy of all software provided with the equipment, provided on solid-state media (flash drive).
- B. Provide one set of all special tools required for the installation, operation and maintenance of all equipment furnished and installed under this Section.
 - C. Provide one set of all diagnostic tools, including diagnostic software and hardware toolkit to evaluate the performance parameters of the GPU.
 - D. Provide a list of recommended additional spare parts for the GPU, including price and availability for each listed item.

1.9 QUALITY ASSURANCE

- A. The Contractor shall be fully responsible for daily quality control of installation, coordination with other Trades, and coordination with DEN Maintenance and Engineering.
- B. Manufacturer qualifications:
 - 1. GPU Manufacturer shall have a minimum of 5 years' experience in the design, manufacture, and provision of Ground Power Units for aircraft applications.
 - 2. Manufacturer shall demonstrate at least 5 years' experience supplying and supporting GPU installations at a large hub airport.
- C. Source Limitations: Obtain each GPU type through one source from a single manufacturer.
 - 1. Products shall be manufactured in the United States.
- D. Perform Factory Acceptance Test of each GPU prior to shipment to the Project Site. Submit test results to the DEN Project Manager for review prior to commencement of

installation. Tests shall include, but are not limited to:

1. Input Power: Test unit at full output load and verify input power, and verify that it meets the requirements of this Section.
2. Inrush Current: Demonstrate that the inrush current meets the requirements of this Section.
3. Overload: Demonstrate that overload capability meets the requirements of this Section.
4. Input and Output characteristics: Demonstrate the GPU meets the input and output power characteristics in accordance with the requirements of this Section.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Handle using only lift eyes and provided brackets. Protect equipment in inclement weather.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

1.12 WARRANTY

- A. Provide a manufacturer's warranty, covering all product defects for a term of not less than (2) years from the date of start-up and commissioning.

PART 2 - PRODUCTS

Edit to suit project. Products not used in the project may be omitted from the specification. Add products and accessories as needed.

2.1 GENERAL REQUIREMENTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Cavotec, INET Airport Systems business unit.
 2. Aviation Ground Equipment Corp., Hobart Ground Power business unit.
 3. JBT Aerotech, Inc.
 4. **<Insert manufacturer's name>**.
- B. Certification: UL 1012 Certified.
- C. Conversion technology: Pulse-width modulation.

2.2 PERFORMANCE REQUIREMENTS

A. Input power characteristics:

1. Input Voltage: 415-480 VAC +/- 15%.
2. Phase Rotation: 3-Phase, 3-Wire with no phase dependence.
3. Frequency: 47-63 Hz.
4. Inrush Current: Provide equipment with integral soft start circuiting to limit inrush current to no greater than 100% of rated full-load current.
5. Total system Harmonic Distortion: 5% or less.

B. Output power characteristics:

Select a power rating below, or defer to the construction drawings for power rating specification where multiple ratings are to be installed on the Project.

Consult the Electrical Design Standards Manual for guidance on GPU rating selection. In general, the minimum rating for a mainline gate will be 90kW.

Do not reduce the performance characteristics below without written approval from the DEN Project Manager.

1. Output Voltage: 115/200 Volt, 3-Phase, 4-Wire with grounded neutral.
2. Voltage Regulation: No more than 1% of nominal when operated from no-load condition to full-load condition and from full-load condition to no-load condition.
3. Voltage modulation: No more than 2.5 volts, RMS, at any load from 0% to 100%.
4. Power Rating: **[90 kW] [180 kW] <Insert number> [As indicated on Drawings]**.
5. Load capacity: Full power rating at **[1.0] <insert number>** Power Factor.
6. Frequency: 400 Hz, +/- 1 Hz, constant under all load conditions.
7. Phase Rotation: 3-Phase, 4-Wire, ABC (clockwise) rotation.
8. Adjustability: Output voltage adjustable from **[+0% to +15%] <Insert range>** of nominal voltage.
9. Crest Factor: 1.414, +/- 5%.
10. Harmonic Distortion: No greater than **[1.5%]** measured line-to-line and line-to-neutral, under 100% load at 0.8 Power Factor.

C. Overall equipment efficiency: 93% or greater at full load.

D. Overload Capacity:

1. Unit shall be capable of supporting the following overload conditions:

Overload, percentage of rated output	Minimum Duration of Stable Operation
125%	20 minutes
150%	150 seconds
200%	30 seconds
300%	8 seconds
400%	4 seconds
500%	2 seconds

- E. Provide Line Drop Compensation.
- F. Protection
 - 1. Provide overload and short circuit protection on the GPU output, specifically rated for 400Hz operation, to isolate the aircraft from the GPU in the event of an overload or short circuit.
 - 2. Overload/short-circuit protection shall operate instantaneously (less than ½ cycle), at no less than 500% of rated output.
 - 3. Provide over/under voltage protection on the GPU output to electrically isolate the aircraft from the GPU in an over/under voltage event.
- G. Controls
 - 1. Manual Start/stop: Momentary pushbuttons, located on the control door.
 - 2. Provide circuitry for remote control.
 - 3. Interlock: Provide E and F interlock circuit, which instantaneously isolates the converter output from the aircraft in the absence of a 28VDC control signal from the aircraft. Provide indicator LED inside the control compartment displaying interlock status.
 - 4. Bypass Switch: Provide aircraft bypass switch for testing purposes to allow operation in the absence of a 28VDC control signal.
- H. Measurement and Verification
 - 1. Provide TCP/IP connection point for Energy Management Control System (EMCS) integration.
 - a. EMCS Protocol: BACNet.
 - b. Data availability:
 - 1) Emergency Stop.
 - 2) Converter Enable/Disable.
 - 3) GPU ON.
 - 4) GPU OFF.
 - 5) Power Available.
 - 6) Summary Fault.
 - 7) E/F signal present.
 - 8) Power Logic Supply Voltage.
 - 9) 90 percent Cable Inserted.
 - 10) Phase Voltage (volts).
 - 11) Line Voltage (volts).
 - 12) Phase Current (amps).
 - 13) Frequency (Hz).
 - 14) Power Factor per phase (pF).
 - 15) System Power Factor (pF).
 - 16) Kilowatts (kW).
 - 17) Kilo-volt-amps (kVA).
 - 18) Neutral Current.
 - 19) Runtime (hours).

2. Elapsed Time Meter: Non-resettable, 0 to 99,999 hours.
 3. Diagnostic Information: GPU shall have integral diagnostics of all vital functionality, including internal components and external cable monitoring. Include an alarm messaging system and an onboard event log that is capable of export via local USB or Ethernet connection.
- I. Noise level: No greater than 65 dBA at a distance of 2 meters.
 - J. Design service life: Not less than 10 years.
 - K. Environmental Conditions
 1. Ambient Temperature Range: -20° F to 140° F.
 2. Humidity: 10% to 100%.
 3. Altitude: 5,500 Feet.
 4. Design Wind Load: 100 MPH.

2.3 PORTABLE GROUND POWER UNITS

Select applicable power source below.

For diesel-powered units, either utilize the DEN-standard generator specification and edit as needed, or add engine, performance, and testing requirements in this section.

- A. Power source: [**Portable cord and plug connection**] [**Onboard diesel generator set**]
 1. Include integral fuel tank with at least [**6 hours**] [**12 hours**] <Insert time> of fuel capacity.
 2. Diesel engine shall be provided with EPA Tier IV emissions controls and comply with all applicable requirements.
- B. Unit mounting: Trailer.
 1. Hitch type: Standard Class III, 2" Ball.
 2. Weight distribution: Comply with Class III tow rating requirements for a standard vehicle
 3. Trailer weight rating: Sufficient for fully-fueled unit, plus all accessories.
 4. Trailer safety factor: 1.8:1, minimum.

Insert cable requirements for input power, if cord-and-plug connected, as well as output cables.

- C. Cabling
 1. <Insert requirements>

2.4 PLB-MOUNTED GROUND POWER UNITS

- A. GPUs shall be designed for installation in a suspended configuration under a passenger loading bridge.

- B. Provide all installation hardware, mounting brackets, and accessories as required to properly secure the unit to the passenger loading bridge.

Insert requirements for input cable as applicable to the project (pantograph system, cable jacket construction, environmental conditions, etc).

C. Input Cable:

1. Provide bundled, UL type STOW severe-service portable cord for use in pantograph system.
2. All cables that are exposed shall be UV stabilized.
3. Cable length: As required to connect to the power distribution box at the rotunda. Provide sufficient slack at each end of the cable to allow full freedom of movement of the bridge in rotation, height, and extension.
4. **<Insert requirements>**.

Insert cable requirements for output cable. Include any specific cord retraction/storage systems needed for the Project.

Ensure that cable length is specified on the drawings or in the specification to allow for connection to all aircraft types planned in the Project.

D. Output Cabling:

1. Supply output cable that complies with the requirements of Paragraph "CABLE SYSTEMS" below.
2. Provide a cord retraction/storage system to store the output cable when not in use.
3. **<Insert requirements>**

2.5 FIXED, STAND-MOUNTED GROUND POWER UNITS

- A. Fixed, stand-mounted GPUs shall be designed for installation on a fixed stand.
- B. Provide all installation hardware, mounting brackets, and accessories as required to properly secure the unit to the stand.
- C. Coordinate installation location to provide required working clearances about the equipment.

2.6 CABLE SYSTEMS

A. General output cable assembly requirements:

1. Nominal Voltage: U_0/U 115/200V, 400Hz.
2. Test Voltage: 4000 VAC, 50 Hz.
3. Current Overload: 700A / 3 min.

B. 400Hz Output Cable:

1. Highly flexible, twisted with double insulated TPE/PUR.
2. Power conductors: Tinned fine copper strands, VDE 0295, IEC 60228, class-6.
3. Insulation: Polyolefin Copolymer Double insulation.
4. Color: Grey, with numbers printed in Black.
5. Outer Sheath: Abrasion-resistant polyurethane (PUR).
6. Operation Temperature: 72° F to 162° F.
7. Material Properties:
 - a. Halogen Free: IEC 60754-1, EN 50267-2-1 (less than 5mg/g).
 - b. Non-corrosive gases: IEC 60754-2, EN 50267-2-2 (pH less than 5).
 - c. Low Toxic gases: NEC 02-713, NFC 20-454.
 - d. Oil Resistance: EN 60811-2-1 (24 h / 210°F).
 - e. Abrasion resistant.
 - f. UV Resistant.
 - g. Flame Retardant: IEC 60332-1, EN 50265-1f.

C. 400Hz Aircraft Connector:

1. VG 95319, ISO 461, MS 25486.
2. UV resistant, oil resistant, microbe and hydrolysis resistant.
3. Operating temperature range: -85 degrees F to 250 degrees F.
4. Control buttons: 4 (ON/OFF/Reel In/Reel Out).
5. Housing: Cross-linked thermoplastic, abrasion, and chemical resistant, field-replaceable.
6. Ends: Field-replaceable.
7. Contacts: Silver-plated, copper-tellurium alloy, field-replaceable.
8. All contacts shall be sealed with waterproof resin.
9. Push-pull forces: Comply with DIN EN 61984 (\leq 100 lbf).
10. Micro-switch signals contact closed when connector is at least 80% inserted.
11. Micro-switch: Maximum 30VDC, 100mA.

PART 3 - EXECUTION

3.1 DELIVERY, STORAGE AND HANDLING

- A. The GPUs shall be contained in a dust- and moisture-resistant container and shall be adequately packaged to ensure protection from damage and weather exposure during transit.
- B. Packaging shall be labeled to clearly identify each component without opening the package. Items not fully assembled to the unit shall be shipped separately.
- C. Adequate means shall be provided for lifting by forklifts and cranes and for moving the equipment on rollers. Lift points shall be clearly marked. Handle equipment according to manufacturer's written instructions.
- D. Touch up any damage for equipment finishes to match adjacent surfaces.

- E. Equipment shall be transported, unloaded, handled, stored, and installed in accordance with manufacturer's written instructions.

3.2 INSTALLATION

Include any special requirements for installation associated with the Project.

A. General

1. All equipment, wiring, and installation shall be in accordance with current applicable codes and industry standards.
2. Packaged GPUs shall be delivered to the site completely assembled and tested.
3. The electrical contractor shall make final electrical connections from the GPU to the power source.

B. PLB-mount GPU

1. Install fixed GPU using mounting brackets listed and rated for the purpose.
2. Installation of the GPU shall not block or inhibit access to any other bridge equipment.
3. Provide high intensity, 4-inch wide, striped red and yellow prismatic reflective warning tape applied to ALL sides of the equipment along the bottom edge for all GPUs mounted on the underside of PLB

C. Stand-mount GPU

1. Install stand-mount GPU using a stand and associated brackets listed and rated for the purpose.
2. . Provide bollards or guard rail for protection. See Section 0550000 "Metal Fabrications" for requirements. Contractor shall coordinate installation of Protection systems so as not to impede working clearances of GPU.

D. Cabling

1. Install input cable for bridge-mounted GPU according to the PLB manufacturer's written instructions. Make all final connections to the GPU.
2. Install output cable, including cord reel/storage system, according to manufacturer's instructions. Make all final connections to the GPU.

E. Miscellaneous

1. Provide equipment labels in accordance with Section 260553, Identification for Electrical Systems.
 - a. Label shall include source of supply (panel name and circuit number), operating voltage, and kVA rating of the GPU.

3.3 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, and to assist in acceptance testing.
 - 2. Verify that equipment and fitting are properly installed, connected, and labelled.
- B. Field Acceptance Testing:
 - 1. Upon completion of installation, perform functional test of the GPU. Include the following:
 - a. Test performance at full load for at least 2 hours, using a load bank.
 - b. Test all protective devices.
 - c. Measure performance parameters including input current, output voltage, output current, harmonic distortion, and output frequency.
 - 2. Provide test results to the DEN Project Manager.

3.4 PROTECTION

- A. Protect GPUs and facilities against damage, mechanical or otherwise and provide maintenance of the equipment until issuance of the certificate of Final Completion. The GPUs shall be kept clean, dry, and protected at all times.

3.5 DEMONSTRATION AND TRAINING

- A. The contractor shall provide start-up of the GPU after installation and conduct on-site operational training.
- B. Engage a Factory-Authorized service representative to conduct training of Owner's maintenance personnel.
 - 1. Provide training for all procedures, maintenance schedules, and service intervals.
 - 2. Review equipment list and data in maintenance manuals.
 - 3. Conduct a minimum of 12 hours of owner training in three sessions: 4 hours each for three work shifts, to be scheduled at times coinciding with the applicable work shifts. Each training session shall be attended by at least 3 representatives from DEN Technical Maintenance, and the DEN Project Manager or their designee.
 - 4. Provide a video recording of all training sessions in accordance with Section 013233 "Photographic Documentation."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this section.

END OF SECTION 263544

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SECTION 263600 - TRANSFER SWITCHES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes transfer switches rated 600 V and less, including the following:
 - 1. Automatic transfer switches.
 - 2. Bypass/isolation switches.
 - 3. Remote annunciation systems.
 - 4. Remote annunciation and control systems.
- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 213113 "Electric-Drive, Centrifugal Fire Pumps" for automatic transfer switches for fire pumps.
- 2. Section 213213 "Electric-Drive, Vertical-Turbine Fire Pumps" for automatic transfer switches for fire pumps.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, weights, operating characteristics, furnished specialties, and accessories.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Dimensioned plans, elevations, sections, and details showing minimum clearances, conductor entry provisions, gutter space, installed features and devices, and material lists for each switch specified.

Retain subparagraph below if retaining Part 2 "Bypass/Isolation Switches" Article.

- 1. Single-Line Diagram: Show connections between transfer switch, bypass/isolation switch, power sources, and load; and show interlocking provisions for each combined transfer switch and bypass/isolation switch.

1.4 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For **[manufacturer] [and] [testing agency]**.

Retain paragraph and subparagraphs below if required by seismic criteria applicable to Project. Coordinate with Section 260548.16 "Seismic Controls for Electrical Systems."

- B. Manufacturer Seismic Qualification Certification: Submit certification that transfer switches accessories, and components will withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Retain one of first two subparagraphs below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Second definition is used for essential facilities where equipment must operate immediately after an earthquake.

- a. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

- b. The term "withstand" means, "The unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of product to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 1. Features and operating sequences, both automatic and manual.
 2. List of all factory settings of relays; provide relay-setting and calibration instructions, including software, where applicable.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Manufacturer Qualifications: Maintain a service center capable of providing training, parts, and emergency maintenance repairs within a response period of less than eight hours from time of notification.

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, use first paragraph below to specify 29 CFR 1910.7 or other more specific criteria (e.g., NETA). 29 CFR 1910.7 defines a nationally recognized testing laboratory as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that meet certain OSHA criteria.

Retain first paragraph and associated subparagraph below if Contractor selects testing agency.

- B. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing

laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

1. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.
- C. Source Limitations: Obtain **[automatic transfer switches] [bypass/isolation switches] [nonautomatic transfer switches] [remote annunciators] [and] [remote annunciator and control panels]** through one source from a single manufacturer.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Comply with NEMA ICS 1.
- F. Comply with NFPA 70.

Retain one or both of first two paragraphs below if applicable to Project.

- G. Comply with NFPA 99.
- H. Comply with NFPA 110.
- I. Comply with UL 1008 unless requirements of these Specifications are stricter.

1.7 PROJECT CONDITIONS

Retain this article if interruption of existing electrical service is required.

- A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service:
1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering.
 2. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 3. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.
- B. Service Conditions:
1. Temperature: minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).
 2. Altitude: 5,500 feet.

1.8 COORDINATION

Retain this article for floor-mounting equipment.

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 033000 "Cast-in-Place Concrete."

1.9 AUTOMATIC SEQUENCE OF OPERATION

- A. Initiate adjustable Time Delay (1 to 6 seconds) set at 1 second to Engine start upon loss of normal source. If normal source returns before time delay times out no action will be taken. If normal source power fails to return before the time delay times out, a start signal will be sent to the emergency engine generator.
- B. After the emergency engine generator is started, an adjustable time delay (0 to 5 minutes) set at 0 seconds, will start timing. If normal power returns during the timing of this time delay no action will be taken, and the engine generator will continue to run unloaded until the adjustable cool down time delay expires. If the commit to transfer is enabled, the switch will transfer to emergency even if normal power returns before the adjustable transfer to emergency time delay times out.
- C. If the Automatic transfer switch transfers to emergency power, the transfer switch will monitor the normal source side to see when normal power returns. When normal power returns an adjustable (0 to 30 minutes) time delay set at 20 minutes, starts timing out before re-transfer back to the normal power source. If during the timing of this time delay normal power is lost, the timer will be reset when normal power returns. If the emergency generator fails during this time delay and normal power is available the automatic transfer switch must transfer back to normal. Otherwise normal power must be available for the full duration of the time delay.
- D. After the automatic transfer switch transfers back to normal, an adjustable engine cool down timer (0 to 60 minutes) set at 10 minutes, will start timing. This allows the engine to run unloaded to cool down before shutting the engine down. If normal power fails during this time the automatic transfer switch will transfer to emergency after the transfer to emergency time delay times out and then resets all other time delays. If there is no failure of the normal power source during the cool down timer, the emergency engine generator set will shut down and the transfer switch is set for the next normal source power failure.
- E. An in-phase monitor or a synchronizer should be used when transferring in either direction when both sources are available to prevent excessive inrush currents due to out-of-phase switching of large inductive loads.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.10 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Contactor Transfer Switches:
 - a. [AC Data Systems, Inc.](#)
 - b. [Caterpillar; Engine Div.](#)
 - c. [Emerson; ASCO Power Technologies, LP.](#)
 - d. [Generac Power Systems, Inc.](#)
 - e. [GE Zenith Controls.](#)
 - f. [Kohler Power Systems; Generator Division.](#)
 - g. [Onan/Cummins Power Generation; Industrial Business Group.](#)
 - h. [Russelectric, Inc.](#)
 - i. [Spectrum Detroit Diesel.](#)
 - j. **<Insert manufacturer's name>.**
 - k. or approved equal.
 2. Transfer Switches Using Molded-Case Switches or Circuit Breakers:
 - a. [AC Data Systems, Inc.](#)
 - b. [Eaton Electrical Inc.; Cutler-Hammer.](#)
 - c. [GE Zenith Controls.](#)
 - d. [Hubbell Industrial Controls, Inc.](#)
 - e. [Lake Shore Electric Corporation.](#)
 - f. **<Insert manufacturer's name>.**
 - g. or approved equal.

2.2 GENERAL TRANSFER-SWITCH PRODUCT REQUIREMENTS

Coordinate paragraph below with Drawings and indicate percentage of tungsten filament lamp load for switches where it exceeds 30 percent. This percentage may affect switch selection. Some manufacturers' ratings for some switch lines apply to all classes of load, including tungsten lamps.

- A. Furnish and install automatic transfer and bypass-isolation switch (ATS/BPS) system. Each system shall be of one manufacturer and shall consist of two elements: an automatic transfer switch and a two-way bypass-isolation switch. The Automatic Transfer Switch will be mechanically held electrically operated. The Bypass Switch will be mechanically held. Mechanical interlock will be provided to prevent the simultaneous closing to both the emergency and normal sources.
1. Adjustable time delay to override momentary normal source outages to delay engine-starting signal. (0 to 6 seconds) set at 1 second.
 2. Adjustable time delay on transfer to emergency (0 to 5 minutes) set at 0 seconds.
 3. Adjustable re-transfer to normal time delay (0 to 30 minutes) set at 20 minutes.
 4. Adjustable unloaded engine cool down time delay (0 to 60 minutes) set at 10 minutes.
 5. Close differential voltage monitoring on the normal source with adjustable pickup from 85 to 100% of 208 Volts. And also an adjustable dropout voltage from 75 to 98% of the pickup setting.
 6. Single phase voltage sensing of the emergency source with pickup adjustable from 85 to 100% (and dropout fixed at 84 to 86% of pickup), and frequency sensing with pickup adjustable from 90 to 100% (and dropout fixed at 87 to 89% of pickup).
 7. Test switch mounted in cabinet.
 8. A set of DPDT gold-flashed contacts rated 10 amps, 32VDC shall be provided for a low-voltage engine start signal.
 - a. The start signal shall prevent dry cranking of the generator by requiring the generator to reach proper output, and to run for the duration of the cool down setting regardless of whether the source restores before the load is transferred.
 - b. Provide a "commit/no commit to transfer" selector switch to select whether the load should be transferred to the emergency generator if the normal source restores before the generator is ready to accept the load.
 9. Normal and emergency position indicating LED's (green - normal, red emergency).
 10. Auxiliary contacts; (2) normally open and (2) normally closed for each position, rated at 10 amps, at 480 VAC.
 11. In-Phase monitor with synchronizer connected between the engine and normal source.
 12. A visual position indicator shall be provided to indicate Bypass-Isolation switch position. Pilot lights shall indicate availability of power sources and automatic transfer switch position. A prominent and detailed instruction plate shall be furnished to shall bypass-isolation procedures.

- B. The Automatic Transfer Switch side of the Bypass-Isolation Automatic Transfer Switch shall automatically transfer the load to a second utility source or the emergency standby generator in the event of a normal source failure.
- C. The transfer switch shall consist of completely enclosed contact assemblies and a separate control logic panel. A non-fused unidirectional motor operator or electric operated solenoid shall operate the contact assemblies with stored energy mechanisms. and be energized only momentarily during transfer providing inherently double throw switching action. Control power for all transfer operations shall be derived From the line side of the source to which the load is being transferred.
- D. The Bypass-Isolation switch part of the automatic transfer switch shall be capable of being operated manually under full load conditions. Manual operation shall be accomplished via a permanently affixed manual operator or integrally mounted push button operator located on the face of the contact assemblies. Removable manual operating handles and handles which move in the event electrical operators should suddenly become energized while performing a manual transfer operation shall not be used acceptable. The manual operator shall provide the same contact-to-contact transfer time as provided under automatic operation to prevent possible flashers from switching the main contacts slowly. In addition, provisions shall be provided to allow disconnection of the electrical operator during manual operation.
- E. Inspection and replacement of all separate arcing contacts and main current carrying contacts shall be possible from the front of the transfer switch.
- F. The control module shall direct the operation of the transfer switch. The module's sensing and logic shall be controlled by a built-in solid state or microprocessor control module for maximum reliability, minimum maintenance, and inherent digital communications capability. The control module shall be connected to the transfer switch by an interconnecting wiring harness. The harness shall include a keyed disconnect plug to enable the control module to be disconnected from the transfer switch for routine maintenance.
- G. The control module shall be completely enclosed with a protective cover and be mounted separately from the transfer switch unit for safety and ease of maintenance. Sensing and control logic shall be provided on plug-in printed circuit boards for maximum reliability. Interfacing relays shall be industrial control grade plug-in type with dust covers, rated 10 Amperes with self-cleaning contacts. All relays shall be identical to minimize the number of unique parts.
- H. The control panel shall meet or exceed the impulse withstand voltage test in accordance with the proposed NEMA Standard ICS 1-109.
- I. Indicated Current Ratings: Apply as defined in UL 1008 for continuous loading and total system transfer, including tungsten filament lamp loads not exceeding 30 percent of switch ampere rating, unless otherwise indicated.

Indicate required ratings on Drawings. See Editing Instruction No. 3 in the Evaluations.

- J. Tested Fault-Current Closing and Withstand Ratings: Adequate for duty imposed by protective devices at installation locations in Project under the fault conditions indicated, based on testing according to UL 1008.

Retain subparagraph below if this Section includes automatic transfer switches based on molded-case-switch or circuit-breaker products or if design includes fault-current protection internal to transfer switch.

1. Where transfer switch includes internal fault-current protection, rating of switch and trip unit combination shall exceed indicated fault-current value at installation location.
- K. Solid-State Controls: Repetitive accuracy of all settings shall be plus or minus 2 percent or better over an operating temperature range of minus 20 to plus 70 deg C.
- L. Resistance to Damage by Voltage Transients: Components shall meet or exceed voltage-surge withstand capability requirements when tested according to IEEE C62.41. Components shall meet or exceed voltage-impulse withstand test of NEMA ICS 1.
- M. Electrical Operation: Accomplish by a nonfused, momentarily energized solenoid or electric-motor-operated mechanism, mechanically and electrically interlocked in both directions.
- N. Switch Characteristics: Designed for continuous-duty repetitive transfer of full-rated current between active power sources.

Delete first subparagraph below if units using switching components designed for molded-case switches or insulated-case circuit breakers are permissible.

1. Limitation: Switches using molded-case switches or circuit breakers or insulated-case circuit-breaker components are not acceptable.
2. Switch Action: Double throw; mechanically held in both directions.
3. Contacts: Silver composition or silver alloy for load-current switching. Conventional automatic transfer-switch units, rated 225 A and higher, shall have separate arcing contacts.

Retain paragraph below and select appropriate option if four-pole transfer switches are required. See Editing Instruction No. 4 in the Evaluations. Coordinate with Drawings.

- O. Neutral Switching. Where four-pole switches are indicated, provide **[neutral pole switched simultaneously with phase poles] [overlapping neutral contacts]**.

Retain paragraph below for single-phase, three-wire systems or three-phase, four-wire systems without neutral switching. Coordinate with Drawings.

- P. Neutral Terminal: Solid and fully rated, unless otherwise indicated.

Retain paragraph below if required for heavy nonlinear loads. This requirement may result in some suppliers' oversizing certain switches to provide an oversize neutral. Coordinate with Drawings.

- Q. Oversize Neutral: Ampacity and switch rating of neutral path through units indicated for oversize neutral shall be double the nominal rating of circuit in which switch is installed.

Retain paragraph below if one or more switches are exposed to outdoor temperatures and humidity. Coordinate with Drawings.

- R. Heater: Equip switches exposed to outdoor temperatures and humidity, and other units indicated, with an internal heater. Provide thermostat within enclosure to control heater.

Retain paragraph and subparagraphs below if charger for generator starting batteries is to be located in transfer switch. Select first option in first subparagraph for same generator units; consider second option for units 250 kW and larger.

- S. Battery Charger: For generator starting batteries.
1. Float type rated [2] [10] A.
 2. Ammeter to display charging current.
 3. Fused ac inputs and dc outputs.

Retain first paragraph below if required. Coordinate with Drawings.

- T. Annunciation, Control, and Programming Interface Components: Devices at transfer switches for communicating with remote programming devices, annunciators, or annunciator and control panels shall have communication capability matched with remote device.
- U. Factory Wiring: Train and bundle factory wiring and label, consistent with Shop Drawings, either by color-code or by numbered or lettered wire and cable tape markers at terminations. Color-coding and wire and cable tape markers are specified in Section 260553 "Identification for Electrical Systems."
1. Designated Terminals: Pressure type, suitable for types and sizes of field wiring indicated.
 2. Power-Terminal Arrangement and Field-Wiring Space: Suitable for top, side, or bottom entrance of feeder conductors as indicated.
 3. Control Wiring: Equipped with lugs suitable for connection to terminal strips.

Use NEMA 250, Type 12 enclosure if environment is generally dusty.

- V. Enclosures: General-purpose NEMA 250, Type [1] [3R] [12], complying with NEMA ICS 6 and UL 508, unless otherwise indicated.
- W. The transfer switch shall consist of completely enclosed contact assemblies and a separate control logic panel. A non-fused unidirectional motor operator or electric operated solenoid shall operate the contact assemblies with stored energy mechanisms. and be energized only momentarily during transfer providing inherently double throw switching action. Control power for all transfer operations shall be derived from the line side of the source to which the load is being transferred.

- X. The Bypass-Isolation switch part of the automatic transfer switch shall be capable of being operated manually under full load conditions. Manual operation shall be accomplished via a permanently affixed manual operator or integrally mounted push button operator located on the face of the contact assemblies. Removable manual operating handles and handles which move in the event electrical operators should suddenly become energized while performing a manual transfer operation shall not be used acceptable. The manual operator shall provide the same contact-to-contact transfer time as provided under automatic operation to prevent possible flashers from switching the main contacts slowly. In addition, provisions shall be provided to allow disconnection of the electrical operator during manual operation.
- Y. Inspection and replacement of all separate arcing contacts and main current carrying contacts shall be possible from the front of the transfer switch.
- Z. The control module shall direct the operation of the transfer switch. The module's sensing and logic shall be controlled by a built-in solid state or microprocessor control module for maximum reliability, minimum maintenance, and inherent digital communications capability. The control module shall be connected to the transfer switch by an interconnecting wiring harness. The harness shall include a keyed disconnect plug to enable the control module to be disconnected from the transfer switch for routine maintenance.
- AA. The control module shall be completely enclosed with a protective cover and be mounted separately from the transfer switch unit for safety and ease of maintenance. Sensing and control logic shall be provided on plug-in printed circuit boards for maximum reliability. Interfacing relays shall be industrial control grade plug-in type with dust covers, rated 10 Amperes with self-cleaning contacts. All relays shall be identical to minimize the number of unique parts.
- BB. The control panel shall meet or exceed the impulse withstand voltage test in accordance with the proposed NEMA Standard ICS 1-109.

2.3 AUTOMATIC TRANSFER SWITCHES

- A. Comply with Level 1 equipment according to NFPA 110.
- B. Switching Arrangement: Double-throw type, incapable of pauses or intermediate position stops during normal functioning, unless otherwise indicated.

Retain one of two paragraphs below. First is optional feature with some manufacturers.

- C. Manual Switch Operation: Under load, with door closed and with either or both sources energized. Transfer time is same as for electrical operation. Control circuit automatically disconnects from electrical operator during manual operation.
- D. Manual Switch Operation: Unloaded. Control circuit automatically disconnects from electrical operator during manual operation.

Retain paragraph below if required for control to minimize elevator disruption or for other purposes.

- E. Signal-Before-Transfer Contacts: A set of normally open/normally closed dry contacts operates in advance of retransfer to normal source. Interval is adjustable from 1 to 30 seconds.

Retain paragraph below if digital communication system is used for remote annunciation or for remote annunciation and control.

- F. Digital Communication Interface: Matched to capability of remote annunciator or annunciator and control panel.

Retain paragraph below if transfer switches based on molded-case-switch or circuit-breaker components are acceptable for Project.

- G. Transfer Switches Based on Molded-Case-Switch Components: Comply with NEMA AB 1, UL 489, and UL 869A.

Retain paragraph and subparagraphs below for loads intolerant of interruptions or for switching large-motor loads. Coordinate with remainder of this Article and with Drawings. See Editing Instruction No. 5 in the Evaluations.

- H. Automatic Closed-Transition Transfer Switches: Include the following functions and characteristics:
1. Fully automatic make-before-break operation.
 2. Load transfer without interruption, through momentary interconnection of both power sources not exceeding 100 ms.
 3. Initiation of No-Interruption Transfer: Controlled by in-phase monitor and sensors confirming both sources are present and acceptable.
 - a. Initiation occurs without active control of generator.
 - b. Controls ensure that closed-transition load transfer closure occurs only when the 2 sources are within plus or minus 5 electrical degrees maximum, and plus or minus 5 percent maximum voltage difference.
 4. Failure of power source serving load initiates automatic break-before-make transfer.

Edit paragraph and subparagraphs below to coordinate terminology for sources, such as "normal," "preferred," "emergency," and "alternate," if such terms are used elsewhere in the Construction Documents.

- I. Automatic Transfer-Switch Features:

Revise pickup, dropout, and time-delay settings in first four subparagraphs below to suit application, and retain required features.

First subparagraph specifies three-phase undervoltage monitor. Retain if loss of one phase of normal source would be a problem for loads downstream from transfer switch. Similar option is available for emergency source.

1. Undervoltage Sensing for Each Phase of Normal Source: Sense low phase-to-ground voltage on each phase. Pickup voltage shall be adjustable from

- 85 to 100 percent of nominal, and dropout voltage is adjustable from 75 to 98 percent of pickup value. Factory set for pickup at 90 percent and dropout at 85 percent.
2. Adjustable Time Delay: For override of normal-source voltage sensing to delay transfer and engine start signals. Adjustable from zero to six seconds, and factory set for one second.
 3. Voltage/Frequency Lockout Relay: Prevent premature transfer to generator. Pickup voltage shall be adjustable from 85 to 100 percent of nominal. Factory set for pickup at 90 percent. Pickup frequency shall be adjustable from 90 to 100 percent of nominal. Factory set for pickup at 95 percent.
 4. Time Delay for Retransfer to Normal Source: Adjustable from 0 to 30 minutes, and factory set for 10 minutes to automatically defeat delay on loss of voltage or sustained undervoltage of emergency source, provided normal supply has been restored.
 5. Test Switch: Simulate normal-source failure.
 6. Switch-Position Pilot Lights: Indicate source to which load is connected.
 7. Source-Available Indicating Lights: Supervise sources via transfer-switch normal- and emergency-source sensing circuits.
 - a. Normal Power Supervision: Green light with nameplate engraved "Normal Source Available."
 - b. Emergency Power Supervision: Red light with nameplate engraved "Emergency Source Available."
 8. Unassigned Auxiliary Contacts: Two normally open, single-pole, double-throw contacts for each switch position, rated 10 A at 240-V ac.
 9. Transfer Override Switch: Overrides automatic retransfer control so automatic transfer switch will remain connected to emergency power source regardless of condition of normal source. Pilot light indicates override status.

Retain subparagraph below if needed to coordinate with engine generator. Do not duplicate control features furnished with generator. See Editing Instruction No. 6 in the Evaluations.

10. Engine Starting Contacts: One isolated and normally closed, and one isolated and normally open; rated 10 A at 32-V dc minimum.

Retain one of first two subparagraphs below.

11. Engine Shutdown Contacts: Instantaneous; shall initiate shutdown sequence at remote engine-generator controls after retransfer of load to normal source.
12. Engine Shutdown Contacts: Time delay adjustable from zero to five minutes, and factory set for five minutes. Contacts shall initiate shutdown at remote engine-generator controls after retransfer of load to normal source.
13. Engine-Generator Exerciser: Solid-state, programmable-time switch starts engine generator and transfers load to it from normal source for a preset time, then retransfers and shuts down engine after a preset cool-down period. Initiates exercise cycle at preset intervals adjustable from 7 to 30 days. Running periods are adjustable from 10 to 30 minutes. Factory settings are for 7-day exercise cycle, 20-minute running period, and 5-minute cool-down period. Exerciser features include the following:

- a. Exerciser Transfer Selector Switch: Permits selection of exercise with and without load transfer.
- b. Push-button programming control with digital display of settings.
- c. Integral battery operation of time switch when normal control power is not available.

2.4 BYPASS/ISOLATION SWITCHES

- A. Comply with requirements for Level 1 equipment according to NFPA 110.
- B. Description: Manual type, arranged to select and connect either source of power directly to load, isolating transfer switch from load and from both power sources. Include the following features for each combined automatic transfer switch and bypass/isolation switch:
 1. Means to lock bypass/isolation switch in the position that isolates transfer switch with an arrangement that permits complete electrical testing of transfer switch while isolated. While isolated, interlocks prevent transfer-switch operation, except for testing or maintenance.
 2. Drawout Arrangement for Transfer Switch: Provide physical separation from live parts and accessibility for testing and maintenance operations.
 3. Bypass/Isolation Switch Current, Voltage, Closing, and Short-Circuit Withstand Ratings: Equal to or greater than those of associated automatic transfer switch, and with same phase arrangement and number of poles.
 4. Contact temperatures of bypass/isolation switches shall not exceed those of automatic transfer-switch contacts when they are carrying rated load.
 5. Operability: Constructed so load bypass and transfer-switch isolation can be performed by 1 person in no more than 2 operations in 15 seconds or less.
 6. Legend: Manufacturer's standard legend for control labels and instruction signs shall describe operating instructions.
 7. Maintainability: Fabricate to allow convenient removal of major components from front without removing other parts or main power conductors.
- C. Interconnection of Bypass/Isolation Switches with Automatic Transfer Switches: Factory-installed copper bus bars; plated at connection points and braced for the indicated available short-circuit current. The only field-installed power connections shall be at the service and load terminals of the bypass-isolation switch. All control interwiring shall be provided with disconnect plugs.

Delete one or both of first two articles below. Coordinate location of equipment and wiring with Drawings. Coordinate with transfer-switch description and with Section 263213 "Engine Generators." Edit retained article to specify required system features and functions. See Editing Instruction No. 2 in the Evaluations.

2.5 REMOTE ANNUNCIATOR SYSTEM

- A. Functional Description: Remote annunciator panel shall annunciate conditions for indicated transfer switches. Annunciation shall include the following:

1. Sources available, as defined by actual pickup and dropout settings of transfer-switch controls.
2. Switch position.
3. Switch in test mode.
4. Failure of communication link.

B. Annunciator Panel: LED-lamp type with audible signal and silencing switch.

1. Indicating Lights: Grouped for each transfer switch monitored.
2. Label each group, indicating transfer switch it monitors, location of switch, and identity of load it serves.
3. Mounting: Flush, modular, steel cabinet, unless otherwise indicated.
4. Lamp Test: Push-to-test or lamp-test switch on front panel.

2.6 REMOTE ANNUNCIATOR AND CONTROL SYSTEM

A. Functional Description: Include the following functions for indicated transfer switches:

1. Indication of sources available, as defined by actual pickup and dropout settings of transfer-switch controls.
2. Indication of switch position.
3. Indication of switch in test mode.
4. Indication of failure of digital communication link.
5. Key-switch or user-code access to control functions of panel.
6. Control of switch-test initiation.

Delete one or both subparagraphs below.

7. Control of switch operation in either direction.

Retain first paragraph below with any combination of functions in subparagraphs above.

B. Malfunction of annunciator, annunciation and control panel, or communication link shall not affect functions of automatic transfer switch. In the event of failure of communication link, automatic transfer switch automatically reverts to stand-alone, self-contained operation. Automatic transfer-switch sensing, controlling, or operating function shall not depend on remote panel for proper operation.

C. Remote Annunciation and Control Panel: Solid-state components. Include the following features:

1. Controls and indicating lights grouped together for each transfer switch.
2. Label each indicating light control group. Indicate transfer switch it controls, location of switch, and load it serves.
3. Digital Communication Capability: Matched to that of transfer switches supervised.

Coordinate description in subparagraph below with floor plan representation and details on Drawings.

4. Mounting: Flush, modular, steel cabinet, unless otherwise indicated.

2.7 SOURCE QUALITY CONTROL

- A. Factory test and inspect components, assembled switches, and associated equipment. Ensure proper operation. Check transfer time and voltage, frequency, and time-delay settings for compliance with specified requirements. Perform dielectric strength test complying with NEMA ICS 1.

PART 3 - EXECUTION

3.1 INSTALLATION

Retain applicable mounting paragraphs in this article. Coordinate with Drawings.

Retain paragraph below if seismic controls are a project requirement. Coordinate with Drawings.

- A. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 260548.16 "Seismic Controls for Electrical Systems."

Retain paragraph below for floor-mounting switches and coordinate with Drawings.

- B. Floor-Mounting Switch: Anchor to floor by bolting.

Retain subparagraph below to require floor-mounting switches to be installed on concrete bases. Coordinate with Drawings.

- 1. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no more than 4 inches (100 mm) in all directions beyond the maximum dimensions of switch, unless otherwise indicated or unless required for seismic support. Construct concrete bases according to Section 260529 "Hangers and Supports for Electrical Systems."
- C. Annunciator and Control Panel Mounting: Flush in wall, unless otherwise indicated.
- D. Identify components according to Section 260553 "Identification for Electrical Systems."
- E. Set field-adjustable intervals and delays, relays, and engine exerciser clock.

3.2 CONNECTIONS

Retain first paragraph below if connections are to remote annunciator, control panel, or motor controller. Coordinate with Drawings.

- A. Wiring to Remote Components: Match type and number of cables and conductors to control and communication requirements of transfer switches as recommended by manufacturer. Increase raceway sizes at no additional cost to Owner if necessary to accommodate required wiring.

- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

Retain first or second paragraph below to identify who shall perform tests and inspections. If retaining option, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections and prepare test reports.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform the following tests and inspections and prepare test reports.

Retain first subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
2. The transfer switch manufacturers representative shall perform a startup test. The Contractor, DEN Project Manager and DEN Maintenance will witness the test. The test shall be conducted in accordance with the manufacturers recommendations. Operation of the Isolation Bypass Automatic Transfer Switch will be verified. This test will verify the interlocks in all positions and the automatic transfer operation to emergency and back to normal as well as the cool down function.
3. After installing equipment and after electrical circuitry has been energized, test for compliance with requirements.
4. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
5. Measure insulation resistance phase-to-phase and phase-to-ground with insulation-resistance tester. Include external annunciation and control circuits. Use test voltages and procedure recommended by manufacturer. Comply with manufacturer's specified minimum resistance.
 - a. Check for electrical continuity of circuits and for short circuits.
 - b. Inspect for physical damage, proper installation and connection, and integrity of barriers, covers, and safety features.
 - c. Verify that manual transfer warnings are properly placed.
 - d. Perform manual transfer operation.

6. After energizing circuits, demonstrate interlocking sequence and operational function for each switch at least three times.
 - a. Simulate power failures of normal source to automatic transfer switches and of emergency source with normal source available.

Retain test in first subparagraph below if three-phase undervoltage sensing is specified in Part 2. Test requires advance preparation by testing agency.

- b. Simulate loss of phase-to-ground voltage for each phase of normal source.
- c. Verify time-delay settings.
- d. Verify pickup and dropout voltages by data readout or inspection of control settings.
- e. Test bypass/isolation unit functional modes and related automatic transfer-switch operations.

Usually require test in first subparagraph below only for critical and extensive installations and for switches rated 1600 A and more in other installations.

- f. Perform contact-resistance test across main contacts and correct values exceeding 500 microhms and values for 1 pole deviating by more than 50 percent from other poles.
- g. Verify proper sequence and correct timing of automatic engine starting, transfer time delay, retransfer time delay on restoration of normal power, and engine cool-down and shutdown.

Retain subparagraph and associated subparagraph below if protective devices for circuits connected to transfer switches include ground-fault protection.

7. Ground-Fault Tests: Coordinate with testing of ground-fault protective devices for power delivery from both sources.
 - a. Verify grounding connections and locations and ratings of sensors.

Retain paragraph and subparagraphs below if retaining "Testing Agency" Paragraph above. Delete if Contractor performs tests and inspections.

C. Testing Agency's Tests and Inspections:

1. After installing equipment and after electrical circuitry has been energized, test for compliance with requirements.
2. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
3. Measure insulation resistance phase-to-phase and phase-to-ground with insulation-resistance tester. Include external annunciation and control circuits. Use test voltages and procedure recommended by manufacturer. Comply with manufacturer's specified minimum resistance.
 - a. Check for electrical continuity of circuits and for short circuits.
 - b. Inspect for physical damage, proper installation and connection, and integrity of barriers, covers, and safety features.
 - c. Verify that manual transfer warnings are properly placed.
 - d. Perform manual transfer operation.

4. After energizing circuits, demonstrate interlocking sequence and operational function for each switch at least three times.
 - a. Simulate power failures of normal source to automatic transfer switches and of emergency source with normal source available.

Retain test in first subparagraph below if three-phase undervoltage sensing is specified in Part 2. Test requires advance preparation by testing agency.

- b. Simulate loss of phase-to-ground voltage for each phase of normal source.
- c. Verify time-delay settings.
- d. Verify pickup and dropout voltages by data readout or inspection of control settings.
- e. Test bypass/isolation unit functional modes and related automatic transfer-switch operations.

Usually require test in first subparagraph below only for critical and extensive installations and for switches rated 1600 A and more in other installations.

- f. Perform contact-resistance test across main contacts and correct values exceeding 500 microhms and values for 1 pole deviating by more than 50 percent from other poles.
- g. Verify proper sequence and correct timing of automatic engine starting, transfer time delay, retransfer time delay on restoration of normal power, and engine cool-down and shutdown.

Retain subparagraph and associated subparagraph below if protective devices for circuits connected to transfer switches include ground-fault protection.

5. Ground-Fault Tests: Coordinate with testing of ground-fault protective devices for power delivery from both sources.
 - a. Verify grounding connections and locations and ratings of sensors.

Observe reaction of circuit-interrupting devices when simulated fault current is applied at sensors. Retain first paragraph below if automatic transfer switch is associated with generator.

- D. Coordinate tests with tests of generator and run them concurrently.
- E. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation and contact resistances and time delays. Attach a label or tag to each tested component indicating satisfactory completion of tests.
- F. Remove and replace malfunctioning units and retest as specified above.

Edit paragraph and subparagraphs below to suit types of switches specified.

- G. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switch. Remove all access panels so joints and connections are accessible to portable scanner.
 1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switch 11 months after date of Substantial Completion.

2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
3. Record of Infrared Scanning: Prepare a certified report that identifies switches checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain transfer switches and related equipment as specified below. Refer to Section 017900 "Demonstration and Training."

Retain paragraph below if generators are in Project.

- B. Coordinate this training with that for generator equipment.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 263600

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SECTION 264113 - LIGHTNING PROTECTION FOR STRUCTURES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes complete lightning protection systems for buildings and associated structures and components.
- B. Complete UL Master Labeled Lightning Protection System, complying with Reference Standards, consisting of, but not limited to: air terminals, down conductors, SPD (TVSS and Surge Arresters) on electrical and other conductive service entrances, bonding of other metal objects; grounding electrodes, perimeter ground conductor and interconnecting conductors.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Submit product data showing dimensions and materials of each component, and include indication of listing in accordance with referenced standards.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Submit shop drawings showing layout of air terminals and roof conductors, ground rods, and conductor sizes, and connection and termination details as well as bonding connections to structure and other metal objects.
 - 1. Layout of the lightning protection system, along with details of the components to be used in the installation.
 - 2. Include indications for use of raceway, data on how concealment requirements will be met, and calculations required by NFPA 780 for bonding of grounded and isolated metal bodies.

1.4 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified Installer and manufacturer. Include data on listing or certification by UL.

Retain first paragraph below for air terminals mounted on single-ply membrane roofing.

- B. Certification, signed by Contractor, that roof adhesive is approved by manufacturer of roofing material.
- C. Field quality-control reports.
- D. Comply with recommendations in NFPA 780, Annex D, "Inspection and Maintenance of Lightning Protection Systems," for maintenance of the lightning protection system.
- E. Other Informational Submittals: Plans showing dimensioned as-built locations of grounding features, including the following:
 - 1. Ground rods.
 - 2. Ground loop conductor.
- F. Submit proof that installer is listed and certified as required by Quality Assurance article.
- G. Copies of completed UL inspection forms.
- H. Submit to the DEN Project Manager a copy of all correspondence with UL .
- I. The Contractor is to provide the DEN Project Manager with one copy of the Reference

Standards. Retain one copy of each at the project site throughout construction for reference.

- J. Ground test results.
- K. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.
- L. U.L. Master Label.

1.5 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.6 QUALITY ASSURANCE

- A. Comply with the requirements of the Reference Standards noted herein, or the latest successor to those standards, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.
- B. Installer Qualifications: Certified by UL as a Master Installer/Designer, trained and approved for installation of units required for this Project.
- C. System Certificate:

Retain one of two subparagraphs below. See "Lightning Protection Standards and System Certifications" Article in the Evaluations.

- 1. UL Master Label.

Retain subparagraph below if Project includes addition to existing UL Master Label building.

- 2. UL Master Label Recertification.

- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 780, "Definitions" Article.

1.7 COORDINATION

- A. Coordinate installation of lightning protection with installation of other building systems and components, including electrical wiring, supporting structures and building materials, metal bodies requiring bonding to lightning protection components, and building finishes.

- B. Coordinate installation of air terminals attached to roof systems with roofing manufacturer and Installer.
- C. Flashings of through-roof assemblies shall comply with roofing manufacturers' specifications.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.8 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 LIGHTNING PROTECTION SYSTEM COMPONENTS

Specified standards stipulate minimum size requirements for components, depending on selected metal and class of building. To require components larger than minimum size, add requirements here.

- A. Comply with UL 96 and NFPA 780.
- B. Lightning protection system materials and components shall be UL Listed for the intended purpose, and comply with manufacturer's standard design, in accordance with published product information. Air terminals, bonding plates, conductors, connectors, conductor straps, fasteners, grounding plates, ground rods, rod clamps, splices, copper cable splices, SPD and all other components required shall be included for a complete system that meets or exceeds Reference Standards.

Retain material classification in NFPA 780; see Table 2 in the Evaluations.

- C. Roof-Mounted Air Terminals: NFPA 780, copper.
- D. Class I or Class II Structures:
 - 1. Class I: For buildings and structures less than 75 feet high, provide Class I rated components.
 - 2. Class II: For buildings and structures 75 feet high or greater, provide Class II rated components. Air terminals, cable, cable connectors and splices for Class II shall be rated as such and conductor cable shall be rated Class II and be continuous from air terminal to ground and interconnected with the balance of the system.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph below and list of manufacturers below. See Section 016000 "Product Requirements."

- E. Manufacturers: Subject to compliance with requirements, provide products by one of

the following:

- a. East Coast Lightning Equipment Inc.
 - b. ERICO International Corporation.
 - c. Harger.
 - d. Heary Bros. Lightning Protection Co. Inc.
 - e. Independent Protection Co.
 - f. Preferred Lightning Protection.
 - g. Robbins Lightning, Inc.
 - h. Thompson Lightning Protection, Inc.
 - i. **<Insert manufacturer>**
 - j. or approved equal.
2. Air Terminals More than **24 Inches** (600 mm) Long: With brace attached to the terminal at not less than half the height of the terminal.

Retain subparagraph below for single-membrane roof system.

3. Single-Membrane, Roof-Mounted Air Terminals: Designed specifically for single-membrane roof system materials. Comply with requirements in roofing Sections.

F. Main and Bonding Conductors: Copper.

Retain first paragraph below for structures exceeding 60 feet (18 m) in height. Revise if Project conditions require use of an above-ground, ground-level, potential equalization conductor.

G. Ground Loop Conductor: The same size and type as the main conductor except tinned.

Copper-clad, steel ground rods are the most common grounding electrodes. See Editing Instruction No. 4 in the Evaluations for assistance in selecting ground rod material. UL 94 and NFPA 780 allow the use of ground rods 1/2 inch (12.7 mm) in diameter and 96 inches (2400 mm) long. Sectional rods are used when electrodes longer than 10 feet (3 m) are required.

H. Ground Rods: Copper-clad steel, **3/4 inch** (19 mm) in diameter by **10 feet** (3 m) long.

I. Heavy-Duty, Stack-Mounted, Lightning Protection Components: Solid copper.

J. Above Grade Connectors and Splicers: Bronze.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Lightning protection systems shall be installed in accordance with equipment manufacturer's written instructions, and meet or exceed requirements of the Contract Documents and Reference Standards.
- B. Verify that surfaces are ready to receive work.

- C. Verify that field measurements are as shown on shop drawings.
- D. Beginning of installation means installer accepts existing conditions.
- E. Protect elements surrounding work of this Section from damage or disfiguration.

Specified standards stipulate minimum size requirements for components, depending on selected metal and class of building. To require components larger than minimum size, add requirements here.

- F. Install lightning protection components and systems according to UL 96A and NFPA 780.
- G. Install conductors with direct paths from air terminals to ground connections. Avoid sharp bends.
- H. Air Terminals shall extend least 10" above the object or area to be protected, and shall be placed on a maximum spacing of 20 feet. If Air Terminals extend 24" above the object or area to be protected, the spacing can be increased to a maximum of 25 feet.
- I. Conceal the following conductors:

Retain one or more of four subparagraphs below depending on degree of concealment desired for lightning protection components. If deleting all four subparagraphs, there will be no restrictions on exposed conductors.

- 1. System conductors.
 - 2. Down conductors.
 - 3. Interior conductors.
 - 4. Conductors within normal view of exterior locations at grade within 200 feet (60 m) of building.
- J. When conductors are installed in CMU or concrete walls they shall be installed in nonmetallic PVC raceway, Schedule 40, (minimum), or rigid steel when exposed below eight feet above finished floor or grade. Where steel conduit is used, follow Reference Standards and choke conduit on both ends. All bends shall have a minimum elbow radius of 8 inches. Nonmetallic conduit clamps shall be used on nonmetallic conduit.

Retain paragraph below. Exothermic-welded connections are considered more permanent than crimped or bolted connections.

- K. Cable Connections: Use crimped or bolted connections for all conductor splices and connections between conductors and other components. Use exothermic-welded connections in underground portions of the system.
- L. All metal bodies of inductance, whether that body is grounded or not, located within 6 feet of a lightning conductor or another bonded metal body, shall be bonded to the lightning conductor system.
- M. Attachment to Roofing: Adhesive shall be recommended by manufacturer of air terminals and approved by manufacturer of roofing material. Follow Reference Standards and use all appropriate care to avoid damage to roofing.

Retain first paragraph below for single-ply membrane roofing.

- N. Air Terminals on Single-Ply Membrane Roofing: Comply with roofing membrane and adhesive manufacturer's written instructions.

Delete first two paragraphs below if NFPA 780 compliance is specified; retain if specifying bonding requirements that exceed minimum UL 96A requirements. See Editing Instruction No. 3 in the Evaluations. Coordinate with Drawings for counterpoise requirements if any.

- O. Bond extremities of vertical metal bodies exceeding 60 feet (18 m) in length to lightning protection components.
- P. Ground Loop: Install ground-level, potential equalization conductor and extend around the perimeter of [structure] [area or item indicated].
1. Bury ground ring not less than [24 inches (600 mm)] <Insert dimension> from building foundation.
 2. Bond ground terminals to the ground loop.
 3. Bond grounded building systems to the ground loop conductor within 12 feet (3.6 m) of grade level.

Retain paragraph below for structures exceeding 60 feet (18 m) in height unless the structure is an electrically continuous steel frame. NFPA 70 lists other instances where paragraph below is not required.

- Q. Bond lightning protection components with intermediate-level interconnection loop conductors to grounded metal bodies of building at 60-foot (18-m) intervals.
- R. Below Grade Connections: Connections shall be exothermic welded for all conductor splices and all connections between conductors and other components below grade.
- S. Ground grid cable shall be a minimum of 2/0 cable. The ground grid shall follow the roof outline, and shall be approximately 30 inches below grade and 3 feet outside of foundations.
- T. In addition to the ground rods required by the Reference Standards, ground rods shall be placed on the ground loop at each change of direction and spaced not over 100 feet apart.
- U. On spacings of not more than 100 feet, test wells, with accessible test leads, shall be provided to provide contact with the ground loop for future ground impedance testing. The test well shall have a hand-hole cover of appropriate traffic or aircraft rating.
- V. Due to extensive cathodic protection of and isolation joints on all underground metal pipes at DEN, these systems shall be bonded to the lightning protection system on the building side only.
- W. Power Outages: Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

3.2 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.3 CORROSION PROTECTION

See Evaluations for discussion of corrosion protection issues.

- A. Do not combine materials that can form an electrolytic couple that will accelerate corrosion in the presence of moisture unless moisture is permanently excluded from junction of such materials.
- B. Use conductors with protective coatings where conditions cause deterioration or corrosion of conductors.
- C. It is the intent of this section that only copper lightning protection system components be used. Where roofing system components exist that may be galvanically incompatible with copper lightning protection system components (such as galvalume parapet caps), the lightning protection system shall be designed and configured to prevent direct contact of the copper with such roofing component. Aluminum lightning protection components may be used only to protect aluminum surfaces or equipment where no UL Listed fittings exist to prevent direct contact of the lightning protection component with such surface.
- D. Where galvanically incompatible metals are connected, use bi-metallic fittings. Where conditions exist that may cause deterioration or corrosion of conductors or other components, use components with suitable protective coatings, sleeves, spacers or other UL listed fittings.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Notify DEN Project Manager at least 48 hours in advance of inspection before concealing lightning protection components.
- B. Field inspection and testing will be performed according to Reference Standards and Contract Documents.
- C. Test the ground resistance to earth of each ground rod prior to connection to the system and submit test results to the DEN Project Manager. Where the resistance to ground is over 5 ohms, specifically notify the DEN Project Manager.
- D. Document all inspections on required UL inspection forms. One copy of each completed form shall be given to the DEN Project Manager.

- E. On existing structures, if, due to pre-existing conditions beyond control of the Contractor, the UL Master Label cannot be obtained, then the Contractor shall obtain a UL "Letter of Findings" (inspection to NFPA 780). If the Letter of Findings is also not possible, also due only to pre-existing conditions, then all work shall nevertheless comply with all other portions of this Specification and Reference Standards.
- F. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.
- G. UL Inspection: Meet requirements to obtain a UL Master Label for system.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 264113

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SECTION 264200 - CATHODIC PROTECTION

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes passive cathodic protection systems that use [magnesium] [zinc] anodes to protect [iron and steel piping] [and] [tanks].

Retain paragraph below if impressed current systems are included in project and approved by DEN Project Manager.

- B. Section includes impressed current systems, for use only with approval by DEN Project Manager.
- C. The contractor shall furnish and install cathodic protection equipment, mounting hardware, etc., as required for complete installation as indicated in these Specifications and on the Drawings.
- D. The galvanic or sacrificial anode system provides protective current to metals by electrically coupling the metal to be protected with another metal that appears higher in the electromotive force series. This sets up a galvanic coupling, because the medium in which both metals are contained acts as an electrolyte. The metal of higher potential becomes the anode, and sacrificially corrodes to protect installations such as piping or tanks that act as the cathode. The return path for current is through an electrical connection between the anode and the cathode. When sufficient current flows through the electrolyte to suppress all local action currents on the protected metal, cathodic

protection is complete. This type system requires no external power supply; it uses sacrificial anodes.

Retain three (3) paragraphs below if impressed current systems are included in project and approved by DEN Project Manager.

- E. Denver International Airport prefers the application of sacrificial or galvanic corrosion protection systems over the use of impressed current system due to the density of infrastructures and the potential for interference corrosion. There will be localized situations where impressed current systems can be successfully installed and represent advantages over the use of sacrificial or galvanic systems. when this situation occurs, the designer should review the specifics with the DEN Project Manager and get their approval along with the DEN Engineering Design Manager's concurrence that an impressed current system is safe and applicable. Thereafter the designer and installer have the responsibility to design and install a system that will not create interference corrosion problems on any existing facilities. In fact, any alterations required to protect existing facilities from new impressed current systems are the responsibility of the systems designer and installation contractor.
- F. The impressed current system employs the principle of providing direct current from an external source, such as provision of a rectifier or fuel driven direct current generator. The current is driven to ground through a ground bed (which consists of a group of anodes), and then drained from the anode bed to the metallic structures to be protected. This type of system, in a deep well fluidized ground bed configuration, shall be utilized as the main area wide cathodic protection system.
- G. Impressed current systems are more difficult and dangerous to apply due to problems with stray current corrosion and are not preferred throughout the airport. the use of this type of system will require written approval by the airport project engineer in consultation with the dia director of engineering or his/her representative. The installation will require a post construction stray current analysis and any resistance drainage bonds and their maintenance shall be the responsibility of the impressed current system operator.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 PERFORMANCE REQUIREMENTS

Retain first paragraph below if Contractor is required to assume responsibility for design.

- A. Delegated Design: Design, supervise, test, and inspect the installation of cathodic protection systems, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

Retain one or both subparagraphs below. See Evaluations.

1. Design cathodic protection for pipelines according to NACE RP0169.
2. Design cathodic protection for metal underground storage tanks according to NACE RP0285.

- B. Sacrificial anode systems may be used only where current requirements are low. Minimum negative voltage potential between structure and Cu/CuSO₄ reference electrode shall be 0.85 volts.
- C. Survey site and determine soil or water corrosivity (resistivity), current requirements, potential surveys, stray currents, and water chemistry/corrosivity (pH).
- D. Select anodes and accessories relevant to level of protection. Design anodes for an estimated life of forty (40) <Insert number> years before replacement. Provide a twenty (20) <Insert number> year design life for the deep ground bed system
- E. Cathodic protection systems shall provide protective potential that complies with referenced NACE standards. Insulators are required if needed to insulate protected metals from other structures.
- F. The drawings are diagrammatic and indicate the general arrangement of electrical work. Locations are approximate and shall be subject to minor modifications as dictated by field conditions and as directed by DEN Project Manager.
- G. Deliver sufficient current to the facilities and systems to be protected and distribute this current so that the criterion for cathodic protection is efficiently attained.
- H. Minimize the interference currents on neighboring underground structures.
- I. Provide adequate allowance for anticipated changes in current requirements with time.
- J. Placement of anodes where the possibility of disturbance or damage is minimal.
- K. The cathodic protection system shall protect all metallic surfaces presently being installed and providing for expansion capabilities for future installed items.
- L. Provide monitoring and alarm system for protection of DG current generation.
- M. Provide sufficient test stations to check the system's performance.
- N. Cathodic protection shall be provided for, but not limited to the following structures:
 - 1. Metallic pipelines.
 - 2. Metallic underground structures, i.e., tanks, vaults, etc.
 - 3. Grounding mats, rods, etc.
 - 4. Metallic structures in contact with earth.
- O. All systems protected shall be bonded, and be electrically continuous.
- P. All surfaces to be cathodically protected shall be coated in conformance to mechanical standards.
- Q. Stray currents will be avoided.
- R. Contractor Responsibilities: The function of the cathodic protection system shall include the following:

1. Recognition of hazardous conditions prevailing at the site and the selection and specification of materials and installation practices in conformance with these standards and which will assure the safe installation and operation of the cathodic protection system.
2. Perform a pre engineering field survey consisting of determining or measuring the following characteristics of the electrolyte and the structures to be protected:
 - a. Collect and compile soil tests with provision for future testing, as required.
 - b. Resistivity of the electrolyte.
 - c. Structure to electrolyte potential (if new installation, base requirement. on design calculations, field tests can only be run on existing structures).
 - d. Cathodic protection current requirements.
 - e. Electrolyte characteristics such as variations and water content of soils, salinity and oxygen content of water, and maximum and minimum temperature.
 - f. Proximity of structure to be protected to other structures.
 - g. Compile characteristics of pipe coatings utilized.
 - h. Source of magnitude of stray currents including free electricity from electrical transmission lines and. strong RF fields, if any.
 - i. Locations of isolation between the protected structure and other metallic structures.
 - j. Locations of resistance bond stations (drain stations).
 - k. Electrical continuity test requirements for the metallic structures and lines that are to be protected, if available.
 - l. Locations of anode beds and rectifiers.
3. The design of cathodic protection system is for optimum economy of installation, maintenance, and operation.
4. Compliance with specification of materials and installation practices which will assure dependable operation throughout the intended operating life of the cathodic protection system.
5. Operation of a system is to minimize excessive protective currents or earth potential gradients, which can cause detrimental effects on pipe, coating, or neighboring buried or submerged metallic structures.
6. Direction of cooperative investigations to determine mutually satisfactory solution(s) of interference problems.
7. Coordinate with cathodic protection designers and installers involved in a common deep well ground bed system. to insure minimum interference currents between systems.
8. Prepare suitable drawings to designate the over all layout of the piping or other structures to be protected and the location of significant items of structure hardware, corrosion control test stations, electrical bonds, electrical insulators, and neighboring buried or submerged metallic structures.
9. Layout shop drawings shall be prepared for each impressed current cathodic protection installation, showing the details and location of the components of the cathodic protection system with respect to the protected structures and to major physical landmarks.
10. The locations of galvanic anode installations shall be recorded on drawings or in tabular form, with appropriate notes as to anode type, weight, spacing, depth, and backfill.

Retain paragraph and sub-paragraphs below if impressed-current ground bed systems are included in project and approved by DEN Project Manager.

S. Impressed-Current Deep Ground Bed System:

1. An impressed current, deep ground bed, cathodic protection system shall be utilized for all protected structures within the area indicated on drawings. The area referred to as the "terminal corridor" shall include all protected structures around the terminal and parking structures, car rental areas, concourses, airport and airline support areas, air cargo facilities, airline maintenance areas, airline offices, fuel farm and other miscellaneous facilities within the terminal corridor area. The area referred to as the pipeline corridor shall include all pipelines and structures within its limits.
2. Basic electrical requirements for the impressed current system shall include the following using Cu/CuSO₄ reference electrodes:
 - a. A negative potential of at least 0.85 volts with a normal negative potential of 1.0 volts measured between the structure and a reference electrode.
 - b. A polarization decay voltage shift of at least 0.10 volts, after the rectifier is turned off, between the structure and the reference electrode.
 - c. A negative voltage shift of at least 0.30 volts between the structure and reference electrode when the protective current is first applied.

T. Environmental Conditions: The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:

1. Altitude: 5,500 feet (1677 m) above sea level.
2. Ambient Temperature Range: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).
3. Wind Load: 115 mph with gust factor of 1.3.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated, including manufacturer's name and product number, electrical ratings, dimensions, mounting position, mounting method, materials, apply to this Section.
1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For cathodic protection. Include plans, evaluations, sections, details, and attachments to other work.
1. Detail locations of cathodic protection equipment, devices, and outlets, with characteristics and cross-references to products.
 2. Include calculations and details of anode designs.
 3. Include labeling and identifying scheme for wires, cables, and test boxes.

Paragraph below is defined in Section 013300 "Submittal Procedures" as a "Delegated-Design Submittal." Retain if design responsibilities have been delegated to Contractor. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

- C. Delegated-Design Submittal: For cathodic protection system indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified corrosion engineer responsible for their preparation.
1. Conduct site tests necessary for design, including soil resistivity, close-interval potential surveys, testing during construction, interference testing, and training of Owner's personnel.
 2. Provide system design calculations, stating the maximum recommended anode current output density, and the rate of gaseous production, if any, at that current density.

Coordinate requirements for coordination drawings with DEN Project Manager.

- D. Coordination Drawings: Include plans and sections to show cathodic protection assembly layouts and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified professional engineer. Submit evidence of current license, corporate authorization (if applicable) of the engineering business, and NACE certifications.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.
- C. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
1. Basic system operation, outlining the step-by-step procedures required for system startup, operation, adjustment of current flow, and shutdown.
 2. Instructions for pipe-to-reference cell and tank-to-reference cell potential measurements and frequency of monitoring.
 3. Instructions for dielectric connections, interference and sacrificial-anode bonds; and precautions to ensure safe conditions during repair of pipe, tank or other metallic systems. Instructions shall be neatly bound.
 4. Locations of all anodes, test stations, and insulating joints.
 5. Structure-to-reference cell potentials as measured during the tests required by "Field Quality Control" Article.

6. Recommendations for maintenance testing, including instructions for pipe-to-reference cell potential measurements and frequency of testing.
7. Precautions to ensure safe conditions during repair of pipe system.

B. Post-Installation Report:

1. A report, prepared by the design consultant and contractor, shall be issued to the DEN Project Manager, which will include all data obtained, analysis of data, record drawings, an Operations and Maintenance Manual and any further recommendations.

Retain paragraph below if impressed current systems are included in project and approved by DEN Project Manager.

2. All impressed current systems will be analyzed for stray current interference with any other buried metallic systems. If interferences are located they will be removed by the contractor using good corrosion engineering practices.

- C. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

1.7 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIALS

1. Furnish extra materials including ten (10) percent of installed cathodic protection assemblies and parts to match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
2. Deliver, store, and handle bus assemblies according to manufacturer's requirements. Store extra materials in location as directed by DEN Project Manager.

1.9 QUALITY ASSURANCE

Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

- A. Corrosion Engineer Qualifications: Engage qualified professional engineer who has education and experience in cathodic protection of buried and submerged metal structures and has NACE accreditation or certification as a Corrosion Specialist or

Cathodic Protection Specialist.

- B. The designer of the cathodic protection system shall be a personnel trained in cathodic protection sciences under a registered Professional Engineer with cathodic protection and corrosion prevention expertise or a NACE certified Corrosion Specialist. The design shall be signed and sealed by a Professional Engineer.
- C. Testing Agency Qualifications: Testing agency as a member company of the International Electrical Testing Association that is acceptable to authorities having jurisdiction.
 - 1. Testing Agency's Field Supervisor: Person currently certified by the International Electrical Testing Association or the National Institute for Certification in Engineering Technologies, to supervise on-site testing.
- D. Source Limitations: Obtain enclosed cathodic protection components through one source from a single manufacturer.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Protect anodes from exposure to rain, snow and direct sunlight.

1.11 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace permanent reference electrodes that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for permanent reference electrodes with manufacturers listed in Part 2 articles.

- 1. Warranty Period: Minimum [forty (40)] <Insert number> years for sacrificial anode system.

Retain paragraph below if impressed-current ground bed systems are included in project and approved by DEN Project Manager.

- 2. Warranty Period: Minimum [twenty (20)] <Insert number> years for deep ground bed system.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Retain one or more of first three articles below for applicable anode materials. Corrosion engineering survey of local conditions will indicate which anode is suitable. Additional adjustment of chemical composition may be indicated to provide adequate and economical service.

2.1 MAGNESIUM ANODES, TYPE II

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Corpro Companies, Inc.
 2. Cott Manufacturing Company.
 3. CPMasters, Inc.
 4. ELTECH Systems Corporation USA; Anode Technologies Group.
 5. Farwest Corrosion Control Company.
 6. Loresco International.
 7. MATCOR.
 8. **<Insert manufacturer>**
 9. or approved equal.
- B. Comply with ASTM B 843.
- C. Chemical composition as percent of weight shall be as follows:
1. Aluminum: 0.010 maximum.
 2. Manganese: 0.50 to 1.3.
 3. Zinc: 0.05 maximum.
 4. Silicon: 0.50 maximum.
 5. Copper: 0.02 maximum.
 6. Nickel: 0.001 maximum.
 7. Iron: 0.03 maximum.
 8. Other Impurities: 0.05 each; 0.3 maximum total.
 9. Magnesium: Remainder.

Typical anode weights and dimensions are listed in the Evaluations and may be inserted here if spacing and size of anodes are not part of delegated design, but are indicated on Drawings.

- D. Anode Core: Galvanized steel with anode wire silver-soldered to the core. Connection shall be recessed and epoxy insulated for 600-V rating. Connection shall be covered

with heat-shrinkable tubing, and insulation shall be extended over connection.

- E. Anode Wires: Factory-installed cables, with copper conductors, suitable for direct burial; not less than No. 10 AWG with Type THWN insulation according to ASTM D 1248 and NEMA WC 70/ICEA S-95-658; long enough to extend to accompanying junction box without splicing.
- F. Anode Backfill: Backfill materials packaged in water-permeable fabric sack or cardboard container. Anodes shall be factory installed in packaged backfill using methods that result in dense packing of fill with factory-installed anode spacers to ensure centering of anode in packaged anode backfill. Backfill material shall have the following chemical composition by weight:
 - 1. Hydrated Gypsum: 75 percent.
 - 2. Bentonite Clay: 20 percent.
 - 3. Anhydrous Sodium Sulfate: 5 percent.

2.2 MAGNESIUM/MANGANESE ALLOY ANODES

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Corpro Companies, Inc.
 - 2. Cott Manufacturing Company.
 - 3. CPMasters, Inc.
 - 4. ELTECH Systems Corporation USA; Anode Technologies Group.
 - 5. Farwest Corrosion Control Company.
 - 6. Loresco International.
 - 7. MATCOR.
 - 8. <Insert manufacturer>
 - 9. or approved equal.
- B. Chemical composition as percent of weight shall be as follows:
 - 1. Aluminum: 0.01 maximum.
 - 2. Manganese: 0.50 to 1.3.
 - 3. Copper: 0.02 maximum.
 - 4. Nickel: 0.001 maximum.
 - 5. Iron: 0.03 maximum.
 - 6. Other Impurities: 0.05 each; 0.3 maximum total.
 - 7. Magnesium: Remainder.
- C. Bare Anode Weight: 40 lb (18 kg), not including core, and a nominal length of 60 inches (1520 mm).
- D. Anode Wires: Factory-installed cables, with copper conductors, suitable for direct burial; not less than No. 10 AWG with Type THWN insulation according to ASTM D

1248 and NEMA WC 70/ICEA S-95-658; long enough to extend to accompanying junction box without splicing.

- E. Anode Backfill: Backfill materials packaged in water-permeable fabric sack or cardboard container. Anodes shall be factory installed in packaged backfill using methods that result in dense packing of fill with factory-installed anode spacers to ensure centering of anode in packaged anode backfill. Backfill material shall have the following chemical composition by weight:
1. Hydrated Gypsum: 75 percent.
 2. Bentonite Clay: 20 percent.
 3. Anhydrous Sodium Sulfate: 5 percent.

2.3 ZINC ANODES FOR BURIED SERVICE, TYPE Z-1

- A. Use: Zinc anodes conforming to the following chemical analysis may be considered only if the use of magnesium anodes is completely unworkable in areas of low soil resistivities (less than 900 ohms per square centimeter). The use of zinc anodes shall be required to be approved by DEN Project Manager.

Retain this article for protection of buried copper pipe and devices.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Corpro Companies, Inc.
 2. Cott Manufacturing Company.
 3. CPMasters, Inc.
 4. ELTECH Systems Corporation USA; Anode Technologies Group.
 5. Farwest Corrosion Control Company.
 6. Loresco International.
 7. MATCOR.
 8. <Insert manufacturer>
 9. or approved equal.
- C. Comply with ASTM B 418, Type II.
- D. Chemical composition as percent of weight shall be as follows:
1. Aluminum: 0.005 maximum.
 2. Cadmium: 0.003 maximum.
 3. Iron: 0.0014 maximum.
 4. Zinc: Remainder.
- E. Bare Anode Ingot Weight: **30 lb** (13.6 kg), **2 inches** (50 mm) square and **30 inches** (760 mm) long. Packaged weight of anode bag shall be **70 lb** (32 kg).

- F. Anode Wires: Factory-installed cables, with copper conductors, suitable for direct burial; not less than No. 10 AWG with Type THWN insulation according to ASTM D 1248 and NEMA WC 70/ICEA S-95-658; long enough to extend to accompanying junction box without splicing.
- G. Anode Backfill: Backfill materials packaged in water-permeable fabric sack or cardboard container. Anodes shall be factory installed in packaged backfill using methods that result in dense packing of fill with factory-installed anode spacers to ensure centering of anode in packaged anode backfill. Backfill material shall have the following chemical composition by weight:
 - 1. Hydrated Gypsum: 75 percent.
 - 2. Bentonite Clay: 20 percent.
 - 3. Anhydrous Sodium Sulfate: 5 percent.

2.4 PERMANENT REFERENCE ELECTRODES

Coordinate reference electrode life with the expected service life of the anodes.

- A. The system shall be equipped with at least two reference electrodes for each rectifier, copper copper sulfate (Cu/CuSO₄) suitable for direct burial. Electrode shall be guaranteed by supplier for min. forty (40) years' service in the installed environment. One electrode shall be installed in a location expecting minimum protection and the other in a location expecting maximum protection.

2.5 WIRE AND CABLE

- A. Anode Header Cable: Single-conductor, Type HMWPE, insulated cable specifically designed for direct-buried dc service in cathodic protection installations.
 - 1. Conductor: Stranded, annealed, uncoated copper, not less than No. 8 AWG, complying with ASTM B 3 and ASTM B 8.
 - 2. Insulation: High-molecular-weight polyethylene, complying with NEMA WC 70/ICEA S-95-658.
 - 3. Minimum Average Thickness of Insulation: **110 mils** (2.8 mm) for Nos. 8 through 2 AWG, and **125 mils** (3.2 mm) for Nos. 1 through 4/0 AWG; rated at 600 V.
 - 4. Connectors: Exothermic welds.
- B. Conductors and Cables: Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
 - 1. Bonding Conductors for Joint and Continuity Bonds: Not less than No. 8 AWG, stranded, Type THWN copper conductors.
 - 2. Flexible Pipe Coupling Bonds: Flexible copper straps with electrical resistance equal to No. 1/0 AWG stranded copper wire and with five holes for five exothermic welds to pipe.
 - 3. Test Wires: No. 12 AWG, Type THWN copper conductors.
 - 4. Resistance Wires: No. 16 or No. 22 AWG nickel-chromium wire.
 - 5. Cables for Installation in Conduit: Type THWN copper conductors.

- C. Where several anodes are connected to one header cable, compute the allowable voltage drop in that cable. Select the cable size in accordance with standard electrical engineering practice. Directly buried conductors should be properly insulated to prevent current leakage, and of a sufficient size to prevent mechanical damage.
- D. All lead wire conductors shall be exothermic welded at splices and to protected surfaces, and sealed with a protective coating.
- E. All cad welded pipeline leads will include two wires to the test stations to allow for the loss of one line during the life of the installation.
- F. Splicing underground cables should be avoided where possible. Necessary splices be made with manufactured, UL. approved, splice kits.
- G. The DC conductors shall be run in rigid conduits of a size large enough to accommodate 1/0 cable or #8 AWG cable to the anodes to a depth of at least 18" below grade. DC conductors below 18" may be run direct buried. All conduits shall be terminated in the ground with a plastic bushing.
- H. The negative DC lead from the rectifier units shall be connected to the protected structure by a exothermic weld connection. The connection shall be coated with a heavy coat of coal tar enamel, or equal with a plastic backfill shield installed over that.
- I. All underground pipe joints, except welded joints, shall be electrically bonded using a #2 AWG HMWPE insulated conductor, exothermic welded to each pipe section, and all component parts except bolts.

2.6 TEST STATIONS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Corpro Companies, Inc.
 - 2. Cott Manufacturing Company.
 - 3. CPMasters, Inc.
 - 4. <Insert manufacturer>
 - 5. or approved equal.
- B. Plastic Test Stations: Flush-mounted type, manufactured of high-impact-resistant PVC or polycarbonate with watertight conduit connections and cover and removable terminal board having at least five terminals.
- C. Test Station Mounting Enclosures:
 - 1. Non-Traffic-Area Boxes: Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

For traffic boxes in subparagraph below, verify that AASHTO's "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals," H 20 traffic loads, is adequate, or delete below if boxes are not in traffic areas.

2. Traffic-Area Boxes: Comply with requirements in Section 260543 "Underground Ducts and Raceways for Electrical Systems." Boxes shall have cast-iron covers with a welded bead legend "CP TEST."

D. POTENTIAL STATIONS

1. This subject pertains to those situations where direct and uninterrupted surface contact to the soil surrounding the cathodically protected structure is not available. Examples include piping that is under concrete, piping that is below an environmental geomembrane, piping that is below coarse grade materials (such as gravel) that are not part of the electrolyte body, and above ground storage tank bottoms that have cathodic protection applied. Easy replacement of reference electrodes in the above mentioned location must be addressed in the design of the referenced electrode's installation. Elimination of the access problem for replacement through the use of test stations that allow access to native soil should be used where possible.
2. Potential stations located in areas with soil surface shall consist of a precast concrete housing, which is open at the bottom and shall be furnished with a cast iron traffic cover marked CP on the top of the cover. The station shall be filled to within 3 inches of its top with clean soil.

2.7 SEALING, POTTING, AND DIELECTRIC COMPOUNDS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Chase Corporation - Chase Specialty Coatings; Royston Business Group.
 2. Chase Corporation - Chase Specialty Coatings; Tapecoat Business Group.
 3. Farwest Corrosion Control Company.
 4. 3M; Electrical Products Division.
 5. or approved equal.
- B. Sealing and Dielectric Insulating Compound: Comply with NACE RP0188. Black, rubber based, soft, permanently pliable, tacky, moldable, and unbacked; [0.125 inch (3 mm)] [0.5 inch (13 mm)] thick.
- C. Potting Compound: Comply with NACE RP0188. Cast-epoxy, two-package type; fabricated for this purpose and covered with heat-shrinkable tape.
- D. Pressure-Sensitive, Vinyl-Plastic Electrical Tape: Comply with UL 510.

2.8 EXOTHERMIC WELDING MATERIALS

- A. Exothermic Weld Kits: Specifically designed by manufacturer for welding materials and shapes required.
- B. Exothermic Weld Caps: Dome of high-density polyethylene, **10-mil** (0.254-mm) minimum thickness, filled with mastic and containing a tunnel portion to separate lead wire from exothermic weld.

2.9 COATING REPAIR MATERIALS

Verify that Section 099600 "High-Performance Coatings" is included in Project Specifications.

- A. Touchup Coating Materials: Comply with requirements in Section 099600 "High-Performance Coatings" for coating systems for touchup of factory-applied coatings.
- B. Adhesive-Applied Coating Materials: Coating materials shall be compatible with factory-applied coating system.
 - 1. Nominal thickness of coating materials shall be not less than [**8 mils** (0.2 mm)] [**16 mils** (0.4 mm)] [**24 mils** (0.6 mm)] [**40 mils** (1.0 mm)] [**60 mils** (1.5 mm)] **<Insert value>**, plus or minus 5 percent.
 - 2. Coating materials shall be one of the following supplied by factory-applied coating system manufacturer:
 - a. Polyvinyl-chloride, pressure-sensitive, adhesive tape.
 - b. High-density polyethylene/bituminous rubber compound tape.
 - c. Butyl rubber tape.
 - d. Coal-tar epoxy.
 - e. **<Insert coating material>**.
- C. Resistor Use:
 - 1. In low resistivity media, where current flow must be limited, and anode output current is in excess of the required cathodic protection current, adjustable resistors must be used to limit the flow of current. The value of this resistance can be determined by applying Ohm's law.

Retain entire article including associated paragraphs below if impressed-current systems are included in project and approved by DEN Project Manager.

2.10 IMPRESSED-CURRENT ANODES:

- A. Anodes for deep well impressed current systems shall be specified to be high silicon iron chromium durichlor type CD with the following analysis and requirements:
 - 1. Silicon: 14.5% min.
 - 2. Manganese: 0.75% min.

3. Carbon: 0.95% min.
4. Chromium: 4.5% min.
5. Iron: Remainder
6. The anode lead wire shall be #8 AWG 7/S, I/C copper with HMWPE insulation, and shall be connected to the interior center of the anode. The anode anchoring device shall withstand a 2,000 pound pull and have a maximum anode to anchoring device electrical resistance of .0009 ohms. Anchoring devices shall be covered with a sealing compound.
7. The use of tubular series wired anode assemblies is not recommended. Anodes with individual lead wires extended up to an above grade junction box is recommended.
8. Resistive localized anodes are acceptable if the installation is designed and certified by a registered Corrosion Engineer or NACE certified Corrosion Specialist.

B. Impressed-Current Backfill:

1. The backfill shall be tamped calcined coke breeze material screened to provide a particle size from 1/81' to 3/811. Resistivity shall not exceed 25 ohm cm at a moisture content of not more than 1%, with a bulk density of 46 to 50 lb/ft' and the following composition:
 - a. Fixed Carbon: 99.4% guaranteed typical (99.0% min., dry basis).
 - b. Ash: 0.3% guaranteed typical (0.5% max., dry basis).
 - c. Volatile matter: 0.3% guaranteed typical (0.5% max., dry basis).
 - d. Sulfur: 0.8% guaranteed typical (1.2% max., dry basis).
 - e. Moisture: 0.02% guaranteed typical (1.0 max.).

C. Impressed-Current Anode Shunt Junction Boxes:

1. Enclosures shall be watertight stainless steel or nonmetallic boxes complete with terminal blocks, shunts, copper jumpers, and bus bars. Shunts shall be in accordance with IEEE 316, 0.01 ohms, 8 amperes.

D. Impressed-Current Rectifiers:

1. Rectifier units shall supply the proper voltage and current output as required in Article 2.12. The Design shall factor in "attenuation" determined from attenuation curves, or the total current required to give protection at the points most distant from the drainage point.
2. The rectifier shall be specified to be of the adjustable type, with a minimum of 20 even adjustments, with conveniently accessible taps over the full voltage output range. This will allow for changes in voltage requirements as a result of seasonal variations in soil resistivity. For above ground tank bottom cathodic protection systems located within release control liners, the rectifiers shall be supplied with variable constant current controls.
3. Rectifier shall be specified to be of the silicone type meeting NEMA MR 20 standards. Semiconductors shall be rated to provide adequate margin for over voltage and over current surges. They shall be mounted on a heat sink designed

to maintain junction temperatures well below manufacturer's recommended maximum temperatures when operating in a 120 F (50 C) ambient. The rectifier stack shall be a single three-phase, full wave, bridge connected. Silicone diodes shall be protected on input and output sides with zener type selenium surge plates and lightning arresters.

4. The rectifier unit transformer shall be specified to be a two winding type with 428 F (220 C) insulation to operate at rated kVA with a temperature rise not exceeding 220 F (105 C) above a 120 F (50 C) ambient. The secondary winding shall have minimum of four coarse and five fine voltage control taps to provide adjustable output voltages in equal steps over the entire operating range. Voltage control taps shall be studs and links shall be rated to carry 125 percent of the rectifier full load current. The transformers shall conform to NEMA ST 1. Provisions for remote monitoring and alarms shall also be provided.
5. The efficiency of the basic rectifier shall be a minimum of 70 percent. Each rectifier unit shall be complete with enclosure, transformer, voltage control taps, and necessary appurtenances. Voltage, phase, AC input, and DC output ratings shall be as necessary. The enclosures shall be in accordance with NEMA ICS 6 110. Sunshades shall be provided for each outdoor rectifier.
6. Rectifiers shall be enclosed in sheet metal enclosures with welded seams in accordance with NF14A MR 20. The enclosures shall be provided with hinged doors. Circuit breakers, ammeters, and voltmeter shall be mounted on an inside panel. The rectifier shall have a ground lug for a minimum 67.44mm (No. 2/0 AWG) ground wire and shall be suitable for wall, post, or pad mounting, with knockouts provided for conduit entrance.
7. Each rectifier unit shall have internally mounted meters to read DC current and DC voltage. The ammeter shall be provided with an external shunt. The meters shall be red lined at approximately the three quarter point of the rectifier unit "full scale" rated value. The meters shall have an accuracy of +/- 2 percent.
8. The main circuit breaker shall be molded case, trip free, flush mounted with toggle handle readily accessible. An overload or short circuit through any single pole shall open all poles simultaneously. The circuit breaker shall conform to NEMA AB 1.
9. Fuses of the non renewable type shall be installed in the secondary side of the rectifier and shall be mounted on the front of the rectifier panel.

E. Impressed-Current Deep Ground Bed Hardware:

1. Casings shall be ES ABS pipe sized as required. Pipe shall be supplied with 1 1/4" diameter holes drilled at an angle of approximately 45° from the longitudinal axis of the pipe.
2. Approximately 50 holes per running foot of pipe is required. Holes shall be positioned in a symmetric and distributed manner so as not to reduce the strength of the pipe. On the outside of the drilled portion of the pipe, a 28 gauge metal membrane shall be installed in a secure manner.
3. Vent pipes shall be 1" PVC with 201 couplings and having 3/16" holes on 6" centers drilled from the bottom of the hole to 51" above the top anode.

PART 3 - EXECUTION

3.1 GENERAL INSTALLATION REQUIREMENTS

- A. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
- B. Install at the locations shown on drawings for anodes and provide for symmetrical spacing to obtain uniform current distribution. Low, poorly drained areas are generally good locations for anodes and are highly desirable for efficient anode operation. Locate anodes in areas having the lowest resistance and nearest those points where corrosion has been determined to be the most severe; space anodes not closer than four (4) feet from the protected structure and space a minimum of twenty (20) feet from foreign structures. Place anodes at a depth that is below the bottom of the structure to be protected. For protection of tank interior or other structure where rod type magnesium anodes are not practicable, zinc anodes can be mounted directly on, but separated by an insulating strip from, the surface of the steel to be protected.
- C. Comply with ANSI/IEEE C2 and NFPA 70.
- D. The cathodic protection equipment installation is to be sequenced and scheduled with other work to reduce possibility of damage and soiling of equipment during the remainder of construction period.
- E. Field Measurements: Verify existing dimensions by field measurements. Verify clearances and locate obstructions within manufacturing and installation tolerances of cathodic protection equipment.
- F. Make connections to ferrous pipe **[and metal tanks]** using exothermic welding.
- G. Coat welds with the coating repair material and apply an exothermic weld cap.
- H. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

3.2 MAGNESIUM ANODE INSTALLATION

- A. Install magnesium anodes at locations that clear obstructions. Install at least **36 inches** (900 mm) and no more than **10 feet** (3 m) from pipe **[or tank]** to be protected. Install in augered holes with top of anode **[24 inches** (600 mm) **below pipe invert elevation]** **[a minimum of 36 inches** (900 mm) **below finished grade]**. In soils that will collapse into augered holes, use casing of galvanized sheet steel.
- B. Install anodes in a dry condition after plastic or waterproof protective covering has been completely removed from water-permeable permanent container that houses anode metal. Anodes shall be lowered into holes by rope sling or by grasping the cloth gather. Do not use anode-connecting wire for lowering anode into hole.

- C. Packaged galvanic anodes shall be wetted and then backfilled with compacted native soil. Where anodes and special chemical backfill are provided separately, anodes shall be centered in special backfill that would be compacted prior to backfilling with native soil. Care should be exercised so that lead wires and connections are not damaged during backfill operations. Sufficient slack should exist in lead wires to avoid strain.
- D. Backfill annular space around anode with fine earth in 6-inch (150-mm) layers; compact each layer using hand tools. Do not strike anode or connecting wire during backfilling and compacting. After backfilling and compacting to within 6 inches (150 mm) of finished grade, pour approximately 5 gal. (20 L) of water into each filled hole. After water has been absorbed by earth, complete backfilling to finished level.
- E. If rock strata are encountered before achieving specified augured hole depth, install anodes horizontally at depth at least as deep as bottom of pipe to be protected.
- F. Install anodes spaced as indicated, **[directly connected] [connected through a test station]** to the pipeline, allowing slack in connecting wire to compensate for movement during backfill operation.
- G. For tank protection, connect groups of anodes to collector cable. Make contact, through a test station, with tank to be protected.
- H. Do not use resistance wires to reduce current output of individual or group anodes.

3.3 ZINC ANODE INSTALLATION

Retain this article if retaining zinc anodes in Part 2, and only if approved by DEN Project Manager. This article is typical for protection of domestic copper water tubing of limited lengths, usually under concrete slabs-on-grade, and should be revised to suit other copper piping and applications.

- A. Install zinc anode horizontally in a hole at least 3 inches (76 mm) larger than anode. Install anode under new copper water tubing, including service lines, blowoffs, and air releases. Separate piping and anode by at least 24 inches (600 mm), but not more than 60 inches (1520 mm).
- B. Install anode midway between both ends of piping. Install anode wire in piping trench and connect to piping at an accessible location. Install anode wire in PVC conduit where rising out of the ground to the aboveground connection.

3.4 INSTALLATION OF REFERENCE ELECTRODES

- A. Install directly beneath the buried metallic component being protected.

3.5 CABLE AND WIRE INSTALLATION

Indicate extent of conduit installation on standard details and plans on Drawings. Revise first paragraph below to require anode wires in conduit. See Editing Instruction No. 3 in the Evaluations for other wiring options.

- A. Install conductors, except anode wires, in PVC conduit with waterproof PVC junction boxes. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for conduit and its installation.
- B. Anode Wire Installation: Cover trench bottom for the anode wire with **3-inch** (76-mm) layer of sand or stone-free earth. Center wire on backfill layer and do not stretch or kink the conductor. Place backfill over wire in layers not exceeding **6 inches** (150 mm) deep, and compact each layer. Use clean fill, free from roots, vegetable matter, and refuse. Place cable underground-line warning tape within **18 inches** (460 mm) of finished grade, above cable and conduit.
- C. Bonding Conductors: Install conductors on metallic pipe and tanks, to and across buried flexible couplings, mechanical joints, and flanged joints except at places where insulating joints are specified. Welded and threaded joints are considered electrically continuous and do not require bonding.
 - 1. Install at least two bonds between parts requiring bonding.
 - 2. Bonding conductors must contain sufficient slack for anticipated movement between structures. Bonding conductors across pipe joints shall have not less than a **4-inch** (100-mm) slack for pipe expansion, contraction, and soil stress.
 - 3. Connect bonding conductors to pipe, coupling follower rings and coupling middle ring or sleeve. Connect bonding conductors with exothermic welds.
- D. For wire splicing, use compression connectors or exothermic welds.

3.6 TEST STATIONS

- A. Install test stations as follows:
 - 1. At max. **1000-foot** (300-m) intervals.
 - 2. At insulating joints.
 - 3. At both ends of casings when casing material is included in the cathodic protection system.
 - 4. Where pipe crosses within 6" of other metal pipes.
 - 5. Where pipe connects to existing piping system.
 - 6. Where pipe connects to dissimilar metal pipe.
 - 7. On each underground storage tank and each buried metallic process tank such as an oil-water separator or grit chamber.
 - 8. At all insulating underground joints (bond site).
 - 9. Where a carrier pipe is used under roads, railroads, etc.
 - 10. For sacrificial anodes added to the fuel system.
- B. Test stations will not be required within 300' of a riser pipe or any place where the pipe may be readily accessible.
- C. Install test stations on backfill complying with requirements for trench bottom fill for anode wires unless otherwise indicated.

- D. Terminate test conductors on terminal boards and install a spare set of test leads at each testing location.
- E. Test stations consist of a weatherproof NEMA: terminal box, with removable cover, test lead wires and five terminals, installed approximately 3 feet above surface. Limit above grade test stations to protected areas only.
- F. Flush type test stations approximately 4" x 18" or 5" x 181 long plastic pipe and heavy cast iron loading covers and collars suitable for both curb and roadway installation shall be installed in all paved areas.
- G. Test station conductors shall be minimum #12 AWG HMWPE insulated, color coded as required.
- H. Test stations shall be labeled with coded identification and shall be carefully located.

3.7 PIPE JOINTS

- A. Insulating Flange Sets: Cover flanges with sealing and dielectric compound.
- B. Insulating Unions: Install electrical isolation at each building entrance and at other locations indicated on approved Delegated-Design Drawings. Cover unions with sealing and dielectric compound.

3.8 INSULATING PIPE SLEEVES

Coordinate requirements in this article with requirements in Section 220529 "Hangers and Supports for Plumbing Piping and Equipment" and with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

- A. Install insulating sleeves between metallic piping and metal buildings, hangers, supports, and other metal structures. Completely surround the metallic pipe for the full length of the steel contact and effectively prevent contact between the cathodically protected metallic pipe and other metallic structures. Support insulating sleeve to prevent damage to coating and to accommodate relative movement, vibrations, and temperature differentials.
- B. Provide electrical isolation between piping systems protected by different cathodic protection systems, at each building riser pipe, and at other points where a short to another pipe or a foreign structure may occur. Provide electrical isolation between anchor plates, leak plates and any other structure penetration.
- C. Electrical isolation shall be provided at the first flange inside any building with the remainder of buried pipe protected. Note the DEN electrical specification which denies the use of water supply up to this flange from the exterior for use as an electrical ground.

3.9 DISSIMILAR METALS

- A. Underground Dissimilar Piping: Coat insulating joint and pipe at joints of dissimilar piping material with sealing and dielectric compound for a minimum distance of 10 pipe diameters on both sides of joint.
- B. Underground Dissimilar Valves: Coat dissimilar ferrous valves and pipe with sealing and dielectric compound for a minimum distance of 10 pipe diameters on both sides of valve.
- C. Aboveground Dissimilar Pipe and Valves: If dissimilar metal pipe joints and valves are not buried and are exposed only to atmosphere, coat connection or valve, including pipe, with sealing and dielectric compound for a minimum distance of three pipe diameters on both sides of junction.

3.10 COATINGS

- A. Field Joints: Apply adhesive-applied coating system in a thickness to achieve corrosion protection equal to adjacent factory-applied coating.

3.11 IDENTIFICATION

- A. Comply with requirements in Section 260553 "Identification for Electrical Systems."
 - 1. Identify anode wires and anode header cables with marker tape.
 - 2. Identify underground wires and cables with underground-line warning tape.
 - 3. Identify text boxes with engraved, laminated acrylic or melamine label, permanently attached to text box.

Retain entire article including associated paragraphs below if impressed-current systems are included in project and approved by DEN Project Manager.

3.12 IMPRESSED-CURRENT INSTALLATION REQUIREMENTS

- A. Deep ground bed anode locations shall be installed as determined by the Design Consultant's Corrosion Engineer's standard design calculations, and field surveys.
- B. The deep ground bed installation shall be of the replaceable type in locations in paved areas, and areas where any construction work may interfere with air traffic operations. In other areas, ground beds may be of the non replaceable type.
- C. The ground beds shall not be placed at a depth greater than 51". The Engineer shall determine if greater limitations are required. The deep ground bed casing shall be positioned at a section of the casing. Upon completing the installation of the perforated and solid plastic casing, enough coke breeze should be pumped to fill the annulus between the casing and the periphery of the drilled hole up to a point 101 above the top anode. The inside casing should then be flushed to remove contaminants until the water is finally clear. The anodes, along with the 1" PVC vent pipe, should then be

lowered down the hole to their respective determined depths. The inside casing should be pumped with the proper amount of coke breeze slurry (51" above the top anodes). After 24 hours of settling, the coke breeze height shall be the annulus of the hole to grade with washed gravel. The top of the plastic casing shall be capped off at grade and a metallic/concrete vault installed.

- D. The individual anode lead wires shall be run to the anode lead junction box mounted adjacent to the hole at the earth surface.
- E. The rectifier units shall be mounted on a concrete pad at least 6" larger and wider than the rectifier base dimensions and 4" thick. The rectifiers shall be located convenient to the deep well ground beds.

3.13 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Comply with NACE RP0169 and NACE RP0285.

Retain first or second paragraph below to identify who shall perform tests and inspections. Retain and edit "Field quality-control reports" Paragraph in "Informational Submittals" Article.

- B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- C. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- D. Tests and Inspections:
 - 1. Static Pull Test: Choose, at random, one completed anode of each type for this destructive test. Demonstrate that anode wire connections have enough strength to withstand a minimum tensile load of 300 lb (136 kg). If test fails, replace all anodes and repeat test at another randomly selected anode.
 - 2. Insulation Testing: Before anode system is connected to [pipe] [and] [tank], test insulation at each insulating joint and fitting. Demonstrate that no metallic contact, or short circuit, exists between the two insulated sections of [pipe] [and] [tank]. Replace defective joints or fittings.
 - 3. Bonding Tests: Test for electrical continuity across all bonded joints. Repair or add additional bonds until electrical continuity is achieved.

4. Baseline Potentials: After backfilling of **[pipe and] [pipe, tank, and]** anodes is completed, but before anodes are connected to **[pipe] [and] [tank]**, measure the static potential of **[pipe] [and] [tank]** to soil. Record initial measurements.
 5. Anode Output: Measure electrical current as anodes or groups of anodes are connected to **[pipe] [and] [tank]**. Use a low-resistance ammeter. Record current, date, time, and location of each measurement.
 6. **[Pipe-] [and-] [Tank-]**to-Reference Electrode Potential Measurements: On completion of installation of entire cathodic protection system, make electrode potential measurements according to NACE RP0169, using a copper/copper-sulfate reference electrode and a potentiometer-voltmeter, or a dc voltmeter with an internal resistance (sensitivity) of not less than 100,000 ohms per volt and a full scale of 1 or 2 V. Make measurements at same locations as those used for baseline potentials. Record voltage, date, time, and location of each measurement, using one of the following two methods:
 - a. 0.85 V Negative Voltage: With cathodic system in operation, measure a negative voltage of at least minus 0.85 V between **[pipe] [or] [tank]** and a saturated copper/copper-sulfate reference electrode contacting the earth directly over **[pipe] [or] [tank]**.
 - b. 100-mV Polarization Voltage: Determine polarization voltage shift by interrupting protective current and measuring polarization decay. An immediate voltage shift will occur if protective current is interrupted. Use voltage reading, after immediate shift, as base reading from which to measure polarization decay. Measure at least a minimum polarization voltage shift of 100 mV between **[pipe] [or] [tank]** and a saturated copper/copper-sulfate reference electrode contacting the earth directly over **[pipe] [or] [tank]**.
- E. Location of Measurements for Piping: For coated piping or conduit, measure from reference electrode in contact with the earth directly over pipe. Measure at intervals not exceeding **400 feet** (120 m). Make additional measurements at each distribution service riser, with reference electrode placed directly over service line.

Retain first paragraph below if tanks are to be protected.

- F. Location of Measurements for Tanks: For underground tanks, measure from reference electrode located as follows:
1. Directly over center of tank.
 2. At a point directly over tank and midway between each pair of anodes.
 3. At each end of tank.

Retain test in first paragraph below if there is a possibility of adverse effects from foreign pipes and tanks.

- G. Interference Testing: Test interference with cathodic protection from any foreign **[pipes] [and] [tanks]** in cooperation with Owner of foreign **[pipes] [and] [tanks]**. Report results and recommendations.

- H. Stray Current Measurements: Perform at each test station. Mitigate stray currents due to lightning or overhead ac power transmission lines as provided for in NACE standards.

See Editing Instruction No. 2 in the Evaluations for discussion of testing and repair of coatings.

- I. Inspect coatings; comply with NACE RP0188. Repair imperfections of factory-applied coatings as specified in "Coatings" Article.
1. Use electronic holiday detectors to detect coating imperfections.
 2. All damage to the protective coating during transit and handling shall be repaired before installation.
 3. Repair factory-applied coatings to have equal or better corrosion resistance than the factory-applied coating system. Field-repair material shall be of the type approved by, and shall be applied as recommended by, manufacturer of the coating material.

Retain paragraph and associated sub-paragraphs below if impressed-current systems are included in project and approved by DEN Project Manager.

- J. Impressed Current Deep Ground Bed System:
1. After the installation is complete, the deep well anode systems shall be energized and tested to determine that the underground structures are receiving adequate protection in accordance with the criteria as set forth in the National Association of Corrosion Engineers, Standard RP 01 69, Latest Revision. All testing shall be performed under the direct supervision of a Corrosion Specialist as certified by the National Association of Corrosion Engineers.
 2. Interference testing shall be conducted.
 3. Static Potential Measurements: Before the ground beds are energized, a complete set of "static" potential measurements shall be obtained at the following locations:

Edit below to suit project.

- a. Fire Water Line at all hydrant and valves.
 - b. Fuel line at all hydrant and valves.
 - c. Above Ground Storage Tanks four (4) readings per tank with tanks greater than 10 ft diameter.
 - d. Above Ground Storage Tanks two (2) reading per tank with tanks less than or equal to 10 ft diameter.
 - e. Main Pipeline Corridors pipe to soil measurements, minimum of 100 ft apart.
 - f. Anode Output As the anodes are energized, current output shall be measured. The values obtained, date, time, and locations shall be recorded.
4. Interference Testing before final acceptance, interference tests shall be made with respect to any foreign pipelines, tanks or wells in cooperation with the owner of the foreign structure. A full report of the tests giving all details shall be made.

Any methods recommended to eliminate interference shall be reported to DEN Project Manager. It is the responsibility of the new installation designer and contractor to assure the resolution to any electrical interference problems resulting from the cathodic protection prior to system acceptance and to resolve any interferences found post construction that are deemed the result of said construction.

5. Anode Output As the anodes are energized, current output shall be measured. The values obtained, date, time, and locations shall be recorded.

3.14 ADJUSTING

- A. Adjust cathodic current using resistors as recommended by corrosion engineer who prepared the Delegated-Design Submittal in Part 1.
- B. During the first year after Substantial Completion, test, inspect, and adjust cathodic protection system every three months to ensure its continued compliance with specified requirements.

3.15 DEMONSTRATION

- A. Contractor to engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain cathodic protection system.
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 264200

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SECTION 264313 - TRANSIENT-VOLTAGE SUPPRESSION FOR LOW-VOLTAGE ELECTRICAL POWER CIRCUITS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section includes field-mounted TVSS for low-voltage (120 to 600 V) power distribution and control equipment.
- B. This specification describes the electrical and mechanical requirements for a multitude of hybrid high-energy power conditioning filter units utilized for a facility-wide protection system. Each unit in the system shall incorporate transient voltage surge suppression (TVSS) and high-frequency electrical line noise filtering. The specified system shall provide effective high-energy transient voltage suppression, surge current diversion, high-frequency attenuation, and line control in all ANSI/IEEE-C62.41 environments connected on the load side of the facility's meter or main overcurrent device. The system shall be connected in parallel with the facility's wiring system and provide minimum attenuation of fast rise-time, high-frequency, error producing transients and electrical line noise as follows:

Attenuation Frequency:	100 kHz	1MHz	10 MHz	100 MHz
Insertion loss(ratio):	355-1	50,000-1	500,000-1	1,000,000-1
Insertion loss(dB):	51	94	114	120

C. In order to assure proven reliability, the facility-wide protection system shall be capable of protecting against and surviving at least 5,000 ANSI/IEEE-C62.41 Category-C surges without failing or degrading the UL-1449 Surge Suppression Rating by more than 5%.

D. Related Sections:

Retain Sections in subparagraphs below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 262413 "Switchboards" for factory-installed TVSS.
2. Section 262416 "Panelboards" for factory-installed TVSS.
3. Section 262726 "Wiring Devices" for devices with integral TVSS.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. ATS: Acceptance Testing Specifications.
- B. SVR: Suppressed voltage rating.
- C. TVSS: Transient voltage surge suppressor(s), both singular and plural; also, transient voltage surge suppression.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include manufacturer's name and product number, rated capacities, operating weights, electrical characteristics, furnished specialties, dimensions, mounting position, mounting method, vertical supports, material and accessories.
 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Detail fabrication and installation of transient voltage surge suppression assemblies including plans, elevations, sections, component details, and

attachments to other construction elements. Detail the connections for the TVSS to switchgear, switchboards, transformers, and panelboards. Detail supports and connections to building.

Coordinate requirements for coordination drawings with DEN Project Manager.

- C. Coordination Drawings: Include floor plans and sections to show transient voltage surge suppression assembly layouts and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified testing agency.
- B. Qualification Data: For product manufacturers specified in PART 2- PRODUCTS.

Retain first paragraph below for material or product certificates from manufacturers.

- C. Product Certificates: For TVSS devices, from manufacturer. Indicate what internal or external fusing is incorporated in the TVSS system and what impact the fusing has on the performance of the device. (I.e. surge capacity and clamping levels).

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- D. Field quality-control and test reports. Indicate and interpret test results for compliance with performance requirements.
 - 1. Certify that the TVSS system is UL 1449 listed.
 - 2. System testing requirements shall be as follows:
 - a. System shall be tested to meet ANSI/IEEE C62.41 1991, tested per ANSI/IEEE C62.45 1992. Category A & B – (0.5 μ SEC x 100 kHz Ring Wave) Category B Biwave – (8 x 20 μ SEC at 3,000 Amperes and 1.2 x 50 μ SEC at 6,000 Volts) Category C3 Biwave – (8 x 20 μ SEC at 10,000 Amperes and 1.2 x 50 μ SEC at 20,000 Volts.
 - b. The system shall be tested to 1,000 sequential ANSI/IEEE C62.41 Category C3 combination wave transients. The Category C3 combination wave is defined as a 1.2 x 50 microsecond at 20,000 volt open circuit voltage waveform and 8 x 20 microsecond at 10,000 ampere short circuit current waveform.
- E. Equipment Manual: The manufacturer shall furnish an installation manual with installation, start-up and operating instructions for the specified system.
 - 1. Installation instructions shall clearly state if the system requires an external over

current device to maintain the system's UL 1449 listing.

- F. Warranties: Sample of special warranties.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For TVSS devices to include in emergency, operation, and maintenance manuals.
- B. Equipment manual: A list of customer-replaceable spare parts shall be included in the unit's installation, operation and maintenance instructions. All spare parts shall be quickly and easily field-replaceable.
- C. Spare parts: A list of customer-replaceable spare parts shall be included in the unit's installation, operation and maintenance instructions. All spare parts shall be quickly and easily field-replaceable.
- D. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.
- E. Warranties: Complete special warranties for systems.

Verify requirements for as-built plans with DEN Project Manager.

- F. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Retain this Article only when modular replaceable TVSS is specified in Part 2 of Section Text.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

See Evaluations for discussion of modular and non-modular construction.

1. Replaceable Protection Modules: [**One (1)**] <Insert number> of each size and type installed.

1.8 QUALITY ASSURANCE

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in

addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency, and marked for intended location and application.
- C. Comply with IEEE C62.41.2 and test devices according to IEEE C62.45.
- D. Comply with NEMA LS 1.

Retain option in first paragraph below to require compliance with UL 1283 if the TVSS devices are to include electromagnetic and radio frequency interference filters. See Evaluations for explanation of the combination electromagnetic interference and radio frequency interference filters.

- E. Comply with [UL 1283 and]UL 1449.
- F. Comply with NFPA 70.

1.9 PROJECT CONDITIONS

Retain first paragraph below if interruption of existing electrical service is required

- A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
 - 2. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.
- B. Service Conditions: The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:
 - 1. Maximum Continuous Operating Voltage: Not less than 115 percent of nominal system operating voltage.
 - 2. Operating Temperature: Operating temperature range shall be minus 40 deg. to 140 deg. F (minus 40 to 60 deg. C).
 - 3. Storage Temperature: Minus 40 deg. to 185 deg. F (minus 40 to 85 deg. C).
 - 4. Relative Humidity: Shall be reliable in an environment with 5 percent to 95 percent non-condensing relative humidity.

5. Operating Altitude: The system shall be capable of operation in altitudes up to 13,000 feet above sea level.
6. Wind Speed: 115 mph wind load with gust factor of 1.3.
7. Audible noise: The system shall not generate any audible noise.
8. Magnetic fields: No appreciable magnetic fields shall be generated. System shall be capable of use directly in computer rooms or in any other location without danger to data storage systems or devices.
9. Location: Indoors/Outdoors.

1.10 COORDINATION

Retain first paragraph below for field-mounted suppressors.

- A. Coordinate location of field-mounted TVSS devices to allow adequate clearances for maintenance.
- B. Coordinate TVSS devices with Section 260913 "Electrical Power Monitoring and Control."

1.11 WARRANTY

Most manufacturers offer five-year extended warranties on their equipment. Some manufacturers of cord-connected, plug-in surge suppressors offer extended warranties that either repair or replace damaged equipment that is protected by the suppressor.

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of surge suppressors that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for surge suppressors with manufacturers listed in Part 2 articles.

1. Warranty Period: Minimum [five (5)] <Insert number> years..

Retain paragraph below if equipment repair or replacement is included.

- B. Special Warranty for Cord-Connected, Plug-in Surge Suppressors: Manufacturer's standard form in which manufacturer agrees to repair or replace electronic equipment connected to circuits protected by surge suppressors.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Other manufacturers, who have been engaged in the design and manufacturer of the specified system for a minimum of seven (7) years, desiring approval shall provide detailed compliance or exception statements to all provisions of this specification and shall comply with Division 01.

2.2 SERVICE ENTRANCE SUPPRESSORS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. ABB USA.
 2. AC Data Solutions.
 3. Advanced Protection Technologies Inc. (APT).
 4. Atlantic Scientific.
 5. Current Technology Inc.; Danaher Power Solutions.
 6. Danaher Power Solutions; United Power Products.
 7. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 8. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
 9. Intermatic, Inc.
 10. LEA International.
 11. Leviton Mfg. Company Inc.
 12. Liebert Corporation; a division of Emerson Network Power.
 13. Northern Technologies, Inc.; a division of Emerson Network Power.
 14. Siemens Energy & Automation, Inc.
 15. Square D; a brand of Schneider Electric.
 16. Surge Suppression Incorporated.
 17. <Insert manufacturer>
 18. or approved equal.

Retain one of first two paragraphs below. Comply with manufacturer's written recommendations for connecting TVSS devices to distribution system.

- B. Surge Protection Devices:

1. Non-modular.
2. LED indicator lights for power and protection status.
3. Audible alarm, with silencing switch, to indicate when protection has failed.
4. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.

C. Surge Protection Devices:

1. Comply with UL 1449.
2. **[Modular design (with field-replaceable modules)] [Non-modular design].**

Retain applicable accessories in subparagraphs below. Not all accessories are available with the modular design, modular design with field-replaceable modules and with non-modular designs. Verify availability and compatibility with manufacturers.

If specifying fuses for connecting TVSS devices to distribution system, verify ability of fuses to withstand surges consistent with ultimate surge current rating of device.

Retain first subparagraph below if fuses are a desired accessory. NFPA 70 requires that the TVSS short-circuit current rating is not exceeded; therefore the short-circuit current ratings should be indicated in schedules or on the Drawings.

3. Fuses, rated at 200-kA interrupting capacity.
4. Fabrication using bolted compression lugs for internal wiring.

Retain first subparagraph below only if a fused switch or circuit breaker is not provided for the TVSS in the panelboard and the TVSS will not have a direct bus bar connection.

5. Integral disconnect switch.
6. Redundant suppression circuits.
7. Redundant replaceable modules.

Retain one of first two subparagraphs below depending on service entrance equipment.

8. Arrangement with copper bus bars and for bolted connections to phase buses, neutral bus, and ground bus.
9. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
10. LED indicator lights for power and protection status.
11. Audible alarm, with silencing switch, to indicate when protection has failed.
12. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
13. **[Four] [Six]-digit transient-event counter set to totalize transient surges.**

Retain first option in first paragraph below for high exposure and cost, second option for medium exposure and cost, third option for low exposure and cost.

- D. Peak Single-Impulse Surge Current Rating: **[320 kA per mode/640 kA] [240 kA per mode/480 kA] [160 kA per mode/320 kA]** per phase.

- E. Minimum single impulse current ratings, using 8-by-20-mic.sec waveform described in IEEE C62.41.2
1. Line to Neutral: **[70,000]<Insert value> A.**
 2. Line to Ground: **[70,000]<Insert value> A.**
 3. Neutral to Ground: **[50,000]<Insert value> A.**

Retain one of four paragraphs below. Verify compatibility of peak surge current rating and clamping voltage. Reference to UL 1449 is to the Second Edition.

- F. Protection modes and UL 1449 SVR for grounded wye circuits with **[480Y/277 V] [208Y/120 V] [600Y/347 V]**, 3-phase, 4-wire circuits shall be as follows:
1. Line to Neutral: **[800 V for 480Y/277 V] [400 V for 208Y/120 V] [1200 V for 600Y/347 V].**
 2. Line to Ground: **[800 V for 480Y/277 V] [400 V for 208Y/120 V] [1200 V for 600Y/347 V].**
 3. Neutral to Ground: **[800 V for 480Y/277 V] [400 V for 208Y/120 V] [1200 V for 600Y/347 V].**
- G. Protection modes and UL 1449 SVR for 240/120 V, single-phase, 3-wire circuits shall be as follows:
1. Line to Neutral: 400 V.
 2. Line to Ground: 400 V.
 3. Neutral to Ground: 400 V.
- H. Protection modes and UL 1449 SVR for 240/120-V, 3-phase, 4-wire circuits with high leg shall be as follows:
1. Line to Neutral: 400 V, 800 V from high leg.
 2. Line to Ground: 400 V.
 3. Neutral to Ground: 400 V.
- I. Protection modes and UL 1449 SVR for 240 V, 480 V, or 600 V, 3-phase, 3-wire, delta circuits shall be as follows:
1. Line to Line: **[2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V].**
 2. Line to Ground: **[2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V].**

2.3 PANELBOARD SUPPRESSORS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. ABB USA.

2. AC Data Solutions.
3. Advanced Protection Technologies Inc. (APT).
4. Atlantic Scientific.
5. Current Technology Inc.; Danaher Power Solutions.
6. Danaher Power Solutions; United Power Products.
7. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
8. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
9. Intermatic, Inc.
10. LEA International.
11. Leviton Mfg. Company Inc.
12. Liebert Corporation; a division of Emerson Network Power.
13. Northern Technologies, Inc.; a division of Emerson Network Power.
14. Siemens Energy & Automation, Inc.
15. Square D; a brand of Schneider Electric.
16. Surge Suppression Incorporated.
17. **<Insert manufacturer>**
18. or approved equal.

Retain one of first two paragraphs below. Comply with manufacturer's written recommendations for connecting TVSS devices to distribution system.

B. Surge Protection Devices:

1. Non-modular.
2. LED indicator lights for power and protection status.
3. Audible alarm, with silencing switch, to indicate when protection has failed.
4. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.

C. Surge Protection Devices:

1. Comply with UL 1449.
2. **[Modular design (with field-replaceable modules)] [Non-modular design]**.
3. Short-circuit current rating complying with UL 1449, and matching or exceeding the panelboard short-circuit rating and redundant suppression circuits; with individually fused metal-oxide varistors.

Retain applicable accessories in subparagraphs below. Not all accessories are available with the modular design, modular design with field-replaceable modules and with non-modular designs. Verify availability and compatibility with manufacturers.

If specifying fuses for connecting TVSS devices to distribution system, verify ability of fuses to withstand surges consistent with ultimate surge current rating of device.

Retain first subparagraph below if fuses are a desired accessory. NFPA 70 requires that the TVSS short-circuit current rating is not exceeded; therefore the short-circuit current ratings should be indicated in schedules or on the Drawings.

4. Fuses, rated at 200-kA interrupting capacity.

5. Fabrication using bolted compression lugs for internal wiring.

Retain first subparagraph below only if a fused switch or circuit breaker is not provided for the TVSS in the panelboard and the TVSS will not have a direct bus bar connection.

6. Integral disconnect switch.
7. Redundant suppression circuits.
8. Redundant replaceable modules.
9. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
10. LED indicator lights for power and protection status.
11. Audible alarm, with silencing switch, to indicate when protection has failed.
12. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
13. **[Four] [Six]**-digit transient-event counter set to totalize transient surges.

Retain first option in first paragraph below for high exposure and cost, second option for medium exposure and cost, third option for low exposure and cost.

- D. Peak Single-Impulse Surge Current Rating: **[160 kA per mode/320 kA] [120 kA per mode/240 kA] [80 kA per mode/160 kA]** per phase.
- E. Minimum single impulse current ratings, using 8-by-20-mic.sec waveform described in IEEE C62.41.2:
 1. Line to Neutral: **[70,000]<Insert value>** A.
 2. Line to Ground: **[70,000]<Insert value>** A.
 3. Neutral to Ground: **[50,000]<Insert value>** A.

Retain one of four paragraphs below. Verify compatibility of peak surge current rating and clamping voltage. Reference to UL 1449 is to the Second Edition.

- F. Protection modes and UL 1449 SVR for grounded wye circuits with **[480Y/277 V] [208Y/120 V] [600Y/347 V]**, 3-phase, 4-wire circuits shall be as follows:
 1. Line to Neutral: **[800 V for 480Y/277 V] [400 V for 208Y/120 V] [1200 V for 600Y/347 V]**.
 2. Line to Ground: **[800 V for 480Y/277 V] [400 V for 208Y/120 V] [1200 V for 600Y/347 V]**.
 3. Neutral to Ground: **[800 V for 480Y/277 V] [400 V for 208Y/120 V] [1200 V for 600Y/347 V]**.
- G. Protection modes and UL 1449 SVR for 240/120-V, single-phase, 3-wire circuits shall be as follows:
 1. Line to Neutral: 400 V.
 2. Line to Ground: 400 V.
 3. Neutral to Ground: 400 V.
- H. Protection modes and UL 1449 SVR for 240/120-V, 3-phase, 4-wire circuits with high

leg shall be as follows:

1. Line to Neutral: 400 V, 800 V from high leg.
 2. Line to Ground: 400 V.
 3. Neutral to Ground: 400 V.
- I. Protection modes and UL 1449 SVR for 240 V, 480 V, or 600 V, 3-phase, 3-wire, delta circuits shall be as follows:
1. Line to Line: **[2000 V for 480 V] [1000 V for 240 V] [2500 V for 600 V]**.
 2. Line to Ground: **[1500 V for 480 V] [800 V for 240 V] [2500 V for 600 V]**.

2.4 ENCLOSURES

- A. Indoor Enclosures: NEMA 250 **[Type 1] [Type 12]**.
- B. Outdoor Enclosures: NEMA 250 **[Type 3R] [Type 4] [Type 4X]**.

Revise or delete article and paragraphs below to suit project.

2.5 ACCESSORIES (OPTIONAL EQUIPMENT)

- A. Integral fused disconnect switch:
1. The MP, DP and DPA Series surface-mounted units shall include an integral fused and safety interlocked disconnect switch located in each unit enclosure with an externally mounted manual operator. Each switch shall disconnect all ungrounded circuit conductors from the distribution system to enable testing and maintenance without interruption of power to the facility's distribution system. Each switch shall be rated for 600 Vac.
 2. Each current-carrying ungrounded circuit conductor connected to the facility's distribution system shall be individually fused with 200,000 AIC rated fuses in order to provide maximum fault current protection.
 3. Each unit shall be UL-1449 listed with the integral fused disconnect switch and the UL-1449 Suppression Rating for this configuration shall be provided.
 4. An integral Fused Disconnect Switch shall be provided on those units which have a "DF" suffix added to their model number.
- B. Remote status monitor contacts:
1. Each unit shall include Form C dry contacts (N.O. or N.C.) to facilitate connection to a building management system in order to monitor the on-line status of the unit. The contacts shall be normally open or normally closed and shall close or open upon failure of the suppression system and/or fuse.
 2. Remote Status Monitor Contacts shall be provided on those units which have a "FCC" suffix added to their model number.
- C. Diagnostic test set:

1. A diagnostic Test Set shall be provided which verifies the operational integrity of each unit's suppression system. The Diagnostic Test Set shall be self-contained and portable, and shall provide complete assurance of the unit's installation and capability without stressing the suppression system or posing detriment to continued operation.
2. Supply a Diagnostic Test Set (DTS 1000) with each facility-wide protection system.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. The unit(s) shall be installed as close as practical to the facility's wiring system in accordance with applicable national/local electrical codes and the manufacturer's recommended installation instructions.
- B. Install TVSS devices at service entrance on load side, with ground lead bonded to service entrance ground.
- C. Install TVSS devices for panelboards and auxiliary panels with conductors or buses between suppressor and points of attachment as short and straight as possible. Do not exceed manufacturer's recommended lead length. Do not bond neutral and ground.

Comply with manufacturer's written recommendation for conductor and circuit-breaker size for connecting TVSS devices to distribution system. Match circuit-breaker size to conductor size. Coordinate with Drawings.

1. Provide multiple, [30] [60] [100]-A circuit breaker as a dedicated disconnecting means for TVSS unless otherwise indicated.
- D. Connection shall be with the following size of copper conductor or larger and not be any longer than necessary, avoiding unnecessary bends:
 1. High exposure service entrance (MP) #2 AWG.
 2. Medium exposure distribution panelboard (DP) #4 AWG.
 3. Lower exposure distribution panelboard (DPA) #8 AWG.
- E. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

3.2 FIELD QUALITY CONTROL

Retain one of first two paragraphs below to identify who shall perform tests and inspections. Retain and edit "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain subparagraph below to require factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- C. Tests and Inspections:

1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS, "Surge Arresters, Low-Voltage Surge Protection Devices" Section. Certify compliance with test parameters.
2. After installing TVSS devices but before electrical circuitry has been energized, test for compliance with requirements.
3. Complete startup checks according to manufacturer's written instructions.

- D. UL-1449 suppression ratings:

1. Documentation of units' UL-1449 suppression rating shall be included as required product data submittal information. Manufacturer shall make available upon request certified documentation of applicable location category testing in full compliance with ANSI/IEEE- C62.41 and ANSI/IEEE-C62.45-1987 Guidelines.

- E. Testing:

1. The unit(s) shall be thoroughly factory-tested before shipment. Testing of each unit shall include but shall not be limited to quality assurance checks, MCOV and clamping verification tests. The MCOV testing shall consist of the unit(s) being burned-in at the applicable MCOV for a minimum of one (1) hour.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- F. TVSS device will be considered defective if it does not pass tests and inspections.

- G. Prepare test and inspection reports.

3.3 STARTUP SERVICE

- A. Do not energize or connect **[service entrance equipment] [panelboards] [control terminals] [data terminals]** to their sources until TVSS devices are installed and connected.

Retain paragraph below if NETA insulation resistance tests are specified in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

- B. Do not perform insulation resistance tests of the distribution wiring equipment with the TVSS installed. Disconnect before conducting insulation resistance tests, and reconnect immediately after the testing is over.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to maintain TVSS devices.
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 Method of Measurement:

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 Payment:

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 264313

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SECTION 265100 - INTERIOR LIGHTING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed. All engineer notes shall be deleted from the file or marked as hidden.

If applying for LEED certification, LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1. ASHRAE/IESNA 90.1, Section 9 - "Lighting," sets maximum interior and exterior lighting power densities and minimum requirements for lighting controls. The selection of the lamp and ballast as a system is an important design decision to optimize energy efficiency of the lighting system.

A reduction in lighting energy usage can be combined with other energy-conserving measures to meet the requirements of LEED-NC, LEED-CS, and LEED for Schools Credit EA 1 or LEED-CI Credit EA 1.1.

LEED-NC, LEED-CS, and LEED for Schools Credit SS 8 and LEED-CI Credit SS 1 Option 1F require that the angle of the maximum candela of any of the interior light fixtures not spill through any of the building's transparent and translucent surfaces to the exterior areas, and that all interior, nonemergency lights be automatically turned off after hours with manual override capabilities for after-hours use. Credit SS 8 and Credit SS 1 Option 1F also set requirements for exterior lighting. See Section 265600 "Exterior Lighting."

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. The contractor shall furnish and install all lighting equipment, lighting fixtures, brackets, hangers, lamps, raceway, cable, panels, and transformers as shown in fixture schedule, drawings and as required for all outlets indicated on the drawings.

B. Section Includes:

1. Interior lighting fixtures, lamps, and ballasts.
2. Emergency lighting units.
3. Exit signs.
4. Lighting fixture supports.
5. Retrofit kits for fluorescent lighting fixtures.

C. Related Sections:

Retain Sections in subparagraphs below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 260923 "Lighting Control Devices" for automatic control of lighting, including time switches, photoelectric relays, occupancy sensors, and multipole lighting relays and contactors.
2. **[Section 260933 "Central Dimming Controls"] [Section 260936 "Modular Dimming Controls"]** for architectural dimming systems.
3. Section 260943 "Network Lighting Controls" for manual or programmable control systems with low-voltage control wiring or data communication circuits.
4. Section 262726 "Wiring Devices" for manual wall-box dimmers for incandescent lamps.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- D. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. BF: Ballast factor.
- B. CCT: Correlated color temperature.
- C. CRI: Color-rendering index.
- D. HID: High-intensity discharge.
- E. LED: Light Emitting Diode.
- F. LER: Luminaire efficacy rating.
- G. Lumen: Measured output of lamp and luminaire, or both.
- H. Luminaire: Complete lighting fixture, including ballast housing if provided.

Retain paragraph below if project contains "neon" lighting.

- I. "Neon" lighting: A generic term meaning lighting consisting of a gaseous discharge inside a glass tube with cold-leads, subjected to a high voltage supplied by an external transformer.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of lighting fixture, arranged in order of fixture designation. Include data on features, accessories, finishes, and the following:
 1. Physical description of lighting fixture including dimensions.
 2. Emergency lighting units including battery and charger.
 3. Ballast, including BF.
 4. Energy-efficiency data.

Retain first two subparagraphs below for projects with air-handling lighting fixtures.

5. Air and Thermal Performance Data: For air-handling lighting fixtures. Furnish data required in "Action Submittals" Article in Section 233713 "Diffusers, Registers, and Grilles."
6. Sound Performance Data: For air-handling lighting fixtures. Indicate sound power level and sound transmission class in test reports certified according to standards specified in Section 233713 "Diffusers, Registers, and Grilles."
7. Life, output (lumens, CCT, and CRI), and energy-efficiency data for lamps.

Coordinate subparagraph below with testing laboratory qualifications in "Quality Assurance" Article.

8. Photometric data and adjustment factors based on laboratory tests, complying with IESNA Lighting Measurements Testing & Calculation Guides, of each lighting fixture type. The adjustment factors shall be for lamps, ballasts, and accessories identical to those indicated for the lighting fixture as applied in this Project.
 - a. Manufacturer Certified Data: Photometric data shall be certified by a manufacturer's laboratory with a current accreditation under the National Voluntary Laboratory Accreditation Program for Energy Efficient Lighting Products.
9. Illumination data with light fixture efficiency, table of zonal cavity coefficients of utilization, recommended maximum spacing-to-mounting ratio and candlepower distribution curves drawn to scale such that candlepower can be scaled at different angles (or provide candlepower data in tabular form at 10 degree increments).
10. Include data substantiating that materials comply with requirements.

Retain first paragraph below for custom lighting fixtures.

- B. Shop Drawings: For non-standard or custom lighting fixtures. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

Retain subparagraph below if equipment includes wiring.

2. Wiring Diagrams: For power, signal, and control wiring.
3. Light fixture shop drawings shall be in booklet form with a separate sheet for each fixture, assembled in "luminaire type" alphabetical or numerical order, with proposed fixture, lamp type, and accessories clearly indicated on each sheet. Details indicating compatibility with ceiling grid system are required.

Retain first paragraph below if Samples of interior lighting fixtures are required. Coordinate with the Interior Lighting Fixture Schedule on Drawings.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: One complete operating unit for each type of interior light fixture when requested by DEN Project Manager. Each Sample shall include the following:
 1. Lamps and ballasts, installed.
 2. Cords and plugs.
 3. Pendant support system.
- D. Installation instructions.
- E. Substitutions:
 1. Substitutions: Under provisions of Division 01. One sample of each proposed light fixture substitution unless the DEN Project Manager waives requirement.
 2. Printed physical, electrical and photometric data clearly highlighted to show the differences between the proposed substitutions and the specified light fixture.
 3. Photometric information in IES standard format on a disc and printed on 8½" x 11" pages.
 4. Point to point lighting calculation for all typical spaces.

Retain paragraph and sub-paragraphs below if project contains "neon" lighting.

- F. "Neon" Lighting:
 1. Installation of neon lighting is not allowed without written authorization by the DEN Project Manager.

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph below unless requirement for coordination drawings is waived by DEN Project Manager.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, on

which the following items are shown and coordinated with each other, using input from installers of the items involved:

Revise subparagraphs below to suit Project.

1. Lighting fixtures.
2. Suspended ceiling components.
3. Partitions and millwork that penetrate the ceiling or extends to within 12 inches (305 mm) of the plane of the luminaires.
4. Ceiling-mounted projectors.
5. Structural members to which suspension systems for lighting fixtures will be attached.
6. Other items in finished ceiling including the following:
 - a. Air outlets and inlets.
 - b. Speakers.
 - c. Sprinklers.
 - d. Smoke and fire detectors.
 - e. Occupancy sensors.
 - f. Access panels.
 - g. <Insert item>.
7. Perimeter moldings.

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For qualified agencies providing photometric data for lighting fixtures.

Retain first paragraph below for product certificates from manufacturers.

- C. Product Certificates: For each type of ballast for bi-level and dimmer-controlled fixtures, from manufacturer.
- D. Field quality-control reports.
- E. Maintenance Data: Maintenance data and parts lists for each interior lighting fixture and accessory; including "trouble-shooting" maintenance guide. All data, product data and shop drawings shall be included in a maintenance manual.
- F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For lighting equipment and fixtures to include in emergency, operation, and maintenance manuals.
 1. Provide a list of all lamp types used on Project; use ANSI and manufacturers' codes.

- B. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

Verify requirements for as-built plans with DEN Project Manager.

- C. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Revise subparagraphs below to suit Project.

1. Lamps: Fifteen (15) for every 100 but not less than four (4) of each type and rating installed.
2. Plastic Diffusers and Lenses: **One for every 100** of each type and rating installed. Furnish at least one of each type.
3. Fluorescent-fixture-mounted, emergency battery pack: One for every **20** emergency lighting unit.
4. Ballasts: **One for every 100** of each type and rating installed. Furnish at least one of each type.
5. Globes and Guards: **One for every 20** of each type and rating installed. Furnish at least one of each type.

1.8 QUALITY ASSURANCE

Retain one of first two paragraphs below, or both, to specify qualifications for laboratories providing photometric data to be submitted for lighting fixtures.

- A. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by manufacturers' laboratories that are accredited under the National Volunteer Laboratory Accreditation Program for Energy Efficient Lighting Products.

"Luminaire Photometric Data Testing Laboratory Qualifications" Paragraph below is to set qualifications for testing laboratories performing testing, in lighting fixture manufacturer's factory, that are creating the photometric data required in "Action Submittals" Article.

- B. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by an independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910, complying with the IESNA Lighting Measurements Testing & Calculation Guides.

- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with NFPA 70.
- E. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents. All equipment furnished under this section shall carry a UL Listing.

Coordinate "FM Global Compliance" Paragraph below with Drawings.

- F. FM Global Compliance: Lighting fixtures for hazardous locations shall be listed and labeled for indicated class and division of hazard by FM Global.

Retain paragraph below if directed by DEN Project Manager. Mockup lighting fixtures are often part of a typical room or module mockup used to evaluate and demonstrate an overall interior concept, not just lighting.

Verify mockup requirements with DEN Project Manager.

- G. Mockups: Provide interior lighting fixtures for room or module mockups, complete with power and control connections.
 - 1. Obtain DEN Project Manager's approval of fixtures for mockups before starting installations.
 - 2. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.

Retain subparagraph below if mockups are installed as part of building rather than erected separately and the intention is to make an exception to the default requirement in Section 014000 "Quality Requirements" for demolishing and removing mockups when directed unless otherwise indicated.

- 3. Approved fixtures in mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.9 COORDINATION

- A. Coordinate layout and installation of lighting fixtures and suspension system with other construction that penetrates ceilings or is supported by them, including HVAC equipment, fire-suppression system, and partition assemblies.
- B. The drawings are diagrammatic and indicate the general arrangement of electrical work. Locations are approximate and shall be subject to minor modifications as dictated by field conditions and as directed by DEN Project Manager.

1.10 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Retain article for rechargeable batteries for emergency lighting equipment. See "Ballast and Lamp Warranties" Article in the Evaluations for a discussion on available warranties.

- A. Special Warranty for Emergency Lighting Batteries: Manufacturer's standard form in which manufacturer of battery-powered emergency lighting unit agrees to repair or replace components of rechargeable batteries that fail in materials or workmanship within specified warranty period.

Subparagraphs below are examples only. Verify available warranties and warranty periods for units and components and insert number below. Coordinate with "Emergency Lighting Units" Article.

1. Warranty Period for Emergency Lighting Unit Batteries: Minimum three (3) years from date of Substantial Completion. Full warranty shall apply for first year, and prorated warranty for the remaining two years.
2. Warranty Period for **Emergency Fluorescent Ballast and Self-Powered Exit Sign** Batteries: Minimum Three (3) years from date of Substantial Completion. Full warranty shall apply for first year, and prorated warranty for the remaining two (2) years.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

Retain "Products" Paragraph below. Delete this article if no manufacturers and product designations are indicated. See Section 016000 "Product Requirements." See Editing Instruction No. 1 in the Evaluations for discussion on specifying lighting fixtures via the Interior Lighting Fixture Schedule on Drawings.

Retain "Products" Paragraph below. Delete this article if no manufacturers and product designations are indicated. See Section 016000 "Product Requirements."

- A. Products: Subject to compliance with requirements, provide products indicated on drawings, or approved equal.

2.2 GENERAL REQUIREMENTS FOR LIGHTING FIXTURES AND COMPONENTS

- A. General: Lighting fixtures are to be of the sizes, types and ratings required complete with, but not limited to, housings, high power factor ballasts, energy-efficient lamps, lamp holders, reflectors, energy-efficient ballasts, starters, and wiring. Fixtures are to be factory-assembled, with those components required for complete installation. Fixtures with concealed hinges and catches are to have metal parts grounded as a

common unit and be constructed to dampen ballast generated noise. Equipment and materials shall bear the UL label.

- B. Environmental Conditions: The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:
1. Location: Indoors.
 2. Altitude 5,500 feet (1677 m) above sea level.
 3. Ambient temperature range minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C), for fixtures in unconditioned locations.
- C. Recessed Fixtures: Comply with NEMA LE 4 for ceiling compatibility for recessed fixtures.

Retain one or more of first three paragraphs below that require compliance with the listed LER. See Editing Instruction No. 5 in the Evaluations for guidance on specifying LER. The numeric value of LER is specified in the Interior Lighting Fixture Schedule on Drawings.

- D. Incandescent Fixtures: Comply with UL 1598. Where LER is specified, test according to NEMA LE 5A.
- E. Fluorescent Fixtures: Comply with UL 1598. Where LER is specified, test according to NEMA LE 5 and NEMA LE 5A as applicable.
- F. HID Fixtures: Comply with UL 1598. Where LER is specified, test according to NEMA LE 5B.
- G. LED Fixtures: RoHS compliant. Comply with ANSI C78.377 and UL 8750.
- H. Metal Parts: Free of burrs and sharp corners and edges.
- I. Provide all ferrous metal surfaces with a protective finish having rust inhibiting properties. Painted finishes shall be a minimum of 1.5 mils thick and shall have a balance between hardness and bending properties suitable for the application. White finishes shall have 87% minimum reflectance.
- J. Fixtures to be installed in a damp or wet location shall be constructed with proper gasketing and corrosion resistant materials and/or coatings, and have appropriate UL Listing label for wet locations. Construct steel fixture channels, end caps, interior barriers, reflectors, etc. of adequate gauge.
- K. Sheet Metal Components: Steel unless otherwise indicated. Form and support to prevent warping and sagging.
- L. Doors, Frames, and Other Internal Access: Smooth operating, free of light leakage under operating conditions, and designed to permit relamping without use of tools. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position.
- M. Diffusers and Globes:

1. Acrylic Lighting Diffusers: 100 percent virgin acrylic plastic. High resistance to yellowing and other changes due to aging, exposure to heat, and UV radiation. Minimum unpenetrated thickness shall be 0.35". Polystyrene plastic shall not be permitted. All plastics shall be ETL certified as light stabilized, non-yellowing.
 - a. Lens Thickness: At least 0.125 inch (3.175 mm) minimum unless otherwise indicated.
 - b. UV stabilized.
2. Glass: Annealed crystal glass unless otherwise indicated.

See Editing Instruction No. 8 in the Evaluations for discussion on luminaire labeling.

- N. Factory-Applied Labels: Comply with UL 1598. Include recommended lamps and ballasts. Labels shall be located where they will be readily visible to service personnel, but not seen from normal viewing angles when lamps are in place.

1. Label shall include the following lamp and ballast characteristics:
 - a. "USE ONLY" and include specific lamp type.
 - b. Lamp diameter code (T-4, T-5, T-8, T-12, etc.), tube configuration (twin, quad, triple, etc.), base type, and nominal wattage for fluorescent and compact fluorescent luminaires.
 - c. Lamp type, wattage, bulb type (ED17, BD56, etc.) and coating (clear or coated) for HID luminaires.
 - d. Start type (preheat, rapid start, instant start, etc.) for fluorescent and compact fluorescent luminaires.
 - e. ANSI ballast type (M98, M57, etc.) for HID luminaires.
 - f. CCT and CRI for all luminaires.

Retain "Electromagnetic-Interference Filters" Paragraph below for special applications where freedom from conducted electromagnetic interference is critical. Coordinate with the Interior Lighting Fixture Schedule on Drawings.

- O. Electromagnetic-Interference Filters: Factory installed to suppress conducted electromagnetic interference as required by MIL-STD-461E. Fabricate lighting fixtures with one filter on each ballast indicated to require a filter.

Retain paragraph and sub-paragraphs below if air-handling fluorescent fixtures are used on project.

- P. Air-Handling Fluorescent Fixtures: For use with plenum ceiling for air return and heat extraction and for attaching an air-diffuser-boot assembly specified in Section 233713 "Diffusers, Registers, and Grilles."
1. Air-Supply Units: Slots in one or both side trims join with air-diffuser-boot assemblies.
 2. Heat-Removal Units: Air path leads through lamp cavity.
 3. Combination Heat-Removal and Air-Supply Unit: Heat is removed through lamp cavity at both ends of the fixture door with air supply same as for air-supply units.
 4. Dampers: Operable from outside fixture for control of return-air volume.

5. Static Fixture: Air-supply slots are blanked off, and fixture appearance matches active units.

Q. Color Rendering Index: All luminaires furnished as part of the project shall have a minimum color rendering index (CRI) of 80.

2.3 BALLASTS FOR LINEAR FLUORESCENT LAMPS

For fixtures requiring other than instant-start ballasts, indicate ballast type in the Interior Lighting Fixture Schedule on Drawings. See Editing Instruction No. 6 in the Evaluations for discussion on instant-, rapid-, and programmed-start ballasts.

A. General Requirements for Electronic Ballasts:

1. Comply with UL 935 and with ANSI C82.11.
2. Designed for type and quantity of lamps served.
3. Ballasts shall be designed for full light output unless another BF, dimmer, or bi-level control is indicated.

ANSI C82.11 states that lamp and ballast combinations are for operation at temperatures of 50 to 105.8 deg F (10 to 41 deg C). Applications outside this range should be noted in the Interior Lighting Fixture Schedule on Drawings.

4. Sound Rating: Class A.

See Evaluations for discussion on harmonic considerations.

5. Total Harmonic Distortion Rating: Less than **10** percent.
6. Transient Voltage Protection: IEEE C62.41.1 and IEEE C62.41.2, Category A or better.

Lower operating frequencies are available but may interfere with default ballasts when used in proximity of infrared sensors.

7. Operating Frequency: 42 kHz or higher.

See Editing Instruction No. 4 in the Evaluations for discussion on lamp current crest factor.

8. Lamp Current Crest Factor: **1.7** or less.
9. BF: **0.88** or higher.
10. Power Factor: **0.95** or higher.

Retain "Parallel Lamp Circuits" Subparagraph below if default ballast is programmed-start type and it is important for surviving lamps to operate when one lamp served by that ballast has failed. There may be a cost premium for this little-used option for programmed-start ballasts.

11. Parallel Lamp Circuits: Multiple lamp ballasts shall comply with ANSI C82.11 and shall be connected to maintain full light output on surviving lamps if one or more lamps fail.

B. Luminaires controlled by occupancy sensors shall have programmed-start ballasts.

C. Electronic Programmed-Start Ballasts for **T8, T5 and T5HO** Lamps: Comply with ANSI C82.11 and the following:

1. Lamp end-of-life detection and shutdown circuit for T5 diameter lamps.

2. Automatic lamp starting after lamp replacement.

Retain "Single Ballasts for Multiple Lighting Fixtures" Paragraph below to require ballasts in some fixtures to serve lamps in other fixtures. Indicate fixture types to which this requirement applies in the Interior Lighting Fixture Schedule on Drawings, and indicate connections on lighting plans.

- D. Single Ballasts for Multiple Lighting Fixtures: Factory wired with ballast arrangements and bundled extension wiring to suit final installation conditions without modification or rewiring in the field.
- E. Ballasts for Low-Temperature Environments:

Retain subparagraph below if lamp starting and operating temperature at minus 30 deg F (minus 35 deg C) is a critical requirement. Verify, with manufacturers, the compatibility of ballasts with indicated lamps for low-temperature operation.

- 1. Temperatures minus 30 deg F (minus 35 deg C) and higher: Electronic type rated for minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C) starting and operating temperature with indicated lamp types.

Retain "Ballasts for Low Electromagnetic-Interference Environments" Paragraph below for projects or locations that have higher than normal sensitivity to electromagnetic interference. Coordinate with Drawings. Products for consumer use (usually household) must suit more stringent electromagnetic-interference limitations than those for nonconsumer environments. See "Ballasts" Article in the Evaluations for more information.

- F. Ballasts for Low Electromagnetic-Interference Environments: Comply with 47 CFR 18, Ch. 1, Subpart C, for limitations on electromagnetic and radio-frequency interference for consumer equipment.
- G. Ballasts for Dimmer-Controlled Lighting Fixtures: Electronic type.
 - 1. Dimming Range: 100 to 1 percent of rated lamp lumens.
 - 2. Ballast Input Watts: Can be reduced to 10 percent of normal.
 - 3. Compatibility: Certified by manufacturer for use with specific dimming control system and lamp type indicated.

Coordinate "Control" Subparagraph below if lighting control Section(s) is used for Project, which may include either Section 260943 "Network Lighting Controls" or Section 260923 "Lighting Control Devices."

- 4. Control: Coordinate wiring from ballast to control device to ensure that the ballast, controller, and connecting wiring are compatible.

Use of bi-level and tri-level ballasts may comply with state and local energy-conservation code requirements, including Title 24, Part 6, of the California Code of Regulations.

- H. Ballasts for Bi-Level Controlled Lighting Fixtures: Electronic type.
 - 1. Operating Modes: Ballast circuit and leads provide for remote control of the light output of the associated lamp between high- and low-level and off.
 - a. High-Level Operation: 100 percent of rated lamp lumens.
 - b. Low-Level Operation: 30 percent of rated lamp lumens.

2. Ballast shall provide equal current to each lamp in each operating mode.
3. Compatibility: Certified by manufacturer for use with specific bi-level control system and lamp type indicated.

I. Ballasts for Tri-Level Controlled Lighting Fixtures: Electronic type.

1. Operating Modes: Ballast circuit and leads provide for remote control of the light output of the associated lamp between high- and low-level and off.
 - a. High-Level Operation: 100 percent of rated lamp lumens.

In first subparagraph below, edit percentages if required for tri-level ballasts, depending on manufacturer.

- b. Low-Level Operation: **30 and 50** percent of rated lamp lumens.
2. Ballast shall provide equal current to each lamp in each operating mode.
3. Compatibility: Certified by manufacturer for use with specific tri-level control system and lamp type indicated.

2.4 BALLASTS FOR COMPACT FLUORESCENT LAMPS

ANSI C82.11 states that lamp and ballast combinations are for operation at temperatures of 50 to 105.8 deg F (10 to 41 deg C). Applications outside this range should be noted in the Interior Lighting Fixture Schedule on Drawings.

- A. Description: Electronic-programmed rapid-start type, complying with UL 935 and with ANSI C 82.11, designed for type and quantity of lamps indicated. Ballast shall be designed for full light output unless dimmer or bi-level control is indicated:
1. Lamp end-of-life detection and shutdown circuit.
 2. Automatic lamp starting after lamp replacement.
 3. Sound Rating: Class A.
 4. Total Harmonic Distortion Rating: Less than 20 percent.
 5. Transient Voltage Protection: IEEE C62.41.1 and IEEE C62.41.2, Category A or better.
 6. Operating Frequency: 20 kHz or higher.
 7. Lamp Current Crest Factor: 1.7 or less.
 8. BF: 0.95 or higher unless otherwise indicated.
 9. Power Factor: **0.95** or higher.

See "Ballasts" Article in the Evaluations for discussion on CFR compliance required in subparagraph below.

10. Interference: Comply with 47 CFR 18, Ch. 1, Subpart C, for limitations on electromagnetic and radio-frequency interference for nonconsumer equipment.

2.5 EMERGENCY FLUORESCENT POWER UNIT

Retain one or both paragraphs in this article to specify emergency battery operation of either linear or compact fluorescent fixtures for code-required egress lighting. Indicate fixture types to be equipped with

these devices in the Interior Lighting Fixture Schedule on Drawings, and indicate connections on lighting plans.

- A. Internal Type: Self-contained, modular, battery-inverter unit, factory mounted within lighting fixture body and compatible with ballast. Comply with UL 924.
1. Emergency Connection: Operate two (2) fluorescent lamp(s) continuously at an output of at least 700 lumens each. Connect unswitched circuit to battery-inverter unit and switched circuit to fixture ballast.

Retain "Nightlight Connection" Subparagraph below to require nightlight connections. If used, differentiate two connection modes on Drawings or in the Interior Lighting Fixture Schedule on Drawings.

2. Nightlight Connection: Operate one fluorescent lamp continuously.
3. Test Push Button and Indicator Light: Visible and accessible without opening fixture or entering ceiling space.
 - a. Push Button: Push-to-test type, in unit housing, simulates loss of normal power and demonstrates unit operability.
 - b. Indicator Light: LED indicates normal power on. Normal glow indicates trickle charge; bright glow indicates charging at end of discharge cycle.
4. Battery: Sealed, maintenance-free, nickel-cadmium type.
5. Charger: Fully automatic, solid-state, constant-current type with sealed power transfer relay.

Retain "Remote Test" Subparagraph below to allow periodic test, as required by codes for emergency equipment, to be performed using a hand-held remote device to trigger simulation of loss of normal power in the tested unit.

6. Remote Test: Switch in hand-held remote device aimed in direction of tested unit initiates coded infrared signal. Signal reception by factory-installed infrared receiver in tested unit triggers simulation of loss of its normal power supply, providing visual confirmation of either proper or failed emergency response.

Retain "Integral Self-Test" Subparagraph below to eliminate necessity to manually perform periodic test required by codes for emergency equipment. Verify requirements of authorities having jurisdiction.

7. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

- B. External Type: Self-contained, modular, battery-inverter unit, suitable for powering one or more fluorescent lamps, remote mounted from lighting fixture. Comply with UL 924.

1. Emergency Connection: Operate one fluorescent lamp continuously. Connect unswitched circuit to battery-inverter unit and switched circuit to fixture ballast.

Retain "Nightlight Connection" Subparagraph below if nightlight connections are used. If used, differentiate two connection modes on Drawings or in the Interior Lighting Fixture Schedule on Drawings.

2. Nightlight Connection: Operate one fluorescent lamp in a remote fixture continuously.
3. Battery: Sealed, maintenance-free, nickel-cadmium type.
4. Charger: Fully automatic, solid-state, constant-current type.

5. Housing: NEMA 250, Type 1 enclosure.
6. Test Push Button: Push-to-test type, in unit housing, simulates loss of normal power and demonstrates unit operability.
7. LED Indicator Light: Indicates normal power on. Normal glow indicates trickle charge; bright glow indicates charging at end of discharge cycle.

Retain "Remote Test" Subparagraph below to allow periodic test, as required by codes for emergency equipment, to be performed using a hand-held remote device to trigger simulation of loss of normal power in the tested unit.

8. Remote Test: Switch in hand-held remote device aimed in direction of tested unit initiates coded infrared signal. Signal reception by factory-installed infrared receiver in tested unit triggers simulation of loss of its normal power supply, providing visual confirmation of either proper or failed emergency response.

Retain "Integral Self-Test" Subparagraph below to eliminate necessity to manually perform periodic test required by codes for emergency equipment. Verify requirements of authorities having jurisdiction.

9. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

2.6 DRIVERS FOR SOLID-STATE LAMPS

- A. Description: Listed, electronic, RoHS compliant, meeting the requirements of ANSI C82.77 and UL 8750.
 1. Dimming: Where required. Meet or exceed specified dimming percentage.
 2. Temperature rating: Match or exceed environmental requirements.
 3. Rated Life: 50,000 hours minimum.
 4. Manufacturer's Warranty: Five (5) years minimum.

2.7 EMERGENCY LED POWER UNIT

- A. Self-contained. Comply with UL 924, ANSI C78.377, and UL 8750. Emergency power unit and associated solid-state light source shall be listed as a complete assembly.
 1. Battery: Sealed, maintenance-free, **nickel-cadmium, lithium-ion, or lithium-polymer type**. All batteries supplied for emergency units shall be of the same type.
 2. Charger: Fully automatic, solid-state, constant-current type.
 3. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

2.8 BALLASTS FOR HID LAMPS

Retain "Electronic Ballast for Metal-Halide Lamps" Paragraph below if Project includes pulse-start, metal-halide fixtures with electronic ballasts. See Evaluations for discussion.

- A. Electronic Ballast for Metal-Halide Lamps: Include the following features unless otherwise indicated:
1. Minimum Starting Temperature: **Minus 30 deg F** (minus 35 deg C) for single-lamp ballasts.
 2. Rated Ambient Operating Temperature: **130 deg F** (54 deg C).
 3. Lamp end-of-life detection and shutdown circuit.
 4. Sound Rating: Class A.
 5. Total Harmonic Distortion Rating: Less than **20** percent.
 6. Transient Voltage Protection: IEEE C62.41.1 and IEEE C62.41.2, Category A or better.
 7. Lamp Current Crest Factor: 1.5 or less.
 8. Power Factor: 0.90 or higher.

See "Ballasts" Article in the Evaluations for discussion on CFR compliance required in "Interference" Subparagraph below.

9. Interference: Comply with 47 CFR 18, Ch. 1, Subpart C, for limitations on electromagnetic and radio-frequency interference for nonconsumer equipment.
 10. Protection: Class P thermal cutout.
- B. High-Pressure Sodium Ballasts: Electromagnetic type, with solid-state igniter/starter. Igniter/starter shall have an average life in pulsing mode of 10,000 hours at an igniter/starter-case temperature of 90 deg C.

Retain "Instant-Restrike Device" Subparagraph below if extinguishing of high-pressure sodium lamps caused by momentary power interruptions is unacceptable for safety, security, or other reasons. When this Section was updated, this device was available for high-pressure lamps in sizes up to 150 W. Dual-arc tube lamp feature specified in "HID Lamps" Article may also be considered. Verify, with manufacturers, availability of individual ratings before scheduling or specifying.

1. Instant-Restrike Device (where indicated on drawings): Integral with ballast, or solid-state potted module, factory installed within fixture and compatible with lamps, ballasts, and mogul sockets up to 150 W.
2. Minimum Starting Temperature: **Minus 40 deg F** (Minus 40 deg C).

2.9 QUARTZ LAMP LIGHTING CONTROLLER

- A. General Requirements for Controllers: Factory installed by lighting fixture manufacturer. Comply with UL 1598.
- B. Standby (Quartz Restrike): Automatically switches quartz lamp on when a HID lamp in the fixture is initially energized and during the HID lamp restrike period after brief power outages.
- C. Connections: Designed for a single branch -circuit connection.

Retain one of two "Switching Off" paragraphs below.

- D. Switching Off: Automatically switches quartz lamp off when HID lamp strikes.

- E. Switching Off: Automatically switches quartz lamp off when HID lamp reaches approximately 60 percent light output.

2.10 EXIT SIGNS

- A. General Requirements for Exit Signs: Comply with UL 924; for sign colors, visibility, luminance, and lettering size, comply with authorities having jurisdiction.
 - 1. All exit signs shall have green illuminated lettering on a white background.
- B. Internally Lighted Signs:

Retain "Lamps for AC Operation" subparagraph below. See "Energy Considerations" Article in the Evaluations for discussion.

- 1. Lamps for AC Operation: LEDs, 50,000 hours minimum rated lamp life.
- 2. Self-Powered Exit Signs (Battery Type): Integral automatic charger in a self-contained power pack.

Revise "Battery" Subparagraph below to specify different battery. See "Emergency Lighting" Article in the Evaluations for discussion on battery types. Verify that battery selection is available as UL-listed unit and coordinate with "Warranty" Article.

- a. Battery: Sealed, maintenance-free, nickel-cadmium type.
- b. Charger: Fully automatic, solid-state type with sealed transfer relay.
- c. Operation: Relay automatically energizes lamp from battery when circuit voltage drops to 80 percent of nominal voltage or below. When normal voltage is restored, relay disconnects lamps from battery, and battery is automatically recharged and floated on charger.
- d. Test Push Button: Push-to-test type, in unit housing, simulates loss of normal power and demonstrates unit operability.
- e. LED Indicator Light: Indicates normal power on. Normal glow indicates trickle charge; bright glow indicates charging at end of discharge cycle.

Retain "Remote Test" Subparagraph below to allow periodic test, as required by codes for emergency equipment, to be performed using a hand-held remote device to trigger simulation of loss of normal power in the tested unit.

- f. Remote Test: Switch in hand-held remote device aimed in direction of tested unit initiates coded infrared signal. Signal reception by factory-installed infrared receiver in tested unit triggers simulation of loss of its normal power supply, providing visual confirmation of either proper or failed emergency response.

Retain "Integral Self-Test" Subparagraph below to eliminate necessity to manually perform periodic test required by codes for emergency equipment. Verify requirements of authorities having jurisdiction.

- g. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

Retain "Master/Remote Sign Configurations" Subparagraph below if master/remote sign configurations are required to suit code locations both above and at floor adjacent to exit door. Coordinate with Drawings.

3. Master/Remote Sign Configurations:
 - a. Master Unit: Comply with requirements above for self-powered exit signs, and provide additional capacity in **battery** for power connection to remote unit.
 - b. Remote Unit: Comply with requirements above for self-powered exit signs, except omit power supply, battery, and test features. Arrange to receive full power requirements from master unit. Connect for testing concurrently with master unit as a unified system.

C. Self-Luminous Signs: Prohibited

2.11 EMERGENCY LIGHTING UNITS

- A. The emergency lighting for the means of egress and exit areas shall be accomplished by the following system:
 1. Self-contained, unitized rechargeable battery-powered fixtures shall be connected to existing emergency power supply.
- B. General Requirements for Emergency Lighting Units: Self-contained units complying with UL 924.

Supplement subparagraphs below with data in the Interior Lighting Fixture Schedule or with details on Drawings.

Revise "Battery" Subparagraph below to specify different battery. See "Emergency Lighting" Article in the Evaluations for discussion on battery types. Verify that battery selection is available as UL-listed unit and coordinate with "Warranty" Article.

1. Battery: Sealed, maintenance-free, lead-acid type.
2. Charger: Fully automatic, solid-state type with sealed transfer relay.
3. Operation: Relay automatically turns lamp on when power-supply circuit voltage drops to 80 percent of nominal voltage or below. Lamp automatically disconnects from battery when voltage approaches deep-discharge level. When normal voltage is restored, relay disconnects lamps from battery, and battery is automatically recharged and floated on charger.
4. Test Push Button: Push-to-test type, in unit housing, simulates loss of normal power and demonstrates unit operability.
5. LED Indicator Light: Indicates normal power on. Normal glow indicates trickle charge; bright glow indicates charging at end of discharge cycle.

Wire guard in first subparagraph below is optional feature. Coordinate with Drawings.

6. Wire Guard: Heavy-chrome-plated wire guard protects lamp heads or fixtures.

Retain "Integral Time-Delay Relay" Subparagraph below for time-delay option if units are indicated for areas normally lighted by HID fixtures that will not relight for a period after power is restored due to lengthy arc restrike delays.

7. Integral Time-Delay Relay: Holds unit on for fixed interval of **15** minutes when power is restored after an outage.

Retain "Remote Test" Subparagraph below to allow periodic test, as required by codes for emergency equipment, to be performed using a hand-held remote device to trigger simulation of loss of normal power in the tested unit.

8. Remote Test: Switch in hand-held remote device aimed in direction of tested unit initiates coded infrared signal. Signal reception by factory-installed infrared receiver in tested unit triggers simulation of loss of its normal power supply, providing visual confirmation of either proper or failed emergency response.

Retain "Integral Self-Test" Subparagraph below to eliminate necessity to manually perform periodic test required by codes for emergency equipment. Verify requirements of authorities having jurisdiction.

9. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

2.12 FLUORESCENT LAMPS

Coordinate this article with Drawings. Where color rendition or color uniformity is important and several types of fluorescent lamps are used, provide consistent manufacturer designations or ANSI lamp designations to define requirements.

Paragraphs below are sample specifications for typical lamps, which are a few of the thousands of types and ratings available for building illumination. Indicate here or in the Interior Lighting Fixture Schedule the standard designations of the lamps that meet lumen output, energy rating, CRI, color temperature, lamp life, and other requirements for specific Project applications.

- A. T8 rapid-start lamps, rated 32 W maximum, nominal length of **48 inches** (1220 mm), 2800 initial lumens (minimum), CRI 80 (minimum), color temperature 4,100 degrees Kelvin. 3,500 degrees Kelvin lamps shall be used in selected areas as indicated on drawings, or as directed by DEN Project Manager. Average rated life 20,000 hours unless otherwise indicated.
- B. T8 rapid-start lamps, rated 17 W maximum, nominal length of **24 inches** (610 mm), 1300 initial lumens (minimum), CRI 80 (minimum), color temperature 4,100 degrees Kelvin. 3,500 degrees Kelvin lamps shall be used in selected areas as indicated on drawings, or as directed by DEN Project Manager. Average rated life of 20,000 hours unless otherwise indicated.
- C. T5 rapid-start lamps, rated 28 W maximum, nominal length of **45.2 inches** (1150 mm), 2900 initial lumens (minimum), CRI 85 (minimum), color temperature 3,500 degrees Kelvin. 3,000 degrees Kelvin lamps shall be used in selected areas as indicated on drawings, or as directed by DEN Project Manager. Average rated life of 20,000 hours unless otherwise indicated.
- D. T5HO rapid-start, high-output lamps, rated 54 W maximum, nominal length of **45.2 inches** (1150 mm), 5000 initial lumens (minimum), CRI 85 (minimum), color temperature

3,500 degrees Kelvin. 3,000 degrees Kelvin lamps shall be used in selected areas as indicated on drawings, or as directed by DEN Project Manager. Average rated life of 20,000 hours unless otherwise indicated.

- E. Compact Fluorescent Lamps: 4-Pin, CRI 80 (minimum), color temperature 4,100 degrees Kelvin. 3,500 degrees Kelvin lamps shall be used in selected areas as indicated on drawings, or as directed by DEN Project Manager. Average rated life of 10,000 hours at three hours operation per start[**and suitable for use with dimming ballasts**] unless otherwise indicated.

1. 13 W: T4, double or triple tube, rated 900 initial lumens (minimum).
2. 18 W: T4, double or triple tube, rated 1200 initial lumens (minimum).
3. 26 W: T4, double or triple tube, rated 1800 initial lumens (minimum).
4. 32 W: T4, triple tube, rated 2400 initial lumens (minimum).
5. 42 W: T4, triple tube, rated 3200 initial lumens (minimum).
6. 57 W: T4, triple tube, rated 4300 initial lumens (minimum).
7. 70 W: T4, triple tube, rated 5200 initial lumens (minimum).

2.13 HID LAMPS

Coordinate this article with Drawings. Where color rendition or color uniformity is important and several types of HID lamps are used, provide consistent manufacturer designations or ANSI lamp designations to define requirements.

- A. High-Pressure Sodium Lamps: ANSI C78.42, CRI 21 (minimum), color temperature [1900] <Insert value> K, and average rated life of 24,000 hours, minimum.

Retain "Dual-Arc Tube Lamps" Subparagraph below if extinguishing of high-pressure sodium lamps caused by momentary power interruptions is unacceptable for safety, security, or other reasons. Instant-restrike device specified in "Ballasts for HID Lamps" Article may also be considered. Verify, with manufacturers, availability of individual ratings before scheduling or specifying.

1. Dual-Arc Tube Lamps: Arranged so only one of two arc tubes is lighted at one time and, when power is restored after an outage, the cooler arc tube, with lower internal pressure, lights instantly, providing an immediate 8 to 15 percent of normal light output.

ANSI has a separate standard for each conventional metal-halide lamp, unlike standards for low- and high-pressure sodium lamps. Consider including the standard number in the Interior Lighting Fixture Schedule on Drawings. Wattage and mean lumen output ratings for each lamp may be included in the Interior Lighting Fixture Schedule on Drawings.

- B. Metal-Halide Lamps: ANSI C78.43, with minimum CRI **65**, and color temperature **4000** K.

1. Clear metal halide lamps are to be used for plants, and phosphor coated metal halide lamps (not for plants) are to be used in specified wattage. A self-extinguishing mechanism is to be provided to stop lamp operation if the lamp envelope fails.

Pulse-start, metal-halide lamps in first paragraph below are available in ratings from 30 to 1000 W and provide higher lumen maintenance and reduced color-shift throughout the life of the lamp, compared with basic metal-halide lamps. This may permit use of lower-wattage lamps to provide the same maintained illumination level provided by an equal number of conventional metal-halide lamps. Consult manufacturers to verify compatibility of lamps with ballasts and fixtures.

- C. Pulse-Start, Metal-Halide Lamps: Minimum CRI 65, and color temperature **4000 K**.

Ceramic, pulse-start, metal-halide lamps in first paragraph below are available in ratings from about 40 to 250 W. Besides advantages inherent in pulse-start technology, these lamps have an improved CRI, between 80 and 94, with higher initial and maintained lumen output.

- D. Ceramic, Pulse-Start, Metal-Halide Lamps: Minimum CRI **80**, and color temperature **4000 K**.
E. Low-Pressure Sodium Lamps: ANSI 78.41, CRI 0, and color temperature 1800 K.

2.14 SOLID-STATE LAMPS

- A. LED lamps: ANSI C78.377, listed and rated for the intended environmental conditions.
B. Minimum CRI: 80.
C. Correlated color temperature (CCT): [**3500K**] [**4000K**].
D. Minimum LED life: 60,000 hours at L70.

2.15 LIGHTING FIXTURE SUPPORT COMPONENTS

Coordinate this article with Drawings. See Editing Instruction No. 2 in the Evaluations for discussion on seismic considerations.

- A. All lighting fixture support components to comply with requirements for Seismic Zone 1.
B. Comply with Section 260529 "Hangers and Supports for Electrical Systems" for channel- and angle-iron supports and nonmetallic channel and angle supports.
C. Single-Stem Hangers: **1/2-inch** (13-mm) steel tubing with swivel ball fittings and ceiling canopy. Finish same as fixture.
D. Twin-Stem Hangers: Two, **1/2-inch** (13-mm) steel tubes with single canopy designed to mount a single fixture. Finish same as fixture.
E. Wires: ASTM A 641/A 641M, Class 3, soft temper, zinc-coated steel, **12 gage** (2.68 mm).

Coordinate "Wires for Humid Spaces" Paragraph below with Drawings to identify humid spaces.

- F. Wires for Humid Spaces: ASTM A 580/A 580M, Composition 302 or 304, annealed stainless steel, 12 gage (2.68 mm).
- G. Rod Hangers: 3/16-inch (5-mm) minimum diameter, cadmium-plated, threaded steel rod.
- H. Hook Hangers: Integrated assembly matched to fixture and line voltage and equipped with threaded attachment, cord, and locking-type plug.

2.16 RETROFIT KITS FOR FLUORESCENT LIGHTING FIXTURES

- A. Reflector Kit: UL 1598, Type I. Suitable for two- to four-lamp, surface-mounted or recessed lighting fixtures by improving reflectivity of fixture surfaces.
- B. Ballast and Lamp Change Kit: UL 1598, Type II. Suitable for changing existing ballast, lamps, and sockets.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Sequencing and scheduling: The interior lighting installation is to be sequenced and scheduled with other work to minimize possibility of interference with pipes, ductwork and conduit. Lighting fixtures shall be protected from damage and soiling during the remainder of construction period.
- B. Power Outages: Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
- C. Lighting fixtures:
 - 1. Set level, plumb, and square with ceilings and walls unless otherwise indicated.
 - 2. Install lamps in each luminaire.
 - 3. Set luminaries true, free of light leaks, warps, dents, or other irregularities. Provide the length of stems as required for the luminaries to be level and in the same horizontal plane. Verify the type of all ceilings before bidding, and provide fixtures and mounting to suit. Mount all outlets at position and height to clear equipment, ductwork, piping, etc., in mechanical equipment rooms, storage rooms, etc. Securely fasten all recessed fixtures in suspended ceiling to the ceiling's framing member, as described below.
 - 4. Surface mounting fixtures containing ballasts shall be mounted with a minimum 1-1/2" spacer where mounted on a combustible material unless specifically approved for the application.
 - 5. Protect wiring with tape or tubing at all points where abrasion is likely to occur. Provide chase nipples where field wiring is through knockouts. Wiring in

fluorescent fixtures shall be suitable for temperature conditions and in no case less than 90 degree C (194 degree F) rating.

6. Connectors and terminals, including screws and bolts, are to be tightened in accordance with equipment manufacturer's published torque tightening values for equipment connectors. Where manufacturer's torquing requirements are not indicated, connectors and terminals are to comply with tightening torques in specified standards and the National Electrical Code. Submit a report of all torquing values with a torque schedule and witness signature to the DEN Project Manager.
7. Surface mounted fixtures greater than 2 feet in length shall be supported at a point in addition to the outlet box fixture stud.
8. Each single phase circuit feeding light fixtures with ballasts shall have a dedicated neutral.
9. Light fixtures in storage areas and fixtures mounted below 8' shall have a guard to protect the lamps.

D. Emergency Lighting:

1. Emergency lighting fixtures are to be installed at locations and heights per applicable codes. Install in accordance with fixture manufacturer's written instructions, applicable requirements of NEC, NECA's "Standard of Installation," NEMA standards, and with recognized industry practices to ensure that lighting fixtures fulfill requirements.
2. All emergency lighting conductors are to be routed in a conduit separate from the normal power circuits.
3. All egress areas shall be served by at least (2) lamps.

E. Temporary Lighting: If it is necessary, and approved by DEN Project Manager, to use permanent luminaires for temporary lighting, install and energize the minimum number of luminaires necessary. When construction is sufficiently complete, remove the temporary luminaires, disassemble, clean thoroughly, install new lamps, and reinstall.

Remote mounting distances might be as short as 60 inches (150 mm) for some pulse-start ballasts.

F. Remote Mounting of Ballasts: Distance between the ballast and fixture shall not exceed that recommended by ballast manufacturer. Verify, with ballast manufacturers, maximum distance between ballast and luminaire.

NFPA 70 requires minimum support for fixtures. Retain "Lay-in Ceiling Lighting Fixtures Supports" Paragraph below for more specific support requirements and for requirements exceeding code minimums. For projects requiring seismic design, additional supports, and restraining devices beyond those specified here may be required. See Editing Instruction No. 2 in the Evaluations.

G. Lay-in Ceiling Lighting Fixtures Supports:

1. Supports shall be designed for Seismic Zone 1.
2. Install ceiling support system rods or wires, independent of the ceiling suspension devices, for each fixture. Locate not more than 6 inches (150 mm) from lighting fixture corners.
3. Support Clips: Fasten to lighting fixtures and to ceiling grid members at or near each fixture corner with clips that are UL listed for the application.

4. Fixtures of Sizes Less Than Ceiling Grid: Install as indicated on reflected ceiling plans or center in acoustical panel, and support fixtures independently with at least two **3/4-inch (20-mm)** metal channels spanning and secured to ceiling tees.
5. Install at least one independent support rod or wire from structure to a tab on lighting fixture. Wire or rod shall have breaking strength of the weight of fixture at a safety factor of 3.
6. Fixtures are to be securely fastened to structural supports. Individually mounted pendant fixtures longer than 2 feet shall have twin stem hangers. All stem hangers shall have ball hangers and provisions for minimum 1-inch vertical adjustment. Continuous rows of fixtures shall have one additional stem hanger greater than the number of fixtures in the row.

H. Lay-in Lighting System Wiring:

1. Lay-in lighting system shall be hard-piped to J-box. J-box shall not be attached to light fixture. Installed 6' flexible steel conduit between J-box and fixture. Modular wiring is not permitted. Flex ran from fixture to fixture is not acceptable.

I. Suspended Lighting Fixture Support:

1. Pendants and Rods: Where longer than **48 inches (1200 mm)**, brace to limit swinging.
2. Stem-Mounted, Single-Unit Fixtures: Suspend with twin-stem hangers.
3. Continuous Rows: Use tubing or stem for wiring at one point and tubing or rod for suspension for each unit length of fixture chassis, including one at each end.
4. Do not use grid as support for pendant luminaires. Connect support wires or rods to building structure.

J. Air-Handling Lighting Fixtures: Install with dampers closed and ready for adjustment.

K. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

L. Installation of "Neon" Lighting:

1. Neon lighting is not allowed without written consent from the DEN Project Manager.

3.2 GROUNDING:

- A. Equipment grounding connections are required for interior lighting fixtures. Connections are to comply with tightening torque values specified in UL standards to assure permanent and effective grounds. Submit a report of all torquing values with a torque schedule and witness signature to DEN Project Manager.

3.3 IDENTIFICATION

- A. Install labels with panel and circuit numbers on concealed junction and outlet boxes. Comply with requirements for identification specified in Section 260553 "Identification

for Electrical Systems."

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Test for Emergency Lighting: Interrupt power supply to demonstrate proper operation. Verify transfer from normal power to battery and retransfer to normal.

Retain first paragraph below when retaining photoluminescent signs specified in "Exit Signs" Article. See Editing Instruction No. 7 in the Evaluations for NFPA requirements pertaining to photoluminescent exit signs.

- B. Verify that self-luminous exit signs are installed according to their listing and the requirements in NFPA 101.
- C. Prepare a written report of tests, inspections, observations, and verifications indicating and interpreting results. If adjustments are made to lighting system, retest to demonstrate compliance with standards.

3.5 STARTUP SERVICE

- A. Burn-in all lamps that require specific aging period to operate properly, prior to occupancy by Owner. Burn-in fluorescent and compact fluorescent lamps intended to be dimmed, for at least 100 hours at full voltage.

3.6 DEMONSTRATION:

- A. Upon completion of the installation of interior lighting fixtures, and after building circuitry has been energized, the interior lighting system and emergency lighting system shall be operated to demonstrate capability and compliance with requirements.
- B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

3.7 ADJUSTING AND CLEANING:

- A. Interior lighting fixtures are to be cleaned of dust, dirt, fingerprints, smudges, and construction debris upon completion of the installation.
- B. Installed fixtures are to be protected from damage during the remainder of the construction period.
- C. Occupancy Adjustments: When requested within **twelve (12)** months of date of Substantial Completion, provide on-site assistance in adjusting aimable luminaires to suit actual occupied conditions. Provide up to **2** visits to Project during

other-than-normal occupancy hours for this purpose. Some of this work may be required after dark.

1. Adjust aimable luminaires in the presence of DEN Project Manager.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 265100

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SECTION 265600 - EXTERIOR LIGHTING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

If applying for LEED certification, LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1. ASHRAE/IESNA 90.1, Section 9 - "Lighting," sets maximum interior and exterior lighting power densities and minimum requirements for lighting controls. The selection of the lamp and ballast as a system is an important design decision to optimize energy efficiency of the lighting system.

A reduction in lighting energy usage can be combined with other energy-conserving measures to meet the requirements of LEED-NC, LEED-CS, and LEED for Schools Credit EA 1.

LEED-NC, LEED-CS, and LEED for Schools Credit SS 8 requires that exterior lights be provided as needed for "safety and comfort" with the lighting power densities for the exterior areas and the building facade and landscape at a minimum of 20 and 50% less than ASHRAE/IESNA 90.1, respectively. In addition, the lighting design must eliminate or minimize any "light trespass" from the site and reduce "sky glow," depending on the zone classification of the site according to IESNA RP-33 requirements. Consider selecting the proper light fixtures, such as low-intensity shielded fixtures, the aiming of the fixtures, and using automatic controllers to turn off nonessential site lighting after a specific hour as defined by this credit. Credit SS 8 also sets requirements for interior lighting. See Section 265100 "Interior Lighting."

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. The contractor shall furnish and install all lighting equipment and lighting fixtures including poles, fixture lowering system, control equipment, etc., or as mentioned in

fixture the schedule and as required for all outlets indicated on the drawings.

B. Section Includes:

1. Exterior luminaires with lamps and ballasts.
2. Luminaire-mounted photoelectric relays.
3. Poles and accessories.
4. Luminaire lowering devices.

C. Related Sections:

Retain Section in subparagraph below that contains requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 265100 "Interior Lighting" for exterior luminaires normally mounted on exterior surfaces of buildings.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- D. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. CCT: Correlated color temperature.
- B. CRI: Color-rendering index.
- C. HID: High-intensity discharge.
- D. LER: Luminaire efficacy rating.
- E. Luminaire: Complete lighting fixture, including ballast housing if provided.
- F. Pole: Luminaire support structure, including tower used for large area illumination.
- G. Standard: Same definition as "Pole" above.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 STRUCTURAL ANALYSIS CRITERIA FOR POLE SELECTION

Retain this article if manufacturer is responsible for selecting poles and other luminaire support components and certifying them to suit wind, ice, and other load conditions as expressed in AASHTO LTS-4-M. Delete if structural considerations have been applied by the design team in selecting

"basis-of-design" or proprietary pole products, and these products have been identified in the Exterior Lighting Device Schedule or in details on Drawings. See Editing Instruction No. 1 in the Evaluations.

- A. Dead Load: Weight of luminaire and its horizontal and vertical supports, lowering devices, and supporting structure, applied as stated in AASHTO LTS-4-M.

Retain "Live Load" Paragraph below if Project includes pole-mounted walkways or service platforms.

- B. Live Load: Single load of 500 lbf (2224 N), distributed as stated in AASHTO LTS-4-M.

Retain "Ice Load" Paragraph below if Project is inside the area shown in the Ice Load Map, Figure 3-1.

- C. Ice Load: Load of 3 lbf/sq. ft. (145 Pa), applied as stated in AASHTO LTS-4-M Ice Load Map.

See Editing Instruction No. 2 in the Evaluations for discussion of wind-load calculations.

- D. Wind Load: Pressure of wind on pole and luminaire and banners and banner arms, calculated and applied as stated in AASHTO LTS-4-M.

1. Basic wind speed for calculating wind load for poles exceeding 50 feet (15 m) in height is 115 mph.
 - a. Wind Importance Factor: 1.3
 - b. Minimum Design Life: [50 years] <Insert number>.
 - c. Velocity Conversion Factors: 1.3
2. Basic wind speed for calculating wind load for poles 50 feet (15 m) high or less is 115 mph
 - a. Wind Importance Factor: 1.3.
 - b. Minimum Design Life: [25 years] <Insert number>.
 - c. Velocity Conversion Factors: 1.3.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each luminaire, pole, and support component, arranged in order of lighting unit designation. Include data on features, accessories, finishes, and the following:
1. Physical description of luminaire, including materials, dimensions, effective projected area, and verification of indicated parameters.
 2. Details of attaching luminaires and accessories.
 3. Details of installation and construction.
 4. Luminaire materials.
 5. Wind loading data.

6. Photometric data based on laboratory tests of each luminaire type, complete with indicated lamps, ballasts, and accessories.

Retain one of first two subparagraphs below. Retain "Testing Agency Certified Data" Subparagraph if photometric data for one or more luminaires are based on independent laboratory tests; coordinate with the Exterior Lighting Device Schedule on Drawings to indicate which units are required to meet this requirement. Retain "Manufacturer Certified Data" Subparagraph if photometric data based on testing by accredited manufacturers' laboratories are considered adequate for all exterior luminaires in this Project. See Evaluations.

- a. Testing Agency Certified Data: For indicated luminaires, photometric data shall be certified by a qualified independent testing agency. Photometric data for remaining luminaires shall be certified by manufacturer.
 - b. Manufacturer Certified Data: Photometric data shall be certified by manufacturer's laboratory with a current accreditation under the National Voluntary Laboratory Accreditation Program for Energy Efficient Lighting Products.
7. Photoelectric relays.
 8. Ballasts, including energy-efficiency data.
 9. Lamps, including life, output, CCT, CRI, lumens, and energy-efficiency data.
 10. Materials, dimensions, and finishes of poles.
 11. Means of attaching luminaires to supports, and indication that attachment is suitable for components involved.
 12. Anchor bolts for poles.

Retain subparagraph below if manufactured pole foundations, including screw foundations, are indicated.

13. Manufactured pole foundations.
14. Include data substantiating that materials comply with requirements.

Retain "Shop Drawings" Paragraph below if foundation-mounted poles are indicated.

- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Anchor-bolt templates keyed to specific poles and certified by manufacturer.

Retain first subparagraph below if screw foundations are indicated.

3. Design calculations, certified by a qualified professional engineer, indicating strength of screw foundations and soil conditions on which they are based.

Retain subparagraph below if equipment includes wiring.

4. Wiring Diagrams: For power, signal, and control wiring.

Retain "Samples" Paragraph below if Samples of exterior luminaires or support components are required for verification purposes. Revise if sample requirements are indicated in other than the Exterior Lighting Device Schedule on Drawings.

Coordinate sample requirements with DEN Project Manager.

- C. Samples: For products designated for sample submission in the Exterior Lighting Device Schedule. Each Sample shall include lamps and ballasts.
- D. Substitutions: For Prebid approval, submit all materials noted in paragraphs A, B and C above.

1.6 INFORMATIONAL SUBMITTALS

Retain "Pole and Support Component Certificates" Paragraph below if retaining "Structural Analysis Criteria for Pole Selection" Article. See Editing Instruction No. 1 in the Evaluations.

- A. Pole and Support Component Certificates: Signed by manufacturers of poles, certifying that products are designed for indicated load requirements in AASHTO LTS-4-M and that load imposed by luminaire and attachments has been included in design. The certification shall be based on design calculations by a professional engineer.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data: For qualified agencies providing photometric data for lighting fixtures.
- C. Field quality-control reports.
- D. Warranty: Sample of special warranty.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For **[luminaires][and poles] [luminaire lowering devices]** to include in emergency, operation, and maintenance manuals.
- B. Connectors and terminals, including screws and bolts, are to be tightened in accordance with equipment manufacturer's published torque tightening values. Record all torque values for bolts and submit report with witness signature to DEN Project Manager.
- C. Contractor shall provide to the DEN Project Manager a Point by Point report showing the light level readings taken after the parking area has been properly aimed and the fixtures have had at least 50 hours of actual run time in the field. The grid spacing for the readings shall be the same as the calculations submitted prior to start of construction.

Verify requirements for as-built plans with DEN Project Manager.

- D. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 MAINTENANCE MATERIAL SUBMITTALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents. Deliver extra materials as directed by DEN Project Manager.

Quantities indicated in subparagraphs below are examples only.

1. Lamps: Fifteen (15) percent of the total number of lamps, but not less than four (4) lamps in each case, for each type and rating installed.
2. Glass and Plastic Lenses, Covers, and Other Optical Parts: **[One (1) for every 100] <Insert quantity>** of each type and rating installed. Furnish at least one of each type.
3. Ballasts: **[One (1) for every 100] <Insert quantity>** of each type and rating installed. Furnish at least one of each type.
4. Globes and Guards: **[One (1) for every 20] <Insert quantity>** of each type and rating installed. Furnish at least one of each type.

1.9 QUALITY ASSURANCE

Retain one of first two paragraphs below, or both, to specify qualifications for laboratories providing photometric data to be submitted for luminaires.

- A. Comply with the requirements of the latest edition of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.
- B. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by manufacturers' laboratories that are accredited under the National Volunteer Laboratory Accreditation Program for Energy Efficient Lighting Products.
- C. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by an independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Comply with IEEE C2, "National Electrical Safety Code."
- F. Comply with NFPA 70.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Store poles on decay-resistant-treated skids at least **12 inches** (300 mm) above grade and vegetation. Support poles to prevent distortion and arrange to provide free air circulation.
- B. Retain factory-applied pole wrappings on metal poles until right before pole installation. Handle poles with web fabric straps.

1.11 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

Coordinate warranty requirements with DEN Project Manager.

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace products that fail in materials or workmanship; that corrode; or that fade, stain, perforate, erode, or chalk due to effects of weather or solar radiation within specified warranty period. Manufacturer may exclude lightning damage, hail damage, vandalism, abuse, or unauthorized repairs or alterations from special warranty coverage.

Verify available warranties and warranty periods for units and components and insert number below.

1. Warranty Period for Luminaires: Minimum **[five (5)]** <Insert number> years from date of Substantial Completion.

Coordinate warranty provisions for resistance to corrosion and for color retention with similar warranties for poles and mast arms. Otherwise, delete first two subparagraphs below.

2. Warranty Period for Metal Corrosion: Minimum **[five (5)]** <Insert number> years from date of Substantial Completion.
3. Warranty Period for Color Retention: Minimum **[five (5)]** <Insert number> years from date of Substantial Completion.
4. Warranty Period for Poles: Repair or replace lighting poles and standards that fail in finish, materials, and workmanship within manufacturer's standard warranty period, but not less than **[three (3)]** <Insert number> years from date of Substantial Completion.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

Retain "Products" Paragraph below. Delete this article if no manufacturers and product designations are indicated. See Section 016000 "Product Requirements."

- A. Products: Subject to compliance with requirements, provide products indicated on Drawings, or approved equal.

2.2 GENERAL REQUIREMENTS FOR LUMINAIRES

- A. Environmental Conditions:
 - 1. The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:
 - a. Location: Outdoors.
 - b. Altitude: 5,500 feet (1677 m) above sea level.
 - c. Ambient Temperature Range: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).
 - d. Wind Load: 115 mph with gust factor of 1.3.
- B. Provide lighting equipment as shown on the drawings and as specified herein. Provide complete lighting equipment, including canopies, poles, supporting brackets, hickey, casing, socket holders, reflectors, ballasts, lamps, as appropriate for the application. Provide special plates, barriers, rings, etc., as required to comply with National Electrical Code. The fixtures to have proper gasketing and made of corrosion resistant materials to be installed in damp and wet locations.
- C. Luminaires shall comply with UL 1598 and be listed and labeled for installation in wet locations by an NRTL acceptable to authorities having jurisdiction.

See Editing Instruction No. 6 in the Evaluations for discussion of LER.

- 1. LER Tests Incandescent Fixtures: Where LER is specified, test according to NEMA LE 5A.
- 2. LER Tests Fluorescent Fixtures: Where LER is specified, test according to NEMA LE 5 and NEMA LE 5A as applicable.
- 3. LER Tests HID Fixtures: Where LER is specified, test according to NEMA LE 5B.

Retain "Lateral Light Distribution Patterns" Paragraph below if some lighting units or luminaires are indicated to have Type I, II, III, IV, or V distribution pattern in the Exterior Lighting Device Schedule or in details on Drawings.

- D. Lateral Light Distribution Patterns: Comply with IESNA RP-8 for parameters of lateral light distribution patterns indicated for luminaires.
- E. Metal Parts: Free of burrs and sharp corners and edges.

- F. Sheet Metal Components: Corrosion-resistant aluminum unless otherwise indicated. Form and support to prevent warping and sagging.
- G. Housings: Rigidly formed, weather- and light-tight enclosures that will not warp, sag, or deform in use. Provide filter/breather for enclosed luminaires.
- H. Doors, Frames, and Other Internal Access: Smooth operating, free of light leakage under operating conditions, and designed to permit relamping without use of tools. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position. Doors shall be removable for cleaning or replacing lenses. Designed to disconnect ballast when door opens.
- I. Exposed Hardware Material: Stainless steel.
- J. Plastic Parts: High resistance to yellowing and other changes due to aging, exposure to heat, and UV radiation.

Retain "Light Shields" Paragraph below if one or more luminaires require partial shielding of light output to avoid light trespass or to meet other requirements. Coordinate with the Exterior Lighting Device Schedule on Drawings.

- K. Light Shields: Metal baffles, factory installed and field adjustable, arranged to block light distribution to indicated portion of normally illuminated area or field.
- L. Reflecting surfaces shall have minimum reflectance as follows unless otherwise indicated:
 - 1. White Surfaces: 85 percent.
 - 2. Specular Surfaces: 83 percent.
 - 3. Diffusing Specular Surfaces: 75 percent.
- M. Lenses and Refractors Gaskets: Use heat- and aging-resistant resilient gaskets to seal and cushion lenses and refractors in luminaire doors.

Revise "Luminaire Finish" Paragraph below to include custom colors. Coordinate custom-color requirements for luminaires with those for poles and other luminaire support requirements.

- N. Luminaire Finish: Manufacturer's standard paint applied to factory-assembled and -tested luminaire before shipping. Where indicated, match finish process and color of pole or support materials.

Retain "Factory-Applied Finish for Steel Luminaires" Paragraph below when luminaire material is steel that is not to be field painted and is not required to match finish of pole or support materials.

- O. Factory-Applied Finish for Steel Luminaires: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - 1. Surface Preparation: Clean surfaces to comply with SSPC-SP 1, "Solvent Cleaning," to remove dirt, oil, grease, and other contaminants that could impair

- paint bond. Grind welds and polish surfaces to a smooth, even finish. Remove mill scale and rust, if present, from uncoated steel, complying with SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning," or SSPC-SP 8, "Pickling."
2. Exterior Surfaces: Manufacturer's hot-dip galvanized finish.

Retain one of three "Color" subparagraphs below.

- a. Color: As selected by DEN Project Manager from manufacturer's standard catalog of colors.
- b. Color: Match DEN Project Manager's sample of [**manufacturer's standard**] [**custom**] color.
- c. Color: As selected by DEN Project Manager from manufacturer's full range.

Retain "Factory-Applied Finish for Aluminum Luminaires" Paragraph below when luminaire material is aluminum that is not to be field painted and is not required to match finish of pole or support materials.

- P. Factory-Applied Finish for Aluminum Luminaires: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
1. Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.

Retain one of three finish subparagraphs below or revise to suit Project.

2. Natural Satin Finish: Provide fine, directional, medium satin polish (AA-M32); buff complying with AA-M20; and seal aluminum surfaces with clear, hard-coat wax.
3. Class I, Clear Anodic Finish: AA-M32C22A41 (Mechanical Finish: medium satin; Chemical Finish: etched, medium matte; Anodic Coating: Architectural Class I, clear coating 0.018 mm or thicker) complying with AAMA 611.
4. Class I, Color Anodic Finish: AA-M32C22A42/A44 (Mechanical Finish: medium satin; Chemical Finish: etched, medium matte; Anodic Coating: Architectural Class I, integrally colored or electrolytically deposited color coating 0.018 mm or thicker) complying with AAMA 611.
 - a. Color: [**Light bronze**] [**Medium bronze**] [**Dark bronze**] [**Black**].

See Editing Instruction No. 7 in the Evaluations for discussion of luminaire labeling.

- Q. Factory-Applied Labels: Comply with UL 1598. Include recommended lamps and ballasts. Labels shall be located where they will be readily visible to service personnel, but not seen from normal viewing angles when lamps are in place.
1. Label shall include the following lamp and ballast characteristics:
 - a. "USES ONLY" and include specific lamp type.
 - b. Lamp diameter code (T-4, T-5, T-8, T-12), tube configuration (twin, quad, triple), base type, and nominal wattage for fluorescent and compact fluorescent luminaires.
 - c. Lamp type, wattage, bulb type (ED17, BD56, etc.) and coating (clear or coated) for HID luminaires.

- d. Start type (preheat, rapid start, instant start) for fluorescent and compact fluorescent luminaires.
- e. ANSI ballast type (M98, M57, etc.) for HID luminaires.
- f. CCT and CRI for all luminaires.

2.3 LUMINAIRE-MOUNTED PHOTOELECTRIC RELAYS

- A. Comply with UL 773 or UL 773A.
- B. Contact Relays: Factory mounted, single throw, designed to fail in the on position, and factory set to turn light unit on at 1.5 to 3 fc (16 to 32 lx) and off at 4.5 to 10 fc (48 to 108 lx) with 15-second minimum time delay. [**Relay shall have directional lens in front of photocell to prevent artificial light sources from causing false turnoff.**]
 1. Relay with locking-type receptacle shall comply with ANSI C136.10.
 2. Adjustable window slide for adjusting on-off set points.

2.4 FLUORESCENT BALLASTS AND LAMPS

See Editing Instruction No. 4 in the Evaluations for discussion of low-temperature application of fluorescent luminaires, lamps, and ballasts.

- A. Ballasts for Low-Temperature Environments:

Retain option in subparagraph below for lamp starting and operating temperature near 30 deg F (minus 35 deg C) is a critical requirement. Verify, with manufacturers, the compatibility of ballasts with indicated lamps for low-temperature operation.

1. Temperatures minus 30 Deg F (minus 35 Deg C) and Higher: Electronic type rated for minus 30 deg F (minus 35 deg C) starting and operating temperature with indicated lamp types.

- B. Ballast Characteristics:

1. Power Factor: 90 percent, minimum.
2. Sound Rating: Class A.

See Evaluations for discussion of harmonic distortion in first subparagraph below.

3. Total Harmonic Distortion Rating: Less than [10] [20] percent.
4. Electromagnetic Ballasts: Comply with ANSI C82.1, energy-saving, high power factor, Class P, automatic-reset thermal protection.
5. Case Temperature for Compact Lamp Ballasts: 65 deg C, maximum.
6. Transient-Voltage Protection: Comply with IEEE C62.41.1 and IEEE C62.41.2, Category A or better.

Coordinate "Low-Temperature Lamp Capability" Paragraph below with Drawings, and indicate lamp type for each fluorescent luminaire in the Exterior Lighting Device Schedule on Drawings or in description in this Section. Where color rendition or color uniformity is important and several types of fluorescent lamps are used, provide consistent manufacturer designations or ANSI lamp designations to define requirements.

For applications at low temperatures, verify that lamp, ballast, and luminaire combinations indicated will start reliably and provide required light output throughout the range of temperatures that may be encountered.

- C. Low-Temperature Lamp Capability: Rated for reliable starting and operation with ballast provided at temperatures minus 30 deg F (minus 35 deg C) and higher.

2.5 DRIVERS FOR SOLID-STATE LAMPS

- A. Description: Listed, electronic, RoHS compliant, meeting the requirements of ANSI C82.77 and UL 8750.
 - 1. Dimming: Where required. Meet or exceed specified dimming percentage.
 - 2. Temperature rating: Match or exceed environmental requirements.
 - 3. Rated Life: 50,000 hours minimum.
 - 4. Manufacturer's Warranty: 5 years minimum.

2.6 BALLASTS FOR HID LAMPS

- A. Comply with ANSI C82.4 and UL 1029 and capable of open-circuit operation without reduction of average lamp life. Include the following features unless otherwise indicated:
 - 1. Ballast Circuit: Constant-wattage autotransformer or regulating high-power-factor type.
 - 2. Minimum Starting Temperature: Minus 30 deg F (minus 35 deg C).
 - 3. Normal Ambient Operating Temperature: 120 deg F (49 deg C).

Retain "Ballast Fuses" Subparagraph below if ballasts are required to be fused. See Editing Instruction No. 3 in the Evaluations for discussion of ballast fusing.

- 4. Ballast Fuses: One in each ungrounded power supply conductor. Voltage and current ratings as recommended by ballast manufacturer.
- B. Auxiliary, Instant-On, Quartz System: Factory-installed feature automatically switches quartz lamp on when fixture is initially energized and when momentary power outages occur. System automatically turns quartz lamp off when HID lamp reaches approximately 60 percent of light output.
- C. High-Pressure Sodium Ballasts: Electromagnetic type with solid-state igniter/starter and capable of open-circuit operation without reduction of average lamp life. Igniter/starter shall have an average life in pulsing mode of 10,000 hours at an igniter/starter-case temperature of 90 deg C.

For lamps up to 150 W, retain "Instant-Restrike Device" Subparagraph below. If unacceptable for safety, security, or other reasons for high-pressure sodium lamps to be extinguished for a lengthy restrike period by momentary power interruptions, dual-arc tube lamp feature in "HID Lamps" Article may also be considered.

- 1. Instant-Restrike Device: Integral with ballast, or solid-state potted module, factory

installed within fixture and compatible with lamps, ballasts, and mogul sockets up to 150 W.

- a. Restrike Range: 105- to 130-V ac.
- b. Maximum Voltage: 250-V peak or 150-V ac rms.

2. Minimum Starting Temperature: **Minus 30 deg F** (minus 35 deg C).

2.7 HID LAMPS

Coordinate this article with Drawings. Where color rendition or color uniformity is important and several types of HID lamps are used, provide consistent manufacturer designations or ANSI designations to define lamp types.

- A. High-Pressure Sodium Lamps: ANSI C78.42, CRI 21 (minimum), CCT color temperature **[1900] <Insert value>** K, and average rated life of 24,000 hours, minimum.

Consider retaining "Dual-Arc Tube Lamp" Subparagraph below if extinguishing of high-pressure sodium lamps caused by momentary power interruptions is unacceptable for safety, security, or other reasons. Instant-restrike device feature specified in "Ballasts for HID Lamps" Article may also be considered. Verify, with manufacturers, availability of individual ratings before scheduling or specifying.

1. Dual-Arc Tube Lamp: Arranged so only one of two arc tubes is lighted at one time and, when power is restored after an outage, the cooler arc tube, with lower internal pressure, lights instantly, providing an immediate 8 to 15 percent of normal light output.

- B. Low-Pressure Sodium Lamps: ANSI C78.43.

ANSI has a separate standard for each conventional metal-halide lamp, unlike standards for low- and high-pressure sodium lamps. Consider including the standard number in the Exterior Lighting Device Schedule on Drawings. Wattage and mean lumen output ratings for each lamp may be included in the Exterior Lighting Device Schedule on Drawings.

- C. Metal-Halide Lamps: ANSI C78.43, with minimum CRI **[65] <Insert value>**, and CCT color temperature **[4000] <Insert value>** K.

Pulse-start, metal-halide lamps in first paragraph below are available in ratings from 30 to 1000 W and provide higher lumen maintenance and reduced color-shift throughout the life of the lamp, compared with basic metal-halide lamps. This may permit use of lower-wattage lamps to provide the same maintained illumination level provided by an equal number of conventional metal-halide lamps. Consult manufacturers to verify compatibility of lamps with ballasts and luminaires.

- D. Pulse-Start, Metal-Halide Lamps: Minimum CRI 65, and CCT color temperature **[4000] <Insert value>** K.

Ceramic, pulse-start, metal-halide lamps in paragraph below are available in ratings from about 40 to 250 W. Besides advantages inherent in pulse-start technology, these lamps have an improved CRI, between 80 and 94, with higher initial and maintained lumen output.

- E. Ceramic, Pulse-Start, Metal-Halide Lamps: Minimum CRI [80] <Insert value>, and CCT color temperature [4000] <Insert value> K.

2.8 SOLID-STATE LAMPS

- A. LED lamps: ANSI C78.377, listed and rated for the intended environmental conditions.
- B. Minimum CRI: 70.
- C. Correlated color temperature (CCT): 5000K.
- D. Minimum LED life: 60,000 hours at L70.

2.9 GENERAL REQUIREMENTS FOR POLES AND SUPPORT COMPONENTS

- A. Structural Characteristics: Comply with AASHTO LTS-4-M.

Retain two subparagraphs below if retaining "Structural Analysis Criteria for Pole Selection" Article and manufacturer is responsible for selecting poles and other luminaire support components and certifying them to suit wind, ice, and other load conditions as expressed in AASHTO LTS-4-M. Delete if structural considerations have been applied by the design team in selecting "basis-of-design" or proprietary pole products, and these products have been identified in the Exterior Lighting Device Schedule or details on Drawings. See Editing Instruction No. 1 in the Evaluations.

- 1. Wind-Load Strength of Poles: Adequate at indicated heights above grade without failure, permanent deflection, or whipping in steady winds of speed indicated in "Structural Analysis Criteria for Pole Selection" Article.

Retain "Strength Analysis" Subparagraph below to help ensure that poles are stiff enough to avoid excessive flexure and vibration. Alternatively, add requirements for minimum pole wall thickness and other parameters. See Editing Instruction No. 5 in the Evaluations.

- 2. Strength Analysis: For each pole, multiply the actual equivalent projected area of luminaires and brackets by a factor of 1.3 to obtain the equivalent projected area to be used in pole selection strength analysis.
- B. Luminaire Attachment Provisions: Comply with luminaire manufacturers' mounting requirements. Use stainless-steel fasteners and mounting bolts unless otherwise indicated.

Coordinate "Mountings, Fasteners, and Appurtenances" Paragraph below with Drawings.

- C. Mountings, Fasteners, and Appurtenances: Corrosion-resistant items compatible with support components.
 - 1. Materials: Shall not cause galvanic action at contact points.
 - 2. Anchor bolts shall meet or exceed wind loading and structural requirements.
 - 3. Anchor Bolts, Leveling Nuts, Bolt Caps, and Washers: Hot-dip galvanized after fabrication unless otherwise indicated.
 - 4. Anchor-Bolt Template: Plywood or steel.
 - 5. Ground bolt near the handhole shall be included.

Coordinate "Handhole" Paragraph below with Drawings for indication of concrete foundations suitable for soil conditions and loads imposed by pole, luminaire, and support components.

- D. Handhole: Oval-shaped, reinforced, with minimum clear opening of 3 inches by 5 inches (76 by 130 mm) minimum, with cover secured by stainless-steel captive screws. Provide larger size handholes to suit pole diameter.
- E. Concrete Pole Foundations: Cast in place, with anchor bolts to match pole-base flange. Concrete, reinforcement, and formwork are specified in Section 033000 "Cast-in-Place Concrete."

Coordinate two paragraphs below with Drawings.

- F. Power-Installed Screw Foundations: Factory fabricated by pole manufacturer, with structural steel complying with ASTM A 36/A 36M and hot-dip galvanized according to ASTM A 123/A 123M; and with top-plate and mounting bolts to match pole base flange and strength required to support pole, luminaire, and accessories.

On Drawings, identify poles that require breakaway supports described in paragraph below. Add description if specific type of breakaway support is required.

- G. Breakaway Supports: Frangible breakaway supports, tested by an independent testing agency acceptable to authorities having jurisdiction, according to AASHTO LTS-4-M.

If using support structures other than poles, insert an article here to specify structure materials.

2.10 STEEL POLES

See Editing Instruction No. 5 in the Evaluations for discussion of pole flexure and vibration resistance.

- A. Poles: Comply with ASTM A 500, Grade B, carbon steel with a minimum yield of 46,000 psig (317 MPa); one-piece construction with access handhole in pole wall.
 - 1. Shape: Round, tapered.

Coordinate "Mounting Provisions" Subparagraph below with Drawings.

- 2. Mounting Provisions: Butt flange for bolted mounting on foundation or breakaway support.

Indicate on Drawings the span and rise of mast arms in "Steel Mast Arms" Paragraph below Delete paragraph if mast arms are adequately described in the Exterior Lighting Device Schedule or in details on Drawings.

- B. Steel Mast Arms: [Single-arm] [Truss] [Davit] type, continuously welded to pole attachment plate. Material and finish same as pole.

Indicate on Drawings the span and rise of luminaire brackets in "Brackets for Luminaires" Paragraph below. Delete paragraph if luminaire brackets are adequately described in the Exterior Lighting Device Schedule or in details on Drawings.

- C. Brackets for Luminaires: Detachable, cantilever, without underbrace.

1. Adapter fitting welded to pole, allowing the bracket to be bolted to the pole mounted adapter, then bolted together with hot-dip galvanized steel bolts.
 2. Cross Section: Tapered oval, with straight tubular end section to accommodate luminaire.
 3. Match pole material and finish.
- D. Pole-Top Tenons: Fabricated to support luminaire or luminaires and brackets indicated, and securely fastened to pole top.
- E. Steps: Fixed steel, with nonslip treads, positioned for 15-inch (381-mm) vertical spacing, alternating on opposite sides of pole; first step at elevation 10 feet (3 m) above finished grade.

Retain "Intermediate Handhole and Cable Support" Paragraph below for poles more than 90 feet (27 m) in height.

- F. Intermediate Handhole and Cable Support: Weathertight, 3-by-5-inch (76-by-127-mm) minimum handhole located at midpoint of pole with cover for access to internal welded attachment lug for electric cable support grip.
- G. Grounding and Bonding Lugs: Welded 1/2-inch (13-mm) threaded lug, complying with requirements in Section 260526 "Grounding and Bonding for Electrical Systems," listed for attaching grounding and bonding conductors of type and size listed in that Section, and accessible through handhole.
- H. Cable Support Grip: Wire-mesh type with rotating attachment eye, sized for diameter of cable and rated for a minimum load equal to weight of supported cable times a 5.0 safety factor.

Coordinate "Platform for Lamp Ballast Servicing" Paragraph below with Drawings, manufacturer's standard details, and Project's structural engineer.

- I. Platform for Lamp and Ballast Servicing: Factory fabricated of steel with finish matching that of pole.
- J. Hot-Dip Galvanized Finish: After fabrication, hot-dip galvanize complying with ASTM A 123/A 123M. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
1. Surface Preparation: Clean surfaces to comply with SSPC-SP 1, "Solvent Cleaning," to remove dirt, oil, grease, and other contaminants that could impair bond. Grind welds and polish surfaces to a smooth, even finish. Remove mill scale and rust, if present, from uncoated steel, complying with SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning," or with SSPC-SP 8, "Pickling."
 2. Interior Surfaces of Pole: Factory hot-dip galvanized finish.
 3. Exterior Surfaces: Factory hot-dip galvanized finish.
 - a. Color: **[Match DEN Project Manager's sample] [As selected by DEN Project Manager from manufacturer's full range].**

2.11 DECORATIVE POLES

See Editing Instruction No. 5 in the Evaluations for discussion of pole flexure and vibration resistance. Show plan and elevation views of decorative poles on Drawings.

A. Pole Material:

Retain one or more materials in subparagraphs below. If retaining more than one, indicate specifics on Drawings. Delete materials not used.

1. Cast ductile iron.
2. Cast gray iron, according to ASTM A 48/A 48M, Class 30.
3. Cast aluminum.
4. Cast concrete.
5. Spun concrete.
6. Steel tube, covered with closed-cell polyurethane foam, with a polyethylene exterior.
7. **<Insert material>**.

B. Mounting Provisions:

1. Bolted to concrete foundation.
2. Embedded.

C. Fixture Brackets:

1. Cast ductile iron.
2. Cast gray iron.
3. Cast aluminum.

D. Pole Finish: **<Insert finish>**.

2.12 POLE ACCESSORIES

Revise this article to suit Project, safety codes, and luminaire servicing methods. Add requirement for removable steps if necessary. Coordinate with the Exterior Lighting Device Schedule on Drawings.

A. Duplex Receptacle: 120 V, 20 A in a weatherproof assembly complying with Section 262726 "Wiring Devices" for ground-fault circuit-interrupter type.

1. Recessed, [12 inches (300 mm)] **<Insert dimension>** above finished grade.
2. Nonmetallic polycarbonate plastic or reinforced fiberglass, weatherproof in use, cover, **<Insert color to match pole,>** that when mounted results in NEMA 250, **[Type 3R] [Type 4X]** enclosure.
3. With cord opening.
4. With lockable hasp and latch that complies with OSHA lockout and tag-out requirements.

B. Minimum 1800-W transformer, protected by replaceable fuses, mounted behind access cover.

Coordinate two "base" paragraphs below with "Breakaway Supports" Paragraph in "General Requirements for Poles and Support Components" Article.

- C. Base Covers: Manufacturers' standard metal units, arranged to cover pole's mounting bolts and nuts. Finish same as pole.
- D. Transformer Type Base: Same material and color as pole. Coordinate dimensions to suit pole's base flange and accept [**ballast(s)**] [**indicated accessories**].

Accessories in paragraph below are usually selected for decorative poles only; verify availability for other types of poles.

- E. Decorative accessories, supplied by decorative pole manufacturer, include the following:
 - 1. Banner Arms: <Insert material>.
 - 2. Flag Holders: <Insert material>.
 - 3. Ladder Rests: <Insert material>.

2.13 LOWERING SYSTEM FOR LUMINAIRES

Retain this article to specify lowering system for either ring- or carriage-mounted, high-mast luminaire assemblies or individual pole-mounted luminaires.

- A. Arrange system to lower luminaire[**assembly**] to a servicing position within 36 inches (900 mm) of finished grade in winds up to 40 mph (65 km/h) and to provide for manual plug connection to electrical power in the lowered position for testing.
- B. Coordinate with luminaire and pole manufacturers for assembly details, wind-load and vibration analysis, and compatibility of materials for electrolysis-free attachment and connection for luminaire mounting assembly, lowering device, lowering cable, and portable winch.
- C. Structural and Mechanical Design: Use a minimum safety factor of 5.0 for static and dynamic loads of load-bearing components, including cable.

Retain one of first two paragraphs below to specify basic features and general arrangement of lowering system. Coordinate with Drawings.

- D. Luminaire Mounting and Disconnect Arrangement: Multiple [**ring**] [**carriage**]-mounted luminaires, arranged for lowering and rising as a group.

Retain one of two subparagraphs below to select method of disconnecting normal electrical operating power for luminaire assembly. First subparagraph is method used for group disconnect for luminaire assemblies. Second subparagraph is method used for both individual luminaires and luminaire assemblies.

- 1. Electrical cable for normal operating power to luminaires manually disconnects inside pole base, using weatherproof multipin connector, and shall be arranged to move within the pole during lowering and rising of luminaire assembly.

2. Electrical cable for normal operating power to luminaires automatically disconnects at a weatherproof multipin connector within the pole-top lowering head at the beginning of the lowering cycle and reconnects when luminaire or luminaire assembly is raised to the operating position.
- E. Lowering Device: Weatherproof, cast-aluminum housing and multiple mechanical latches. Moving parts of latching assembly shall be located in the portion of the unit that is lowered to the servicing position. Positive latching in the operating position shall be indicated to the operator at the base of the pole by a clear visual signal, or by other means acceptable to Owner or authorities having jurisdiction.

Stainless-steel cable in "Lowering Cable" Paragraph below may be standard with some manufacturers. Specify stainless-steel cable for corrosive environments.

- F. Lowering Cable: Stainless steel aircraft cable.

Coordinate "Portable Winch" Paragraph below with Drawings.

- G. Portable Winch: **[Manual]** **[120-V electric]** type. **[One]** **<Insert number>** required.

Retain two subparagraphs below if winch is electric.

1. Winch Power Connection: Cord and plug.
2. Winch Raise-Lower Control: Remote-control station with **[15 feet (5 m)]** **<Insert dimension>** of cable.

Retain "Winch Transformer" Paragraph below if using a pole lighting circuit rated above 120 V to power electric winch.

- H. Winch Transformer: Portable, totally enclosed, encapsulated, single-phase, dry type. Primary rated at lighting-circuit voltage; secondary rated at 120 V. Permanent, primary and secondary, twist-locking plug connectors on pigtails shall match pole-base power outlet and winch plug.

PART 3 - EXECUTION

3.1 INSTALLATION GENERAL

- A. Sequence and Schedule: The exterior lighting installation is to be sequenced and scheduled with other work to reduce possibility of damage and soiling of fixtures during the remainder of construction period.
- B. Power Outages: Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
- C. Photocells and Timers: The fixtures shall operate on the voltage shown. Provide and install all photocells and/or timer devices for automatic operation of the fixtures as

described in the construction documents.

- D. Torque Values: Connectors and terminals, including screws and bolts, are to be tightened in accordance with equipment manufacturer's published torque tightening values. Record all torque values for bolts and submit report with witness signature to DEN Project Manager.

3.2 LUMINAIRE INSTALLATION

- A. Install lamps in each luminaire.
- B. Fasten luminaire to indicated structural supports.

Retain subparagraph below if seismic restraint is required by local code or authorities having jurisdiction. See Evaluations.

- 1. Use fastening methods and materials selected to resist seismic forces defined for the application and approved by manufacturer.
- C. Adjust luminaires that require field adjustment or aiming. [**Include adjustment of photoelectric device to prevent false operation of relay by artificial light sources, favoring a north orientation.**]

3.3 POLE INSTALLATION

Retain "Alignment" Paragraph below if luminaire alignment for desired light distribution depends on alignment of pole.

- A. The pole will be installed according to the manufacturer's recommendations.
- B. Grounding will comply with National Electrical Code requirements.
- C. Individual fuses at each pole.
- D. Alignment: Align pole foundations and poles for optimum directional alignment of luminaires and their mounting provisions on the pole.

Coordinate "Clearances" Paragraph below with Drawings and revise to suit Project.

- E. Clearances: Maintain the following minimum clear horizontal distances of poles from surface and underground features unless otherwise indicated on Drawings:
 - 1. Fire Hydrants and Storm Drainage Piping: [60 inches (1520 mm)] <Insert dimension>.
 - 2. Water, Gas, Electric, Communication, and Sewer Lines: [10 feet (3 m)] <Insert dimension>.
 - 3. Trees: [15 feet (5 m)] <Insert dimension> from tree trunk.
 - 4. <Insert features and clearance dimensions>.

Coordinate first five paragraphs below with Drawings. See Evaluations for structural- and soil-engineering coordination.

- F. Concrete Pole Foundations: Set anchor bolts according to anchor-bolt templates furnished by pole manufacturer. Concrete materials, installation, and finishing requirements are specified in Section 033000 "Cast-in-Place Concrete."
- G. Foundation-Mounted Poles: Mount pole with leveling nuts, and tighten top nuts to torque level recommended by pole manufacturer.

Retain first subparagraph below if seismic restraint is required by local code or authorities having jurisdiction. See Evaluations.

- 1. Use anchor bolts and nuts selected to resist seismic forces defined for the application and approved by manufacturer.
- 2. Grout void between pole base and foundation. Use nonshrink or expanding concrete grout firmly packed to fill space.
- 3. Install base covers unless otherwise indicated.
- 4. Use a short piece of 1/2-inch- (13-mm-) diameter pipe to make a drain hole through grout. Arrange to drain condensation from interior of pole.

Retain one of first two paragraphs below for embedded poles and coordinate with Drawings.

- H. Embedded Poles with Tamped Earth Backfill: Set poles to depth below finished grade indicated on Drawings, but not less than one-sixth of pole height.
 - 1. Dig holes large enough to permit use of tampers in the full depth of hole.
 - 2. Backfill in 6-inch (150-mm) layers and thoroughly tamp each layer so compaction of backfill is equal to or greater than that of undisturbed earth.
- I. Embedded Poles with Concrete Backfill: Set poles in augered holes to depth below finished grade indicated on Drawings, but not less than one-sixth of pole height.
 - 1. Make holes 6 inches (150 mm) in diameter larger than pole diameter.
 - 2. Fill augered hole around pole with air-entrained concrete having a minimum compressive strength of 3000 psi (20 MPa) at 28 days, and finish in a dome above finished grade.
 - 3. Use a short piece of 1/2-inch- (13-mm-) diameter pipe to make a drain hole through concrete dome. Arrange to drain condensation from interior of pole.
 - 4. Cure concrete a minimum of 72 hours before performing work on pole.

For projects in seismic areas, retain first paragraph below to minimize possible concentration of horizontal forces during seismic events where poles or pole foundations meet the finished grade.

- J. Poles and Pole Foundations Set in Concrete Paved Areas: Install poles with minimum of 6-inch- (150-mm-) wide, unpaved gap between the pole or pole foundation and the edge of adjacent concrete slab. Fill unpaved ring with [pea gravel] <Insert material> to a level 1 inch (25 mm) below top of concrete slab.
- K. Raise and set poles using web fabric slings (not chain or cable).

3.4 BOLLARD LUMINAIRE INSTALLATION

- A. Align units for optimum directional alignment of light distribution.

Retain paragraph below if bollards require protection from damage at base due to landscaping maintenance or snow removal operations. Coordinate with Drawings.

- B. Install on concrete base with top [4 inches (100 mm)] <Insert dimension> above finished grade or surface at bollard location. Cast conduit into base, and shape base to match shape of bollard base. Finish by troweling and rubbing smooth. Concrete materials, installation, and finishing are specified in Section 033000 "Cast-in-Place Concrete."

3.5 INSTALLATION OF INDIVIDUAL GROUND-MOUNTING LUMINAIRES

Coordinate this article with Drawings. Delete if installation is detailed on Drawings.

- A. Install on concrete base with top [4 inches (100 mm)] <Insert dimension> above finished grade or surface at luminaire location. Cast conduit into base, and finish by troweling and rubbing smooth. Concrete materials, installation, and finishing are specified in Section 033000 "Cast-in-Place Concrete."

3.6 CORROSION PREVENTION

- A. Aluminum: Do not use in contact with earth or concrete. When in direct contact with a dissimilar metal, protect aluminum by insulating fittings or treatment.
- B. Steel Conduits: Comply with Section 260533 "Raceways and Boxes for Electrical Systems." In concrete foundations, wrap conduit with 0.010-inch- (0.254-mm-) thick, pipe-wrapping plastic tape applied with a 50 percent overlap.

3.7 GROUNDING

Coordinate first paragraph below with Drawings.

- A. Ground metal poles and support structures according to Section 260526 "Grounding and Bonding for Electrical Systems."
1. Install grounding electrode for each pole unless otherwise indicated.
 2. Install grounding conductor pigtail in the base for connecting luminaire to grounding system.
- B. Ground nonmetallic poles and support structures according to Section 260526 "Grounding and Bonding for Electrical Systems."

Retain first subparagraph below if lightning damage is of concern.

1. Install grounding electrode for each pole.

2. Install grounding conductor and conductor protector.
3. Ground metallic components of pole accessories and foundations.

3.8 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Inspect each installed fixture for damage. Replace damaged fixtures and components.
- B. Illumination Observations: Verify normal operation of lighting units after installing luminaires and energizing circuits with normal power source.
 1. Verify operation of photoelectric controls.

Retain "Illumination Tests" Paragraph below if specific illumination performance is indicated.

- C. Illumination Tests:
 1. Measure light intensities at night. Use photometers with calibration referenced to NIST standards. Comply with the following IESNA testing guide(s):

Retain one or more of five subparagraphs below.

- a. IESNA LM-5, "Photometric Measurements of Area and Sports Lighting Installations."
 - b. IESNA LM-50, "Photometric Measurements of Roadway Lighting Installations."
 - c. IESNA LM-52, "Photometric Measurements of Roadway Sign Installations."
 - d. IESNA LM-64, "Photometric Measurements of Parking Areas."
 - e. IESNA LM-72, "Directional Positioning of Photometric Data."
- D. Prepare a written report of tests, inspections, observations, and verifications indicating and interpreting results. If adjustments are made to lighting system, retest to demonstrate compliance with standards.
 - E. Cleaning: Clean all fixtures of dirt and debris upon completion of the installation and protect fixtures from damage during construction period.

3.9 DEMONSTRATION

- A. Demonstrate capability and compliance with specified requirements upon completion of installation of exterior lighting fixtures and associated circuiting.
- B. All lighting fixtures having an adjustable type beam spread or pole mounted apron ramp area being of the adjustable aiming type shall be field adjusted or aimed at the Contractor's expense and to the satisfaction of the DEN Project Manager.
- C. All fixtures of the above types (refer to drawings) shall be field adjusted (verify final placement of fixtures also) in accordance with the manufacturer's aiming

recommendations, and as indicated on the drawings and as required in the field. Include an allowance in the bid to cover all costs of aiming or adjusting these fixtures. Include an overtime allowance in the bid for aiming or adjusting exterior fixtures at night.

- D. Submit photometric report of light levels in all exterior areas to DEN Project Manager. All photometric readings shall be taken after a minimum of forty (40) hours burn-in of light fixtures.
- E. Contractor shall provide to the DEN Project Manager a Point by Point report showing the light level readings taken after the parking area has been properly aimed and the fixtures have had at least 50 hours of actual run time in the field. The grid spacing for the readings shall be the same as the calculations submitted prior to start of construction.
- F. Training: Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain all exterior lighting components, and luminaire lowering devices, if any.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 265600

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SECTION 270526 - GROUNDING AND BONDING FOR COMMUNICATIONS SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

NFPA 70 and IEEE C2 include basic grounding requirements for electrical safety. This Section supplements those requirements with grounding requirements for communications systems and with optional grounding methods and materials for power and electronic systems that go beyond basic minimum safety requirements.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes:
 - 1. Grounding conductors.
 - 2. Grounding connectors.
 - 3. Grounding busbars.
 - 4. Grounding rods.
 - 5. Grounding labeling.
- B. Related Sections:
 - 1. Section 260526 "Grounding and Bonding for Electrical Systems."

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. BCT: Bonding conductor for telecommunications.
- B. EMT: Electrical metallic tubing.
- C. TGB: Telecommunications grounding busbar.
- D. TMGB: Telecommunications main grounding busbar.

1.4 SYSTEM DESCRIPTION

- A. Provide each communications room with a ground bar for equipment bonding.
- B. Provide minimum #6 copper grounding conductor from each communications room ground bar and connect to nearest referenced ground bar in the electrical room.
- C. Bond together all communications equipment racks, cable trays, equipment enclosures, and metal raceway systems. Connect to the nearest equipment ground bar.
- D. Requirements of this section shall be considered as a supplement to the requirements of 260526 "Grounding and Bonding for Electrical Systems."

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For communications equipment room signal reference grid. Include plans, elevations, sections, details, and attachments to other work.

1.6 INFORMATIONAL SUBMITTALS

Retain "As-Built Data" Paragraph below to require Contractor to provide Drawings that locate significant grounding features. Section 017823 "Operation and Maintenance Data" and Section 017839 "Project

Record Documents" require submittals to be included in those documents for use by maintenance forces throughout the life of Project.

- A. As-Built Data: Plans showing as-built locations of grounding and bonding infrastructure, including the following:
 - 1. Ground rods.
 - 2. Ground and roof rings.
 - 3. BCT, TMGB, TGBs, and routing of their bonding conductors.

Coordinate two "Qualification Data" paragraphs below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- B. Qualification Data: For [Installer,]installation supervisor, and field inspector.
- C. Qualification Data: For testing agency and testing agency's field supervisor.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- D. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

Retain "Operation and Maintenance Data" Paragraph below if specifying test wells, separately derived systems, or ground ring or other grounding for sensitive electronic equipment. Field quality-control test-result values are important benchmarks for future preventive maintenance tests.

- A. Operation and Maintenance Data: For grounding to include in emergency, operation, and maintenance manuals.

Retain subparagraph below when it is anticipated that Owner's preventive maintenance program is likely to include periodic ground- and bonding-resistance tests.

- 1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Result of the ground-resistance test, measured at the point of BCT connection.
 - b. Result of the bonding-resistance test at each TGB and its nearest grounding electrode.
 - c. <Insert field quality-control test results>.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.8 QUALITY ASSURANCE

BICSI is an industry trade association. See Editing Instruction No. 2 in the Evaluations for summaries of qualifications for registration.

- A. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
 - 1. Installation Supervision: Installation shall be under the direct supervision of ITS [Technician] [Installer 2], who shall be present at all times when Work of this Section is performed at Project site.
 - 2. Field Inspector: Currently registered by BICSI as [a registered communications distribution designer] [ITS Installer 2] to perform the on-site inspection.

Edit below to include applicable sections.

- B. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.
- C. NFPA Compliance: NFPA 70 "National Electrical Code (NEC)," as adopted and amended by the Denver Building Code, Chapter 10.
- D. UL Compliance: Applicable requirements of UL Standards Nos. 467 "Electrical Grounding and Bonding Equipment," and 869, "Electrical Service Equipment," pertaining to grounding and bonding of systems, circuits and equipment. In addition, require compliance with UL Std 486A, "Wire Connectors." Grounding and bonding products shall be UL-listed and labeled for the use.
- E. IEEE Compliance: Applicable requirements and recommended installation practices of IEEE Standards 80, 81, 141 and 142 pertaining to grounding and bonding of systems, circuits and equipment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Grounding Connection Accessories:

1. Electrical insulating tape, heat-shrinkable insulating tubing, welding materials, bonding straps, as recommended by accessories manufacturers for type of service required.
- B. Exothermic welded connections are required where grounding conductors connect to underground grounding conductors and to underground grounding electrodes, and for bonding to steel. All underground connections shall be exothermic welded.
- C. All ground wires shall be copper except where stainless steel is specified for manholes, sized according to the NEC or as shown on the drawings whichever is larger.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.2 SYSTEM COMPONENTS

- A. Comply with J-STD-607-A.

2.3 CONDUCTORS

See "Grounding Products" Article in the Evaluations for discussion on alternative conductor materials.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Harger Lightning and Grounding.
 2. Panduit Corp.
 3. Tyco Electronics Corp.
 4. **<Insert manufacturer's name>.**
 5. or approved equal.
- B. Comply with UL 486A-486B.
- C. Insulated Conductors: Stranded copper wire, green or green with yellow stripe insulation, insulated for 600 V, and complying with UL 83.
 1. Ground wire for custom-length equipment ground jumpers shall be No. 6 AWG, 19-strand, UL-listed, Type THHN wire.

Retain "Cable Tray Equipment Grounding Wire" Subparagraph below if an equipment grounding conductor is required. If the ground wire serves as the telecommunications bonding backbone, indicate wire size on Drawings.

If cable tray contains electrical power conductors, then NFPA 70, Article 392 "Cable Trays" governs, and the minimum equipment grounding conductor size is No. 4 AWG.

2. Cable Tray Equipment Grounding Wire: No. 6 AWG.

D. Cable Tray Grounding Jumper:

Retain one of two subparagraphs below depending on the selection of the cable tray in Section 2 Not smaller than No. 6 AWG [26 kcmils (13.3 sq. mm)] and not longer than 12 inches (300 mm). If jumper is a wire, it shall have a crimped grounding lug with one hole and standard barrel for one crimp. If jumper is a flexible braid, it shall have a one- or two-hole ferrule. Attach with grounding screw or connector provided by cable tray manufacturer.

E. Bare Copper Conductors:

1. Solid Conductors: ASTM B 3.
2. Stranded Conductors: ASTM B 8.
3. Tinned Conductors: ASTM B 33.

Sizes and types of conductors in three subparagraphs below are typical examples. 28-kcmil ((14.2-sq. mm)) bonding cable in "Bonding Cable" Subparagraph is slightly larger than No. 6 AWG.

4. Bonding Cable: 28 kcmils (14.2 sq. mm), 14 strands of No. 17 AWG conductor, and 1/4 inch (6.3 mm) in diameter.
5. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
6. Bonding Jumper: Tinned-copper tape, braided conductors terminated with two-hole copper ferrules; 1-5/8 inches (41 mm) wide and 1/16 inch (1.6 mm) thick.

2.4 CONNECTORS

- A. Irreversible connectors listed for the purpose. Listed by an NRTL as complying with NFPA 70 for specific types, sizes, and combinations of conductors and other items connected. Comply with UL 486A-486B.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Burndy; Part of Hubbell Electrical Systems.
2. Chatsworth Products, Inc.
3. Harger Lightning and Grounding.
4. Panduit Corp.
5. Tyco Electronics Corp.
6. **<Insert manufacturer's name>.**
7. or approved equal.

- C. Compression Wire Connectors: Crimp-and-compress connectors that bond to the conductor when the connector is compressed around the conductor. Comply with UL 467.
 - 1. Electroplated tinned copper, C and H shaped.
- D. Signal Reference Grid Connectors: Combination of compression wire connectors, access floor grounding clamps, bronze U-bolt grounding clamps, and copper split-bolt connectors, designed for the purpose.
- E. Busbar Connectors: Cast silicon bronze, solderless [**compression**] [**or**] [**exothermic**]-type, mechanical connector; with a long barrel and two holes spaced on **5/8- or 1-inch** (15.8- or 25.4-mm) centers for a two-bolt connection to the busbar.
- F. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions.

2.5 GROUNDING BUSBARS

Retain this article if size of grounding bus and mounting details are not indicated on Drawings. The default dimension is recommended by BICSI for telecommunications busbar.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. [Chatsworth Products, Inc.](#)
 - 2. [Harger Lightning and Grounding.](#)
 - 3. [Panduit Corp.](#)
 - 4. **<Insert manufacturer's name>**.
 - 5. or approved equal.

Indicate length of TMGB on Drawings.

- B. TMGB: Predrilled, wall-mounted, rectangular bars of hard-drawn solid copper, [**1/4 by 4 inches** (6.3 by 100 mm)] **<Insert dimensions>** in cross section, length as indicated on Drawings. The busbar shall be NRTL listed for use as TMGB and shall comply with J-STD-607-A.
 - 1. Predrilling shall be with holes for use with lugs specified in this Section.

In "Mounting Hardware" Subparagraph below, the minimum required clearance is 2 inches (50 mm). 4 inches (100 mm) is typical in the industry. Indicate busbar length on Drawings.

- 2. Mounting Hardware: Stand-off brackets that provide a [**4-inch** ((100-mm))] **<Insert dimension>** clearance to access the rear of the busbar. Brackets and bolts shall be stainless steel.

3. Stand-off insulators for mounting shall be Lexan or PVC. Comply with UL 891 for use in 600-V switchboards, impulse tested at 5000 V.
- C. TGB: Predrilled rectangular bars of hard-drawn solid copper, [1/4 by 3 inches (6.3 by 50 mm)] <Insert dimensions> in cross section, length as indicated on Drawings. The busbar shall be for wall mounting, shall be NRTL listed as complying with UL 467, and shall comply with J-STD-607-A.
1. Predrilling shall be with holes for use with lugs specified in this Section.
 2. Mounting Hardware: Stand-off brackets that provide at least a 2-inch ((50-mm) clearance to access the rear of the busbar. Brackets and bolts shall be stainless steel.
 3. Stand-off insulators for mounting shall be Lexan or PVC. Comply with UL 891 for use in 600-V switchboards, impulse tested at 5000 V.

Retain "Rack and Cabinet Grounding Busbars" Paragraph below if equipment cabinets and racks are not specified with grounding busbars.

- D. Rack and Cabinet Grounding Busbars: Rectangular bars of hard-drawn solid copper, accepting conductors ranging from No. 14 to No. 2/0 AWG, NRTL listed as complying with UL 467, and complying with J-STD-607-A. Predrilling shall be with holes for use with lugs specified in this Section.
1. Cabinet-Mounted Busbar: Terminal block, with stainless-steel or copper-plated hardware for attachment to the cabinet.
 2. Rack-Mounted Horizontal Busbar: Designed for mounting in 19- or 23-inch (483- or 584-mm) equipment racks. Include a copper splice bar for transitioning to an adjoining rack, and stainless-steel or copper-plated hardware for attachment to the rack.
 3. Rack-Mounted Vertical Busbar: 72 or 36 inches ((1827 or 914 mm) long, with)stainless-steel or copper-plated hardware for attachment to the rack.

2.6 GROUND RODS

Retain this article if ground rods incidental to ground rings and duct banks are required. Indicate ground rod locations and connections on Drawings. See "Grounding Products" Article in the Evaluations for discussion on alternative materials.

The installation of grounding electrode system for the alternating-current (ac) power system, which includes ground rods, ground rings, metal underground water pipes, metal building frames, concrete-encased electrodes, and pipe and plate electrodes, is specified in Section 260526 "Grounding and Bonding for Electrical Systems." The grounding and bonding system of this Section is connected to the grounding and bonding of the ac power system with the BCT from the TMGB specified in "Grounding Electrode System" Article.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:

1. Harger Lightning and Grounding.
2. Tyco Electronics Corp.
3. **<Insert manufacturer's name>.**
4. or approved equal.

B. Ground Rods: Copper-clad steel, **3/4 inch by minimum 10 feet** (19 mm by 3 m) in diameter.

1. In manholes, ground rods shall be stainless steel $\frac{3}{4}$ -inch diameter and a minimum length of 10 feet.

2.7 LABELING

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Brother International Corporation.
 2. HellermannTyton.
 3. Panduit Corp.
 4. **<Insert manufacturer's name>.**
 5. or approved equal.
- B. Comply with TIA/EIA-606-A and UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.
- C. Adhesive Film Label with Clear Protective Overlay: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be **3/8 inch** (10 mm). Overlay shall provide a weatherproof and UV-resistant seal for label.

PART 3 - EXECUTION

3.1 EXAMINATION

See "Ground Resistance" Article in the Evaluations for discussion of ground-resistance levels.

- A. Examine the ac grounding electrode system and equipment grounding for compliance with requirements for maximum ground-resistance level and other conditions affecting performance of grounding and bonding of the electrical system.
- B. Inspect the test results of the ac grounding system measured at the point of BCT connection.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

- D. Proceed with connection of the BCT only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Bonding shall include the ac utility power service entrance, the communications cable entrance, and the grounding electrode system. The bonding of these elements shall form a loop so that each element is connected to at least two others.
- B. Comply with NECA 1.
- C. Comply with J-STD-607-A.
- D. Supplementary Grounding Electrode: Use grounding mats, where indicated, or driven ground rods. Install ground rods in suitable recessed well; fill with gravel after connection is made.
- E. Provide a No. 6 AWG and ground plate to each Communications Room or board. Connect to nearest Electrical Room ground plate.
- F. Provide isolated and insulated ground conductors for all microprocessor and data processing equipment.
- G. Tighten grounding and bonding connectors and terminals, including screws and bolts, in accordance with manufacturer's published torque tightening values for connectors and bolts. Where manufacturer's torquing requirements are not indicated, connections are to be tightened to comply with tightening torque values specified in UL 486A to assure permanent and effective grounding.
- H. Provide code-sized ground cable bonding jumpers, installed with ground clamps, across all conduit expansion couplings and fittings, including flexible steel conduit used as expansion fittings.
- I. Provide a corrosion-resistant finish to field connections, buried metallic bonding products, and where factory applied protective coatings have been destroyed.
- J. All continuous runs of cable tray and all isolated sections of cable tray shall be bonded and grounded.

3.3 APPLICATION

- A. Conductors: Install solid conductor for **[No. 8]** <Insert number> AWG and smaller and stranded conductors for **[No. 6]** <Insert number> AWG and larger unless otherwise indicated.
 - 1. The bonding conductors between the TGB and structural steel of steel-frame buildings shall not be smaller than **[No. 6]** <Insert number> AWG.

2. The bonding conductors between the TMGB and structural steel of steel-frame buildings shall not be smaller than **[No. 6]** <Insert number> AWG.
- B. Underground Grounding Conductors: Install bare [~~tinned-~~]copper conductor, **[No. 2]** <Insert number> AWG minimum.
- C. Conductor Terminations and Connections:
1. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors.
 2. Underground Connections: Welded connectors except at test wells and as otherwise indicated.
 3. Connections to Ground Rods at Test Wells: Bolted connectors.
 4. Connections to Structural Steel: Welded connectors.
- D. Conductor Support:
1. Secure grounding and bonding conductors at intervals of not less than **36 inches** ((900 mm).)
- E. Grounding and Bonding Conductors:
1. Install in the straightest and shortest route between the origination and termination point, and no longer than required. The bend radius shall not be smaller than eight times the diameter of the conductor. No one bend may exceed 90 degrees.
 2. Install without splices.
 3. Support at not more than **36-inch** (900-mm) intervals.
 4. Install grounding and bonding conductors in **3/4-inch** (21-mm) PVC conduit until conduit enters a telecommunications room. The grounding and bonding conductor pathway through a plenum shall be in EMT. Conductors shall not be installed in EMT unless otherwise indicated.
 - a. If a grounding and bonding conductor is installed in ferrous metallic conduit, bond the conductor to the conduit using a grounding bushing that complies with requirements in Section 270528 "Pathways for Communications Systems," and bond both ends of the conduit to a TGB.

3.4 GROUNDING ELECTRODE SYSTEM

Retain paragraph below if the size of the BCT between the TMGB and the ac service is not indicated on Drawings. For bonding conductor length up to 52 feet (16 m), use No. 1/0 AWG; if longer, use No. 3/0 AWG. For selection details, see Editing Instruction No. 3 in the Evaluations. The length of the BCT should be less than 30 feet (9 m) because the impedance of this conductor, due to its length, limits its effectiveness.

- A. The BCT between the TMGB and the ac service equipment ground shall not be smaller than **[No. 1/0]** **[No. 3/0]** <Insert number> AWG.

3.5 GROUNDING BUSBARS

- A. Indicate locations of grounding busbars on Drawings. Install busbars horizontally, on insulated spacers **2 inches (50 mm)** minimum from wall, **12 inches (300 mm)** above finished floor unless otherwise indicated.
- B. Where indicated on both sides of doorways, route bus up to top of door frame, across top of doorway, and down; connect to horizontal bus.

3.6 CONNECTIONS

- A. Bond metallic equipment in a telecommunications equipment room to the grounding busbar in that room, using equipment grounding conductors not smaller than No. 6 AWG.
- B. Stacking of conductors under a single bolt is not permitted when connecting to busbars.
- C. Assemble the wire connector to the conductor, complying with manufacturer's written instructions and as follows:
 - 1. Use crimping tool and the die specific to the connector.
 - 2. Pretwist the conductor.
 - 3. Apply an antioxidant compound to all bolted and compression connections.
- D. Primary Protector: Bond to the TMGB with insulated bonding conductor.

Retain "Interconnections" Paragraph below if all telecommunications backbone and grounding equalizer conductors are not sized on Drawings.

- E. Interconnections: Interconnect all TGBs with the TMGB with the telecommunications backbone conductor. If more than one TMGB is installed, interconnect TMGBs using the grounding equalizer conductor. The telecommunications backbone conductor and grounding equalizer conductor size shall not be less than **2 kcmils/linear foot (1 sq. mm/linear meter)** of conductor length, up to a maximum size of No. 3/0 AWG [**168 kcmils (85 sq. mm)**] unless otherwise indicated.
- F. Telecommunications Enclosures and Equipment Racks: Bond metallic components of enclosures to the telecommunications bonding and grounding system. Install [**top-mounted**] [**vertically mounted**] rack grounding busbar unless the enclosure and rack are manufactured with the busbar. Bond the equipment grounding busbar to the TGB No. 2 AWG bonding conductors.

Retain "Shielded Cable" Paragraph below if screened twisted-pair cables and coaxial cables are installed in communications equipment rooms.

- G. Shielded Cable: Bond the shield of shielded cable to the TGB in communications rooms and spaces. Comply with TIA/EIA-568-B.1 and TIA/EIA-568-B.2 when grounding screened, balanced, twisted-pair cables.

- H. Rack- and Cabinet-Mounted Equipment: Bond powered equipment chassis to the cabinet or rack grounding bar. Power connection shall comply with NFPA 70; the equipment grounding conductor in the power cord of cord- and plug-connected equipment shall be considered as a supplement to bonding requirements in this Section.
- I. Access Floors: Bond all metal parts of access floors to the TGB.

Retain "Equipment Room Signal Reference Grid" Paragraph below for equipment rooms with a raised floor. TIA-942 recommends No. 6 as the minimum bonding network conductor size. Paragraph is for 4-foot (1200-mm) conductive floor tiles; adjust for other sizes.

- J. Equipment Room Signal Reference Grid: Provide a low-impedance path between telecommunications cabinets, equipment racks, and the reference grid, using [No. 6] <Insert number> AWG bonding conductors.
 - 1. Install the conductors in grid pattern on 4-foot (1200-mm) centers, allowing bonding of one pedestal from each access floor tile.
 - 2. Bond the TGB of the equipment room to the reference grid at two or more locations.
 - 3. Bond all conduits and piping entering the equipment room to the TGB at the perimeter of the room.
- K. Towers and Antennas:
 - 1. Ground Ring: Buried at least 30 inches (760 mm) below grade and at least 24 inches (610 mm) from the base of the tower or mounting.
 - 2. Bond each tower base and metallic frame of a dish to the ground ring, buried at least 18 inches (460 mm) below grade.
 - 3. Bond the ground ring and antenna grounds to the equipment room TMGB or TGB, buried at least 30 inches (760 mm) below grade.
 - 4. Bond metallic fences within 6 feet (1.8 m) of towers and antennas to the ground ring, buried at least 18 inches (460 mm) below grade.

When retaining "Special Requirements for Roof-Mounted Towers" Subparagraph below, coordinate the grounding system of the tower with the lightning protection system of the building.

- 5. Special Requirements for Roof-Mounted Towers:
 - a. Roof Ring: Meet requirements for the ground ring except the conductors shall comply with requirements in Section 264113 "Lightning Protection for Structures."
 - b. Bond tower base footings steel, the TGB in the equipment room, and antenna support guys to the roof ring.
 - c. Connect roof ring to the perimeter conductors of the lightning protection system.
- 6. Waveguides and Coaxial Cable:
 - a. Bond cable shields at the point of entry into the building to the TGB and to the cable entrance plate, using No. 2 AWG bonding conductors.

- b. Bond coaxial cable surge arrester to the ground or roof ring using bonding conductor size recommended by surge-arrester manufacturer.

L. **<Insert connections of other equipment>.**

3.7 GROUNDING UNDERGROUND DISTRIBUTION SYSTEM COMPONENTS

Retain this article if grounding underground distribution system components is not specified in Section 260526 "Grounding and Bonding for Electrical Systems." Coordinate "Duct-Bank Grounding Conductor" Paragraph below with Drawings and with Section 260543 "Underground Ducts and Raceways for Electrical Systems."

- A. Duct-Bank Grounding Conductor: Bury 12 inches (300 mm) above duct bank when indicated as part of duct-bank installation.
- B. Comply with IEEE C2 grounding requirements.
- C. Grounding Manholes and Handholes: Install a driven ground rod through manhole or handhole floor, close to wall, and set rod depth so 4 inches (100 mm) extends above finished floor. If necessary, install ground rod before manhole is placed and provide No. 1/0 AWG bare, tinned-copper conductor from ground rod into manhole through a waterproof sleeve in manhole wall. Protect ground rods passing through concrete floor with a double wrapping of pressure-sensitive insulating tape or heat-shrunk insulating sleeve from 2 inches (50 mm) above to 6 inches (150 mm) below concrete. Seal floor opening with waterproof, nonshrink grout.
- D. Grounding Connections to Manhole Components: Bond exposed-metal parts such as inserts, cable racks, pulling irons, ladders, and cable shields within each manhole or handhole, to ground rod or grounding conductor. Make connections with No. 4 AWG minimum, bonding conductor. Train conductors level or plumb around corners and fasten to manhole walls. Connect grounding conductors to cable armor and cable shields according to written instructions by manufacturer of splicing and termination kits.

3.8 IDENTIFICATION

- A. Labels shall be preprinted or computer-printed type.
 - 1. Label TMGB(s) with "fs-TMGB," where "fs" is the telecommunications space identifier for the space containing the TMGB.
 - 2. Label TGB(s) with "fs-TGB," where "fs" is the telecommunications space identifier for the space containing the TGB.
 - 3. Label the BCT and each telecommunications backbone conductor at its attachment point: "WARNING! TELECOMMUNICATIONS BONDING CONDUCTOR. DO NOT REMOVE OR DISCONNECT!"

3.9 FIELD QUALITY CONTROL

Retain "Testing Agency" or "Perform tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph, or if retaining "Perform tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- B. Perform tests and inspections.

Retain "Tests and Inspections" Paragraph below to describe tests and inspections to be performed.

The maximum acceptable connection resistance and ac loop current values are based on recommendations of BICSI TDMM.

- C. Tests and Inspections:
1. Inspect physical and mechanical condition. Verify tightness of accessible, bolted, electrical connections with a calibrated torque wrench according to manufacturer's written instructions.
 2. Test the ground resistance to earth of each ground rod prior to connection to the system. Where test show resistance to ground is over 5 OHMS, report to DEN Project Manager locations and values. Submit test results to the DEN Project Manager.
 3. Test the bonding connections of the system using an ac earth ground-resistance tester, taking two-point bonding measurements in each telecommunications equipment room containing a TMGB and a TGB and using the process recommended by BICSI TDMM. Conduct tests with the facility in operation.
 - a. Measure the resistance between the busbar and the nearest available grounding electrode. The maximum acceptable value of this bonding resistance is 100 milliohms.
 4. Test for ground loop currents using a digital clamp-on ammeter, with a full-scale of not more than 10 A, displaying current in increments of 0.01 A at an accuracy of plus/minus 2.0 percent.
 - a. With the grounding infrastructure completed and the communications system electronics operating, measure the current in every conductor connected to the TMGB[**and in each TGB**]. Maximum acceptable ac current level is 1 A.

- D. Excessive Ground Resistance: If resistance to ground at the BCT exceeds [5] <Insert value> ohms, notify DEN Project Manager promptly and include recommendations to reduce ground resistance.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. Grounding system will be considered defective if it does not pass tests and inspections. Correct all work that fails testing requirements and re-test system.
- F. Prepare test and inspection reports.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 270526

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SECTION 270528 - PATHWAYS FOR COMMUNICATIONS SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

1. Metal conduits and fittings.
2. Nonmetallic conduits and fittings.
3. Optical-fiber-cable pathways and fittings.
4. Metal wireways and auxiliary gutters.
5. Nonmetallic wireways and auxiliary gutters.
6. Surface pathways.
7. Boxes, enclosures, and cabinets.
8. Handholes and boxes for exterior underground cabling.

- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

Retain one or both of first two subparagraphs below to suit Project. Coordinate with electrical Sections to determine which Section is included in the Project and for the requirements for communications systems.

1. Section 260536 "Cable Trays for Electrical Systems" for cable tray systems.
2. Section 260543 "Underground Ducts and Raceways for Electrical Systems" for exterior ductbanks, manholes, and underground utility construction.
3. Section 260533 "Raceways and Boxes for Electrical Systems" for conduits, wireways, surface raceways, boxes, enclosures, cabinets, handholes, and faceplate adapters serving electrical systems.
4. Section 280528 "Pathways for Electronic Safety and Security" for conduits, surface pathways, innerduct, boxes, and faceplate adapters serving electronic safety and security.
5. Section 271100 "Communications Equipment Rooms and Fittings".

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. ARC: Aluminum rigid conduit.
- B. GRC: Galvanized rigid steel conduit.
- C. IMC: Intermediate metal conduit.
- D. IDF: Intermediate Distribution Facility
- E. MDF: Main Distribution Facility

1.4 GENERAL

- A. Denver International Airport (DEN) owns and operates a private telecommunications infrastructure that provides voice, data and video services to all airport, airline and tenant facilities throughout the fifty-three square mile site. Tenants developing leasehold spaces or facilities on ground-leased sites are required to design their horizontal wiring pathways in accordance with these guidelines. Horizontal wiring pathways include all types of raceway systems to support voice, data, LAN, CATV and fiber cabling between DEN telecommunications rooms and outlets in the tenant, public or City areas.
- B. Designers are required to submit a complete set of plans and specifications for their projects to the DEN Telecommunications Department for review and approval. Designers are also required to meet with representatives from the DEN Telecommunications Department at one or more times during the course of design to work out specific interface details prior to the final submittal.

- C. Tenants and designers are encouraged to utilize the services of the current DEN Premise Wiring and Communications System (PWCS) contractor for installation of all horizontal cabling, outlets and termination. The City's contract with this contractor stipulates that all wiring and other components installed by the PWCS contractor be serviced and maintained by that contractor as part of the ongoing PWCS system maintenance agreement. The PWCS contractor is permitted to add a fair and reasonable amount to any such work to cover the expected maintenance through the duration of the current contract. The use of the PWCS contractor for this work affords the tenant a single party with end-to-end responsibility for the horizontal cabling system.
- D. A tenant may elect to install a privately owned and maintained system of horizontal wiring within its leasehold space. This wiring would extend from outlets within the leasehold area to a designated point of demarcation with the DEN PWCS system. In this configuration, circuits ordered through the PWCS contractor or regulated telephone company will be terminated and tagged at the designated point of demarcation. Responsibility for cross connecting these circuits from the point of demarcation to their final destination remains the responsibility of the tenant. The PWCS contractor will troubleshoot any reported problems with a circuit only as far as the designated point of demarcation.
- E. Any tenant vacating their leasehold space shall leave any horizontal wiring in place and in serviceable condition. This shall include outlets, horizontal wiring and termination blocks at the telecommunications equipment room.
- F. An effective Design of a building's Horizontal Wiring Pathway System should meet the following criteria:
1. All applicable codes.
 2. Provide flexible cable distribution to workstation locations.
 3. Facilitate ongoing maintenance.
 4. Easily accommodate future changes in equipment and services.
 5. Minimize occupant disruption when horizontal pathways and spaces are accessed.
- G. The horizontal distribution system must be designed to accommodate all types of communications cabling (i.e., UTP, Coax, and Fiber Optic cabling). When determining the type and size of the cable pathway, consider the quantity and size of the cables that the pathway is intended to house, and potential for growth in the area served.
- H. When designing the horizontal distribution system it is important to consider Moves, Adds and Changes (MACs) and minimal disruption to immediate occupants.
- I. Electromagnetic Interference (EMI):
1. EMI causes severe problems with electronic equipment, telecommunications and data communications, avoidance of all potential sources or, electromagnetic interference must be a primary consideration when designing a horizontal distribution system. To avoid electromagnetic interference, all distribution pathways should provide clearances of at least:

- a. Four (4) ft. (1.2 m) from large motors and/or transformers.
 - b. One (1) ft. (0.3 m) from conduit and cables used for electrical power distribution.
 - c. Five (5) in. (12 cm) from fluorescent lighting.
2. Note: Horizontal Distribution Pathways should cross perpendicular to fluorescent lighting and electrical power cables or conduits.
- J. Horizontal Pathways must be grounded and bonded in accordance with the requirements specified in ANSI/NFPA 70, except where other codes or local authorities impose more stringent requirements.
- K. Maximum cable distance between any outlet and the telecommunications room, closet or cabinet shall not exceed ninety **295 feet** (90 meters).
- L. Conduit Entry to Telecommunications Rooms: Horizontal distribution conduits entering a telecommunications closet should terminate above the room's cable ladder system to allow for proper cable racking. If conduits are entering through the floor, they must terminate four (4) inches above the finished floor. Conduits must be reamed, equipped with a bonding bushing and terminated as close as possible to the terminating rack or wall. Provide a #6 AWG bare copper bonding connection between the bonding bushing(s) and cable ladder system or equipment room grounding bar.

1.5 INTERMEDIATE DISTRIBUTION FACILITIES

- A. Intermediate Distribution Facilities shall be provided at locations as required to reach any area of the facility with a 90-meter length of cabling. Reserve fifteen meters of this cabling length for patch cord connections between horizontal cabling terminations in the IDF and tenant LAN equipment in a directly adjacent tenant equipment room space.
- B. The IDF will serve as the demarcation point between the DEN Premise Wiring and Communications System backbone cabling system and horizontal cabling system. In addition to cable terminations, these rooms may contain active electronic equipment for DEN Local Area Network services, data circuit conditioning equipment, DEN access control (card reader) equipment, DEN closed circuit television equipment and other equipment that may be required by DEN Telecommunications to support the building.
- C. Tenant equipment shall not be permitted within any IDF room. Provide a separately accessible tenant equipment room to support tenant LAN equipment in lockable tenant provided cabinets. Cabling for tenant LAN services will be terminated in the DEN IDF room and extended with Category 5e jumpers to the tenant equipment.
- D. IDF rooms shall not be placed in locations that are subject to the effects of water infiltration, steam infiltration, humidity from nearby water or steam, excessive heat (e.g., direct sunlight) or any other corrosive atmospheric or environmental conditions. Avoid locations that are below grade unless preventive measures against water infiltration are employed. The room must be free of plumbing and electrical utilities that

are not directly required to support the equipment room function. A floor drain is required if there is any risk of water entering the facility.

- E. NEC Section 110-16 requires three (3) feet of clear working space around equipment with exposed live parts. This shall apply to all communication equipment in the IDF room.
- F. Telecommunications equipment requires heating, ventilating and air conditioning equipment to functions properly at all times. All IDF spaces shall be designed to maintain a temperature range 64 degrees to 75 degrees F at 30 percent to 55 percent relative humidity. Heat Dissipation 750 to 5000 BTUs per cabinet (number of cabinets to be determined through consultation with DEN Telecommunications).
- G. The floor rating under distributed loading must be greater than 250 lb/ft.2. The floor loading under equipment racks and other concentrated loads must be greater than 1000 lbs per square foot. Floor finish shall be static resistant vinyl tile.
- H. IDF room walls should extend from the finished floor to the structural ceiling (e.g., the slab), be covered with two coats of fire-retardant white or light colored paint, and carry a minimum fire rating of two hours or as required by the applicable codes and regulations. All equipment room walls shall be lined with ¾" fire retardant B/C plywood to a height of 8'-0" above the finished floor. Plywood shall be painted with fire retardant paint to match room finish.
- I. DEN Telecommunications generally does not recommend a finished ceiling in an IDF room as such ceilings impede the installation of raceways and cable pulling. A sealed dust-free concrete finish is acceptable. Where ceilings must be installed, the recommended height of the finished ceiling to the finished floor is a minimum of 8'-6" to allow for cable ladder and cabling above the racks and frames. Any ceiling protrusions (ventilation, sprinklers, etc.) must be placed to assure a minimum clearance height of 8 ft. The ceiling finish must minimize the introduction of dust, and be white to enhance room lighting. Hard, non-accessible ceilings shall not be used in IDF rooms under any circumstance.
- J. IDF rooms shall be provided with adequate and uniform lighting that provides a minimum equivalence of 540 lux (50 footcandles) when measured 3 ft. above the finished floor to illuminate wall mounted equipment and the front and rear surfaces of racks and frames. Locate lighting fixtures a minimum of 8 ft. 6 in. above the finished floor. Locate light switches near the entrance(s) to the equipment room. Power for lighting should not come from the same circuits as power for the communications equipment. Provide emergency lighting as required by applicable building codes.
- K. Each IDF room shall be provided with a 120/208Volt, 3-Phase, 4-wire load center served with a separate feeder. The size of this load center will vary with the size of the building and the type of demarcation equipment installed. Quadplex power receptacles with separate 20 amp circuit and isolated grounds, shall be mounted on every wall in the equipment room. Spacing shall be on six (6) foot centers and receptacles shall be located at 16-inches above the finished floor. Other power requirements (e.g., fluorescent lighting, motors, air conditioning equipment) shall be supplied by a separate feeder, conduit, and branch panel. Provide a UL listed transient voltage surge

suppressor directly adjacent to the IDF load center. Connect suppressor to line buses through spare 3-pole circuit breaker. Connect suppressor ground and neutral conductor from suppressor to panel ground and neutral buses. Keep all leads short and as straight as possible. Nipple between suppressor and panel shall not exceed 3-inches. Provide 12" x 2" x 1/4" isolated ground bar directly below panel. Extend #6AWG bare conductor from ground bus on load center to ground bar. Extend #2AWG bare copper from ground bar to building electrical service ground.

- L. All IDF spaces shall be provided with smoke detector(s) interconnected with the building fire alarm system. Fire alarm components shall conform to applicable DEN standards and local codes. One portable type ABC fire extinguishers shall be located in the room close to the entrance.
- M. All IDF spaces equipped with a DEN access control system card reader inside and outside the IDF door. Equip door with door position switch, electric hinge and solenoid operated lockset which remains operable from inside the room at all times.
- N. A contiguous 12-inch wide cable ladder shall be provided around the full perimeter of all walls of the IDF room at a height of 84-inches measured from the bottom of the cable runway to the finished floor. Wall brackets used to support cable ladder shall be of sufficient length to allow the passage of a 4-inch EMT conduit between the cable ladder and finished wall. Provide bonding strap at all connections between sections of cable ladder. Provide one #6AWG bare copper bond from cable ladder system to IDF ground bar. Two-inch and larger conduits entering the room from above shall be terminated at a height of 24-inches above the cable ladder system. Smaller conduits shall terminate at a height of 12-inches above the cable ladder system. All conduits shall terminate with a bonding bushing which is in turn bonded individually or in groups to the cable ladder.
- O. Conduits entering the IDF from below shall be racked on a unistrut frame and terminated at approximately 8-inches above the floor with a bonding bushing. These bushings shall be bonded either individually or collectively to the IDF grounding bar with a #6AWG bare copper conductor. Provide a 6-inch concrete housekeeping curb around each conduit grouping as shown on the details that accompany this section.
- P. IDF rooms on multiple floors of a building shall be vertically aligned to permit the use of fire-safed sleeves between IDF rooms. Designers may wish to place IDF rooms adjacent to fixed vertical elements of the building such as elevators or stairwells as long as these vertical elements do not unduly restrict the entry of horizontal cabling into the IDF rooms. Do not allow conduit to be embedded in the floor or ceiling slab of any IDF room to allow for future core drilling between floors.
- Q. IDF Room Configuration and Sizes:

Verify if current IDF Room plans are included on Drawings, or attach to the end of this Section. Edit below to suit Project.

Verify if current IDF Room plans are included on Drawings, or attach to this Section. Edit below to suit Project.

1. Reference [**Drawings**] [**Diagram attached at end of Section**] <Insert location>

for DEN IDF Room Configuration plans.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.6 ACTION SUBMITTALS

- A. Product Data: For surface pathways, wireways and fittings, floor boxes, hinged-cover enclosures, and cabinets.
- B. LEED Submittals:

"Product Data for Credit IEQ 4.1" Subparagraph below applies to LEED-NC, LEED-CI, and LEED-CS; coordinate with requirements for solvent cements and adhesive primers.

- 1. Product Data for Credit IEQ 4.1: For solvent cements and adhesive primers, documentation including printed statement of VOC content.

"Laboratory Test Reports for Credit IEQ 4" Subparagraph below applies to LEED for Schools.

- 2. Laboratory Test Reports for Credit IEQ 4: For solvent cements and adhesive primers, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

Retain "Shop Drawings" Paragraph below for custom enclosures only.

- C. Shop Drawings: For custom enclosures and cabinets. Include plans, elevations, sections, and attachment details.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager. Coordinate sample requirements with DEN Project Manager.

- D. Samples: For [wireways] [nonmetallic wireways] [and] [surface pathways] and for each color and texture specified, [12 inches (300 mm)] <Insert dimension> long.

1.7 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below if Drawings do not include detailed conduit routing plans and if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Pathway routing plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of items involved:
 - 1. Structural members in paths of pathway groups with common supports.
 - 2. HVAC and plumbing items and architectural features in paths of conduit groups with common supports.

Retain "Qualification Data" Paragraph below if source quality-control tests are required to be certified by a professional engineer. Coordinate with qualification requirements in Section 014000 "Quality Requirements."

- B. Qualification Data: For professional engineer.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- C. Source quality-control reports.
- D. As built drawings: Provide complete as-built drawings for all IDF rooms, backbone conduit routes and tray routes indicating actual routing.

1.8 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Provide complete as-built drawings for all IDF rooms, backbone conduit routes and tray routes indicating actual routing.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 METAL CONDUITS AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. AFC Cable Systems, Inc.
2. Allied Tube & Conduit; a Tyco International Ltd. Co.
3. Alpha Wire Company.
4. Anamet Electrical, Inc.
5. Electri-Flex Company.
6. O-Z/Gedney; a brand of EGS Electrical Group.
7. Picoma Industries; Subsidiary of Mueller Water Products, Inc.
8. Republic Conduit.
9. Robroy Industries.
10. Southwire Company.
11. Thomas & Betts Corporation.
12. Western Tube and Conduit Corporation.
13. Wheatland Tube Company; a division of John Maneely Company.
14. <Insert manufacturer>
15. or approved equal.

B. General Requirements for Metal Conduits and Fittings:

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with TIA-569-B.
3. 4-inch electrical metallic tubing or rigid metallic conduit may be used at above grade locations between MDF and IDF rooms or between IDF rooms. Refer to DEN standards for electrical raceways for the applicability of each type of conduit by location. All conduits shall terminate with bonding bushings at the IDF or MDF rooms that are bonded to the cable ladder system in the room.
4. Conduits entering the IDF from below shall be racked on a unistrut frame and terminated at approximately 8-inches above the floor with a bonding bushing. These bushings shall be bonded either individually or collectively to the IDF grounding bar with a #6 AWG bare copper conductor. Provide a 6-inch concrete housekeeping curb around each conduit grouping.

C. GRC: Comply with ANSI C80.1 and UL 6.

Retain "ARC" Paragraph below for corrosion resistance and other special conditions.

D. ARC: Comply with ANSI C80.5 and UL 6A.

E. IMC: Comply with ANSI C80.6 and UL 1242.

F. PVC-Coated Steel Conduit: PVC-coated [**rigid steel conduit**] [**IMC**].

1. Comply with NEMA RN 1.
2. Coating Thickness: 0.040 inch (1 mm), minimum.

G. EMT: Comply with ANSI C80.3 and UL 797.

H. Fittings for Metal Conduit: Comply with NEMA FB 1 and UL 514B.

Coordinate "Conduit Fittings for Hazardous (Classified) Locations" Subparagraph below with Drawings.

1. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 886 and NFPA 70.
2. Fittings for EMT:
 - a. Material: Steel.
 - b. Type: [**Setscrew**] [**or**] [**compression**].
3. Expansion Fittings: PVC or steel to match conduit type, complying with UL-467, rated for environmental conditions where installed, and including flexible external bonding jumper.
4. Coating for Fittings for PVC-Coated Conduit: Minimum thickness of 0.040 inch (1 mm), with overlapping sleeves protecting threaded joints.

Retain "Joint Compound for IMC, GRC, or ARC" Paragraph below to require some threaded joints of IMC, GRC, or ARC, or their fittings, to be treated with joint compound for improved conductivity, resistance to oxidation, or ease of assembly and disassembly.

- I. Joint Compound for IMC, GRC, or ARC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.
- J. Vertical (Backbone) Communications Pathways - Conduit:
 1. 4-inch electrical metallic tubing or rigid metallic conduit may be used at above grade locations between MDF and IDF rooms or between IDF rooms. Refer to DEN standards for electrical raceways for the applicability of each type of conduit by location. All conduits shall terminate with bonding bushings at the IDF or MDF rooms that are bonded to the cable ladder system in the room.
 2. 4-inch schedule 40 PVC may be used in new construction between communications rooms. Conduit shall transition to PVC coated galvanized rigid steel at all elbows and at terminations at IDF or MDF rooms. Provide 4'-0" minimum radius on all bends. All conduits shall be provided with bonding bushings at equipment room terminations that are bonded either individually or collectively to the equipment room grounding bar.
 3. Conduits used for vertical cabling shall have no more than 270-degrees in bends. Straight-through pull boxes shall be used in conduit runs which exceed this value. Pull boxes shall be sufficiently large to accommodate the number of 4-inch conduits in the run assuming a single cable of 51% fill in each of the raceways. All pull boxes shall be equipped with hinged covers.
 4. All conduit shall be verified after installation by pulling a mandrel through the conduit that is 80% of the internal diameter of the conduit. After completion of the mandrel test install one 3/4" wide woven aramid fiber pull tape in each conduit. Feed tape straight through pull boxes without breaking or splicing. Pull tape shall provide 2500 pounds of tensile strength and be marked with consecutive footage numbers at one-foot intervals. Permanently tie off tapes at both ends.
 5. Upon completion vertical communications conduit shall be left clean, dry and unobstructed. Cap each conduit to prevent entry of debris. Provide a permanent label on the bonding bushing for each conduit indicating the number of the conduit and destination of the remote end.

2.2 NONMETALLIC CONDUITS AND FITTINGS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. AFC Cable Systems, Inc.
2. Allied Tube & Conduit; a Tyco International Ltd. Co.
3. Anamet Electrical, Inc.
4. Arnco Corporation.
5. CANTEX Inc.
6. CertainTeed Corp.
7. Condux International, Inc.
8. Electri-Flex Company.
9. Kraloy.
10. Lamson & Sessions; Carlon Electrical Products.
11. Niedax-Kleinhuis USA, Inc.
12. RACO; a Hubbell company.
13. Thomas & Betts Corporation.
14. <Insert manufacturer>
15. or approved equal.

B. General Requirements for Nonmetallic Conduits and Fittings:

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with TIA-569-B.
3. 4-inch schedule 40 PVC may be used in new construction between communications rooms. Conduit shall transition to PVC coated galvanized rigid steel at all elbows and at terminations at IDF or MDF rooms. Provide 4'-0" minimum radius on all bends. All conduits shall be provided with bonding bushings at equipment room terminations that are" bonded either individually or collectively to the equipment room grounding bar.

See Evaluations for descriptions of nonmetallic conduit types.

C. RNC: [**Type EPC-40-PVC**] <Insert type>, complying with NEMA TC 2 and UL 651 unless otherwise indicated.

Retain one or both HDPE paragraphs below. See Evaluations for a discussion of both types.

- D. Rigid HDPE: Comply with UL 651A.
- E. Continuous HDPE: Comply with UL 651B.
- F. RTRC: Comply with UL 1684A and NEMA TC 14.
- G. Fittings for RNC: Comply with NEMA TC 3; match to conduit or tubing type and material.

Retain first paragraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1. VOC limit is that for PVC welding compounds and adhesive primers for plastic.

- H. Solvent cements and adhesive primers shall have a VOC content of 510 and 550 g/L or less, respectively, when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain paragraph below if required for LEED for Schools Credit IEQ 4.

- I. Solvent cements and adhesive primers shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.3 OPTICAL-FIBER-CABLE PATHWAYS AND FITTINGS

Retain this article to specify special-purpose, flexible, nonmetallic pathways permitted by NFPA 70 in its "Optical Fiber Cables and Raceways" and "Communications Circuits" articles. See Evaluations.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Alpha Wire Company.
 - 2. Arnco Corporation.
 - 3. Endot Industries Inc.
 - 4. IPEX.
 - 5. Lamson & Sessions; Carlon Electrical Products.
 - 6. <Insert manufacturer>
 - 7. or approved equal.

In "Description" Paragraph below, if retaining more than one type of pathway, indicate extent and location of each type on Drawings.

- B. Description: Comply with UL 2024; flexible-type pathway, approved for **[plenum]** **[riser]** **[or]** **[general-use]** installation unless otherwise indicated.
 - 1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - 2. Comply with TIA-569-B.

2.4 METAL WIREWAYS AND AUXILIARY GUTTERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper B-Line, Inc.
 2. Hoffman; a Pentair company.
 3. Mono-Systems, Inc.
 4. Square D; a brand of Schneider Electric.
 5. **<Insert manufacturer>**
 6. or approved equal.
- B. Description: Sheet metal, complying with UL 870 and NEMA 250, **[Type 1] [Type 3R] [Type 4] [Type 12] <Insert type>** unless otherwise indicated, and sized according to NFPA 70.
1. Metal wireways installed outdoors shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with TIA-569-B.
- C. Fittings and Accessories: Include covers, couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for complete system.

Retain one or more options in "Wireway Covers" Paragraph below. If retaining more than one type, indicate locations of each type on Drawings.

- D. Wireway Covers: **[Hinged type] [Screw-cover type] [Flanged-and-gasketed type]** unless otherwise indicated.
- E. Finish: Manufacturer's standard enamel finish.

2.5 NONMETALLIC WIREWAYS AND AUXILIARY GUTTERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Allied Moulded Products, Inc.
 2. Hoffman; a Pentair company.
 3. Lamson & Sessions; Carlon Electrical Products.
 4. Niedax-Kleinhuis USA, Inc.
 5. **<Insert manufacturer>**
 6. or approved equal.
- B. General Requirements for Nonmetallic Wireways and Auxiliary Gutters:
1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with TIA-569-B.

Retain one of two "Description" paragraphs below.

- C. Description: Fiberglass polyester, extruded and fabricated to required size and shape, without holes or knockouts. Cover shall be gasketed with oil-resistant gasket material and fastened with captive screws treated for corrosion resistance. Connections shall be flanged and have stainless-steel screws and oil-resistant gaskets.
- D. Description: PVC, extruded and fabricated to required size and shape, and having snap-on cover, mechanically coupled connections, and plastic fasteners.
- E. Fittings and Accessories: Couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings shall match and mate with wireways as required for complete system.

Retain first paragraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1. VOC limit is that for PVC welding compounds and adhesive primers for plastic.

- F. Solvent cements and adhesive primers shall have a VOC content of 510 and 550 g/L or less, respectively, when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain paragraph below if required for LEED for Schools Credit IEQ 4.

- G. Solvent cements and adhesive primers shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.6 SURFACE PATHWAYS

- A. General Requirements for Surface Pathways:
 - 1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - 2. Comply with TIA-569-B.

Insert requirements for finish-coat paint color, if applicable, in "Surface Metal Pathways" Paragraph below. See Section 099123 "Interior Painting" for optional field-finish coats.

- B. Surface Metal Pathways: Galvanized steel with snap-on covers complying with UL 5. **[Manufacturer's standard enamel finish in color selected by DEN Project Manager] [Prime coated, ready for field painting].**

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Mono-Systems, Inc.
 - b. Niedax-Kleinhuis USA, Inc.
 - c. Panduit Corp.

- d. Wiremold / Legrand.
 - e. **<Insert manufacturer>**
 - f. or approved equal.
- C. Surface Nonmetallic Pathways: Two- or three-piece construction, complying with UL 5A, and manufactured of rigid PVC with texture and color selected by DEN Project Manager from [**manufacturer's standard**] [**custom**] colors. Product shall comply with UL-94 V-0 requirements for self-extinguishing characteristics.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hubbell Incorporated; Wiring Device-Kellems Division.
 - b. Lamson & Sessions; Carlon Electrical Products.
 - c. Mono-Systems, Inc.
 - d. Panduit Corp.
 - e. Wiremold / Legrand.
 - f. **<Insert manufacturer>**
 - g. or approved equal.

2.7 BOXES, ENCLOSURES, AND CABINETS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- 1. Adalet.
 - 2. Cooper Technologies Company; Cooper Crouse-Hinds.
 - 3. EGS/Appleton Electric.
 - 4. Erickson Electrical Equipment Company.
 - 5. Hoffman; a Pentair company.
 - 6. Hubbell Incorporated; Killark Division.
 - 7. Lamson & Sessions; Carlon Electrical Products.
 - 8. Milbank Manufacturing Co.
 - 9. Molex; Woodhead Brand.
 - 10. Mono-Systems, Inc.
 - 11. O-Z/Gedney; a brand of EGS Electrical Group.
 - 12. RACO; a Hubbell company.
 - 13. Robroy Industries.
 - 14. Spring City Electrical Manufacturing Company.
 - 15. Stahlin Non-Metallic Enclosures; a division of Robroy Industries.
 - 16. Thomas & Betts Corporation.
 - 17. Wiremold / Legrand.
 - 18. **<Insert manufacturer>**
 - 19. or approved equal.

- B. General Requirements for Boxes, Enclosures, and Cabinets:
1. Comply with TIA-569-B.
 2. Boxes, enclosures and cabinets installed in wet locations shall be listed for use in wet locations.
 3. Pull boxes shall be sufficiently large to accommodate the number of conduits in the run assuming a single cable of 51% fill in each of the raceways. All pull boxes shall be equipped with hinged covers.
- C. Sheet-Metal Outlet and Device Boxes: Comply with NEMA OS 1 and UL 514A.

In "Cast-Metal Outlet and Device Boxes" Paragraph below, aluminum boxes are suitable for use with steel pathways in most environments. Type FD is a device box with extra depth. Many other configurations are available.

- D. Cast-Metal Outlet and Device Boxes: Comply with NEMA FB 1, [**ferrous alloy**] [**aluminum**], Type FD, with gasketed cover.
- E. Box extensions used to accommodate new building finishes shall be of same material as recessed box.

See Editing Instruction No. 2 in the Evaluations for a discussion of floor boxes.

- F. Metal Floor Boxes:
1. Material: [**Cast metal**] [**or**] [**sheet metal**].
 2. Type: [**Fully adjustable**] [**Semi-adjustable**].
 3. Shape: Rectangular.
 4. Listing and Labeling: Metal floor boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- G. Nonmetallic Floor Boxes: Nonadjustable, [**round**] [**rectangular**].
1. Listing and Labeling: Nonmetallic floor boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- H. Small Sheet Metal Pull and Junction Boxes: NEMA OS 1.
- I. Cast-Metal Access, Pull, and Junction Boxes: Comply with NEMA FB 1 and UL 1773, [**cast aluminum**] [**galvanized, cast iron**] with gasketed cover.
- J. Device Box Dimensions: [4 inches square by 2-1/8 inches deep (100 mm square by 60 mm deep)] [4 inches by 2-1/8 inches by 2-1/8 inches deep (100 mm by 60 mm by 60 mm deep)] <Insert other dimension>.
- K. Gangable boxes are allowed.
- L. Nonmetallic Outlet and Device Boxes: Comply with NEMA OS 2 and UL 514C.

Coordinate "Hinged-Cover Enclosures" Paragraph below with Drawings if hinged cover enclosures other than NEMA 250, Type 1 are required, such as for very dusty areas; or if consideration should be given to use of NEMA 250, Type 3R or Type 12 enclosures.

- M. Hinged-Cover Enclosures: Comply with UL 50 and NEMA 250, [Type 1] [Type 3R] [Type 4] [Type 12] <Insert type> with continuous-hinge cover with flush latch unless otherwise indicated.
1. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
 2. Nonmetallic Enclosures:
 - a. Material: [Plastic] [Fiberglass].

Retain subparagraph below to require radio-frequency-resistant paint.

- b. Finished inside with radio-frequency-resistant paint.
 3. Interior Panels: Steel; all sides finished with manufacturer's standard enamel.

N. Cabinets:

1. NEMA 250, [Type 1] [Type 3R] [Type 12] <Insert type>, galvanized-steel box with removable interior panel and removable front, finished inside and out with manufacturer's standard enamel.
2. Hinged door in front cover with flush latch and concealed hinge.
3. Key latch to match panelboards.
4. Metal barriers to separate wiring of different systems and voltage.
5. Accessory feet where required for freestanding equipment.
6. Nonmetallic cabinets shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.8 HANDHOLES AND BOXES FOR EXTERIOR UNDERGROUND CABLING

See Editing Instruction No. 3 in the Evaluations. Verify with manufacturers that units of types specified are available in sizes required. Indicate the size of each enclosure on Drawings, and use a symbol or other notation to differentiate between handholes and pull boxes.

A. General Requirements for Handholes and Boxes:

1. Boxes and handholes for use in underground systems shall be designed and identified as defined in NFPA 70, for intended location and application.
2. Boxes installed in wet areas shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Comply with TIA-569-B.

Retain one or more of three paragraphs below to select enclosure type(s) for areas not subject to traffic by vehicles. Indicate location of each type in "Pathway Application" Article. For enclosures with cover options, verify that selected cover is available with load rating specified in "Pathway Application" Article. If retaining more than one type of box and cover combination, indicate location of each type on Drawings.

- B. Polymer-Concrete Handholes and Boxes with Polymer-Concrete Cover: Molded of sand and aggregate, bound together with polymer resin, and reinforced with steel, fiberglass, or a combination of the two.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armorcast Products Company.
 - b. Carson Industries LLC.
 - c. CDR Systems Corporation; Hubbell Power Systems.
 - d. NewBasis.
 - e. Oldcastle Precast, Inc.; Christy Concrete Products.
 - f. Synertech Moulded Products; a division of Oldcastle Precast, Inc.
 - g. <Insert manufacturer>
 - h. or approved equal.
2. Standard: Comply with SCTE 77.

First option in "Configuration" Subparagraph below facilitates bottom conduit entry. Second option may be provided by a separate slab placed in the excavation under an open-bottom enclosure; third option is obtained by molding or fabricating the bottom integrally with the body of unit.

3. Configuration: Designed for flush burial with [open] [closed] [integral closed] bottom unless otherwise indicated.
4. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure and handhole location.
5. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
6. Cover Legend: Molded lettering, ["COMMUNICATIONS."] <Insert legend>.

Retain "Conduit Entrance Provisions" Subparagraph below if conduit enters enclosure through the side. Otherwise, entry is made through an open bottom or through side openings cut in the field, as specified in "Installation of Underground Handholes and Boxes" Article. Coordinate with Drawings.

7. Conduit Entrance Provisions: Conduit-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
8. Handholes [12 Inches Wide by 24 Inches Long (300 mm Wide by 600 mm Long)] <Insert dimensions> and Larger: Have inserts for cable racks and pulling-in irons installed before concrete is poured.

- C. Fiberglass Handholes and Boxes: Molded of fiberglass-reinforced polyester resin, with frame and covers of [polymer concrete] [reinforced concrete] [cast iron] [hot-dip galvanized-steel diamond plate] [fiberglass].

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armorcast Products Company.

- b. Carson Industries LLC.
- c. CDR Systems Corporation; Hubbell Power Systems.
- d. NewBasis.
- e. Nordic Fiberglass, Inc.
- f. Oldcastle Precast, Inc.; Christy Concrete Products.
- g. Synertech Moulded Products; a division of Oldcastle Precast, Inc.
- h. **<Insert manufacturer>**
- i. or approved equal.

2. Standard: Comply with SCTE 77.

Retain "Color of Frame and Cover" Subparagraph below if choosing a metal frame and cover; otherwise, delete.

3. Color of Frame and Cover: **[Gray] [Green]**.

First option in "Configuration" Subparagraph below facilitates bottom conduit entry. Second option may be provided by a separate slab placed in the excavation under an open-bottom enclosure; third option is obtained by molding or fabricating the bottom integrally with the body of unit.

4. Configuration: Designed for flush burial with **[open] [closed] [integral closed]** bottom unless otherwise indicated.
5. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure and handhole location.
6. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
7. Cover Legend: Molded lettering, **["COMMUNICATIONS."]** **<Insert legend>**.

Retain "Conduit Entrance Provisions" Subparagraph below if conduit enters enclosure through the side. Otherwise, entry is made through an open bottom or through side openings cut in the field, as specified in "Installation of Underground Handholes and Boxes" Article. Coordinate with Drawings.

8. Conduit Entrance Provisions: Conduit-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
9. Handholes **[12 Inches Wide by 24 Inches Long (300 mm Wide by 600 mm Long)]** **<Insert dimensions>** and Larger: Have inserts for cable racks and pulling-in irons installed before concrete is poured.

2.9 SOURCE QUALITY CONTROL FOR UNDERGROUND ENCLOSURES

Retain this article for underground handholes and pull boxes. Delete if handholes and pull boxes are specified only in Section 260543 "Underground Ducts and Raceways for Electrical Systems." See Evaluations.

- A. Handhole and Pull-Box Prototype Test: Test prototypes of handholes and boxes for compliance with SCTE 77. Strength tests shall be for specified tier ratings of products supplied.

Retain one of first two subparagraphs below; retain first subparagraph to require an independent testing agency to test for compliance with SCTE requirements; retain second subparagraph to require testing by manufacturers' laboratories. See Evaluations for a discussion of testing.

1. Tests of materials shall be performed by an independent testing agency.

2. Strength tests of complete boxes and covers shall be by either an independent testing agency or manufacturer. A qualified registered professional engineer shall certify tests by manufacturer.
3. Testing machine pressure gages shall have current calibration certification complying with ISO 9000 and ISO 10012, and traceable to NIST standards.

PART 3 - EXECUTION

3.1 PATHWAY APPLICATION

Retain this article to specify the type of pathway to be installed. Coordinate with cabling methods specified in Section 271300 "Communications Backbone Cabling" and Section 271500 "Communications Horizontal Cabling" and in other Sections. See "Writing Guide" Article in the Evaluations for instructions on editing this article.

- A. Outdoors: Apply pathway products as specified below unless otherwise indicated:
 1. Exposed Conduit: [GRC] [IMC] [RNC, Type EPC-40-PVC] [RNC, Type EPC-80-PVC].
 2. Concealed Conduit, Aboveground: [GRC] [IMC] [EMT] [RNC, Type EPC-40-PVC].
 3. Underground Conduit: RNC, [Type EPC-40-PVC] [Type EPC-80-PVC], [direct buried] [concrete encased].
 4. Boxes and Enclosures, Aboveground: NEMA 250, [Type 3R] [Type 4].
- B. Indoors: Apply pathway products as specified below unless otherwise indicated:
 1. Exposed, Not Subject to Physical Damage: [EMT] [or] [RNC].
 2. Exposed, Not Subject to Severe Physical Damage: [EMT] [RNC identified for such use].
 3. Exposed and Subject to Severe Physical Damage: [GRC] [IMC]. Pathway locations include the following:
 - a. Loading dock.
 - b. Corridors used for traffic of mechanized carts, forklifts, and pallet-handling units.
 - c. Mechanical rooms.
 - d. Gymnasiums
 - e. <Insert designations of applicable spaces or locations>.
 4. Concealed in Ceilings and Interior Walls and Partitions: [EMT] [RNC, Type EPC-40-PVC] [or] [innerduct].
 5. Damp or Wet Locations: [GRC] [IMC].
 6. Pathways for Optical-Fiber or Communications Cable in Spaces Used for Environmental Air: [Plenum-type, optical-fiber-cable pathway] [Plenum-type, communications-cable pathway] [EMT] <Insert pathway type>.
 7. Pathways for Optical-Fiber or Communications-Cable Risers in Vertical Shafts: [Riser-type, optical-fiber-cable pathway] [Riser-type, communications-cable pathway] [EMT] <Insert pathway type>.

8. Pathways for Concealed General-Purpose Distribution of Optical-Fiber or Communications Cable: **[General-use, optical-fiber-cable pathway]** **[Riser-type, optical-fiber-cable pathway]** **[Plenum-type, optical-fiber-cable pathway]** **[General-use, communications-cable pathway]** **[Riser-type, communications-cable pathway]** **[Plenum-type, communications-cable pathway]** **[EMT]** .
 9. Boxes and Enclosures: NEMA 250 Type 1, except use NEMA 250 Type 4 **[stainless steel]** **[nonmetallic]** in institutional and commercial kitchens and damp or wet locations.
- C. Minimum Pathway Size: **3/4-inch** (21-mm) trade size. Minimum size for optical-fiber cables is **1 inch** (27 mm).
- D. Pathway Fittings: Compatible with pathways and suitable for use and location.
1. Rigid and Intermediate Steel Conduit: Use threaded rigid steel conduit fittings unless otherwise indicated. Comply with NEMA FB 2.10.
 2. PVC Externally Coated, Rigid Steel Conduits: Use only fittings listed for use with this type of conduit. Patch and seal all joints, nicks, and scrapes in PVC coating after installing conduits and fittings. Use sealant recommended by fitting manufacturer and apply in thickness and number of coats recommended by manufacturer.
 3. EMT: Use **[setscrew]** **[or]** **[compression]**, **[steel]** **[cast-metal]** fittings. Comply with NEMA FB 2.10.
- E. Do not install aluminum conduits, boxes, or fittings in contact with concrete or earth.
- Coordinate first paragraph below with Drawings.
- F. Install surface pathways only where indicated on Drawings.
- G. Do not install nonmetallic conduit where ambient temperature exceeds **[120 deg F (49 deg C)]** **<Insert temperature>**.

3.2 INSTALLATION

- A. Comply with NECA 1, NECA 101, and TIA-569-B for installation requirements except where requirements on Drawings or in this article are stricter. Comply with NECA 102 for aluminum pathways. Comply with NFPA 70 limitations for types of pathways allowed in specific occupancies and number of floors.
- B. Keep pathways at least **6 inches** (150 mm) away from parallel runs of flues and steam or hot-water pipes. Install horizontal pathway runs above water and steam piping.
- C. Complete pathway installation before starting conductor installation.
- D. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for hangers and supports.
- E. Arrange stub-ups so curved portions of bends are not visible above finished slab.

First paragraph below is more restrictive than NFPA 70, which permits up to four quarter bends in a conduit run. Retain paragraph for more conservative design, in compliance with TIA-569-B, with less stress being placed on conductors being pulled in.

- F. Install no more than the equivalent of three 90-degree bends in any pathway run. Support within **12 inches (300 mm)** of changes in direction. Utilize long radius ells for all optical-fiber cables.
- G. Conceal conduit and EMT within finished walls, ceilings, and floors unless otherwise indicated. Install conduits parallel or perpendicular to building lines.
- H. Support conduit within **12 inches (300 mm)** of enclosures to which attached.
- I. Communications room penetrations shall be made with a group of 4-inch metallic conduits equivalent in cross sectional area to the tray. Conduits shall be secured to both sides of the equipment room wall with unistrut and 4-inch unistrut clamps. Bonding bushings shall be provided on both sides of penetrating sleeves and bonded to tray/cable ladder on both sides. Firestop between conduits and wall.
- J. Pathways Embedded in Slabs:
 - 1. Run conduit larger than **1-inch (27-mm)** trade size, parallel or at right angles to main reinforcement. Where at right angles to reinforcement, place conduit close to slab support. Secure pathways to reinforcement at maximum **10-foot (3-m)** intervals.
 - 2. Arrange pathways to cross building expansion joints at right angles with expansion fittings.
 - 3. Arrange pathways to keep a minimum of [**1 inch (25 mm)**] [**2 inches (50 mm)**] **<Insert dimension>** of concrete cover in all directions.
 - 4. Do not embed threadless fittings in concrete unless specifically approved by DEN Project Manager for each specific location.

Some authorities having jurisdiction may not permit nonmetallic tubing in fire-rated slabs in subparagraph below.

- 5. Change from ENT to [**RNC, Type EPC-40-PVC,**] [**GRC**] [**or**] [**IMC**] before rising above floor.
- K. Stub-ups to Above Recessed Ceilings:
 - 1. Use EMT, IMC, or RMC for pathways.
 - 2. Use a conduit bushing or insulated fitting to terminate stub-ups not terminated in hubs or in an enclosure.

Retain "Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions" Paragraph below to require application of protective joint compound to threads of rigid steel conduit or IMC and to their fittings where these pathways are installed outdoors or in wet, damp, or corrosive conditions. This optional requirement exceeds NFPA 70 rules. If retaining, coordinate with Drawings indicating wet, damp, or corrosive indoor locations.

- L. Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions: Apply listed compound to threads of pathway and fittings before making up joints. Follow compound manufacturer's written instructions.
- M. Coat field-cut threads on PVC-coated pathway with a corrosion-preventing conductive compound prior to assembly.

Retain one of first two paragraphs below to exceed NFPA 70 requirements. NFPA 70 does not require insulated bushings for communications cables, but TIA-569-B does.

- N. Terminate threaded conduits into threaded hubs or with locknuts on inside and outside of boxes or cabinets. Install insulated bushings on conduits terminated with locknuts.
- O. Install pathways square to the enclosure and terminate at enclosures with locknuts. Install locknuts hand tight plus 1/4 turn more.
- P. Do not rely on locknuts to penetrate nonconductive coatings on enclosures. Remove coatings in the locknut area prior to assembling conduit to enclosure to assure a continuous ground path.
- Q. Cut conduit perpendicular to the length. For conduits of 2-inch (53-mm) trade size and larger, use roll cutter or a guide to ensure cut is straight and perpendicular to the length.
- R. All conduit shall be verified after installation by pulling a mandrel through the conduit that is 80% of the internal diameter of the conduit. After completion of the mandrel test install one 3/4" wide woven aramid fiber pull tape in each conduit. Feed tape straight through pull boxes without breaking or splicing. Pull tape shall provide 2500 pounds of tensile strength and be marked with consecutive footage numbers at one-foot intervals. Permanently tie off tapes at both ends
- S. Install pull wires in empty pathways. Use polypropylene or monofilament plastic line with not less than 200-lb (90-kg) tensile strength. Leave at least 12 inches (300 mm) of slack at each end of pull wire. Cap underground pathways designated as spare above grade alongside pathways in use.

Retain "Surface Pathways" Paragraph below if applicable.

- T. Surface Pathways:
 - 1. Install surface pathway for surface telecommunications outlet boxes only where indicated on Drawings.
 - 2. Install surface pathway with a minimum 2-inch (50-mm) radius control at bend points.
 - 3. Secure surface pathway with screws or other anchor-type devices at intervals not exceeding 48 inches (1200 mm) and with no less than two supports per straight pathway section. Support surface pathway according to manufacturer's written instructions. Tape and glue are not acceptable support methods.

"Pathways for Optical-Fiber and Communications Cable" Paragraph below is applicable for EMT, IMC, RMC, RNC, and optical-fiber- or communications-cable pathways.

- U. Pathways for Optical-Fiber and Communications Cable: Install pathways, metal and nonmetallic, rigid and flexible, as follows:
1. **3/4-Inch (21-mm) Trade Size and Smaller:** Install pathways in maximum lengths of **50 feet (15 m)**.
 2. **1-Inch (27-mm) Trade Size and Larger:** Install pathways in maximum lengths of **75 feet (23 m)**.
 3. Install with a maximum of two 90-degree bends or equivalent for each length of pathway unless Drawings show stricter requirements. Separate lengths with pull or junction boxes or terminations at distribution frames or cabinets where necessary to comply with these requirements.
- V. Install pathway sealing fittings at accessible locations according to NFPA 70 and fill them with listed sealing compound. For concealed pathways, install each fitting in a flush steel box with a blank cover plate having a finish similar to that of adjacent plates or surfaces. Install pathway sealing fittings according to NFPA 70.

See Evaluations for discussion of types of and locations for pathway seals.

- W. Install devices to seal pathway interiors at accessible locations. Locate seals so no fittings or boxes are between the seal and the following changes of environments. Seal the interior of all pathways at the following points:
1. Where conduits pass from warm to cold locations, such as boundaries of refrigerated spaces.
 2. Where an underground service pathway enters a building or structure.
 3. Where otherwise required by NFPA 70.
- X. Comply with manufacturer's written instructions for solvent welding PVC conduit and fittings.

Retain "Expansion-Joint Fittings" Paragraph below unless locations for expansion fittings for PVC conduits are indicated on Drawings. See Evaluations.

- Y. Expansion-Joint Fittings:
1. Install in each run of aboveground RNC that is located where environmental temperature change may exceed **30 deg F (17 deg C)**, and that has straight-run length that exceeds **25 feet (7.6 m)**. Install in each run of aboveground RMC[**and EMT**] conduit that is located where environmental temperature change may exceed **100 deg F (55 deg C)** and that has straight-run length that exceeds **100 feet (30 m)**.
 2. Install type and quantity of fittings that accommodate temperature change listed for each of the following locations:

Revise list below to include all locations in Project with environmental conditions that require considering expansion-joint fittings in conduit runs. For each Project, consider only locations with PVC conduit with straight-run length exceeding 25 feet (7.6 m) or metal conduit in lengths over 100 feet (30 m). Also revise temperature change for each location so it safely represents conditions anticipated. Temperature-change figures below are examples of maximum total swings from the lowest to the highest environmental temperatures at the indicated types of locations and must be revised to represent temperature swings or

changes that may occur at Project locations.

- a. Outdoor Locations Not Exposed to Direct Sunlight: [125 deg F (70 deg C)] <Insert temperature> temperature change.
- b. Outdoor Locations Exposed to Direct Sunlight: [155 deg F (86 deg C)] <Insert temperature> temperature change.
- c. Indoor Spaces Connected with Outdoors without Physical Separation: [125 deg F (70 deg C)] <Insert temperature> temperature change.
- d. Attics: [135 deg F (75 deg C)] <Insert temperature> temperature change.
- e. <Insert location and corresponding temperature change>.

Formula in first subparagraph below provides about 15 percent safety factor (extra expansion-contraction capability).

3. Install fitting(s) that provide expansion and contraction for at least 0.00041 inch per foot of length of straight run per deg F (0.06 mm per meter of length of straight run per deg C) of temperature change for PVC conduits. Install fitting(s) that provide expansion and contraction for at least 0.000078 inch per foot of length of straight run per deg F (0.0115 mm per meter of length of straight run per deg C) of temperature change for metal conduits.
 4. Install expansion fittings at all locations where conduits cross building or structure expansion joints.
 5. Install each expansion-joint fitting with position, mounting, and piston setting selected according to manufacturer's written instructions for conditions at specific location at time of installation. Install conduit supports to allow for expansion movement.
- Z. Mount boxes at heights indicated on Drawings. If mounting heights of boxes are not individually indicated, give priority to ADA requirements. Install boxes with height measured to [center] [top] [bottom] of box unless otherwise indicated.
- AA. Recessed Boxes in Masonry Walls: Saw-cut opening for box in center of cell of masonry block, and install box flush with surface of wall. Prepare block surface to provide a flat surface for a raintight connection between box and cover plate or supported equipment and box.
- BB. Horizontally separate boxes mounted on opposite sides of walls so they are not in the same vertical channel.
- CC. Support boxes of three gangs or more from more than one side by spanning two framing members or mounting on brackets specifically designed for the purpose.
- DD. Fasten junction and pull boxes to or support from building structure. Do not support boxes by conduits.
- EE. Set metal floor boxes level and flush with finished floor surface.
- FF. Set nonmetallic floor boxes level. Trim after installation to fit flush with finished floor surface.

3.3 INSTALLATION OF UNDERGROUND CONDUIT

Retain this article if Project includes small amounts of exterior underground cabling 600 V and less. Delete if Section 260543 "Underground Ducts and Raceways for Electrical Systems" is included in the Project Manual.

A. Direct-Buried Conduit:

1. Excavate trench bottom to provide firm and uniform support for conduit. Prepare trench bottom as specified in Section 312000 "Earth Moving" for pipe less than 6 inches (150 mm) in nominal diameter.
2. Install backfill as specified in Section 312000 "Earth Moving."
3. After installing conduit, backfill and compact. Start at tie-in point, and work toward end of conduit run, leaving conduit at end of run free to move with expansion and contraction as temperature changes during this process. Firmly hand tamp backfill around conduit to provide maximum supporting strength. After placing controlled backfill to within 12 inches (300 mm) of finished grade, make final conduit connection at end of run and complete backfilling with normal compaction as specified in Section 312000 "Earth Moving."

Retain one of first two subparagraphs below to specify type of stub-up for direct-buried conduits in Project.

4. Install manufactured duct elbows for stub-ups at poles and equipment and at building entrances through floor unless otherwise indicated. Encase elbows for stub-up ducts throughout length of elbow.
5. Install manufactured rigid steel conduit elbows for stub-ups at poles and equipment and at building entrances through floor.

Retain first two subparagraphs below with either of last two subparagraphs above.

- a. Couple steel conduits to ducts with adapters designed for this purpose, and encase coupling with 3 inches (75 mm) of concrete for a minimum of 12 inches (300 mm) on each side of the coupling.
- b. For stub-ups at equipment mounted on outdoor concrete bases and where conduits penetrate building foundations, extend steel conduit horizontally a minimum of 60 inches (1500 mm) from edge of foundation or equipment base. Install insulated grounding bushings on terminations at equipment.

Retain "Warning Planks" or "Underground Warning Tape" Subparagraph below to specify type of underground warning for direct-buried conduits in Project.

6. Warning Planks: Bury warning planks approximately 12 inches (300 mm) above direct-buried conduits, but a minimum of 6 inches (150 mm) below grade. Align planks along centerline of conduit.
7. Underground Warning Tape: Comply with requirements in Section 260553 "Identification for Electrical Systems."

3.4 INSTALLATION OF UNDERGROUND HANDHOLES AND BOXES

Retain this article if Project includes small amounts of exterior underground cabling 600 V and less.

Delete if Section 260543 "Underground Ducts and Raceways for Electrical Systems" is included in the Project Manual. See Editing Instruction No. 3 in the Evaluations.

- A. Install handholes and boxes level and plumb and with orientation and depth coordinated with connecting conduits to minimize bends and deflections required for proper entrances.
- B. Unless otherwise indicated, support units on a level bed of crushed stone or gravel, graded from 1/2-inch (12.5-mm) sieve to No. 4 (4.75-mm) sieve and compacted to same density as adjacent undisturbed earth.
- C. Elevation: In paved areas, set so cover surface will be flush with finished grade. Set covers of other enclosures 1 inch (25 mm) above finished grade.
- D. Install handholes with bottom below frost line, <Insert depth of frost line below grade at Project site> below grade.

First paragraph below requires Contractor to select hardware to install and support cable. Delete if cable support is not required. If required, revise paragraph to refer Contractor to Drawings, and show specific requirements on Drawings for each enclosure.

- E. Install removable hardware, including pulling eyes, cable stanchions, cable arms, and insulators, as required for installation and support of cables and conductors and as indicated. Select arm lengths to be long enough to provide spare space for future cables, but short enough to preserve adequate working clearances in enclosure.

Delete paragraph below if conduits enter enclosure through open bottom.

- F. Field cut openings for conduits according to enclosure manufacturer's written instructions. Cut wall of enclosure with a tool designed for material to be cut. Size holes for terminating fittings to be used, and seal around penetrations after fittings are installed.

3.5 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR COMMUNICATIONS PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling."

3.6 FIRESTOPPING

- A. Install firestopping at penetrations of fire-rated floor and wall assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.7 PROTECTION

- A. Protect coatings, finishes, and cabinets from damage or deterioration.

1. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
2. Repair damage to PVC coatings or paint finishes with matching touchup coating recommended by manufacturer.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 270528

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SECTION 270536 - CABLE TRAYS FOR COMMUNICATIONS SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Ladder cable trays.
 - 2. Wire-basket cable trays.
 - 3. Single-rail cable trays.
 - 4. Trough cable trays.
 - 5. Fiberglass cable trays.
- B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 260536 "Cable Trays for Electrical Systems" for cable trays and accessories serving electrical systems.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of cable tray.
 - 1. Include data indicating dimensions and finishes for each type of cable tray indicated.
- B. Shop Drawings: For each type of cable tray.

1. Show fabrication and installation details of cable trays, including plans, elevations, and sections of components and attachments to other construction elements. Designate components and accessories, including clamps, brackets, hanger rods, splice-plate connectors, expansion-joint assemblies, straight lengths, and fittings.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

- C. Delegated-Design Submittal: For seismic restraints.
 1. Seismic-Restraint Details: Signed and sealed by a qualified professional engineer, licensed in the state where Project is located, who is responsible for their preparation.
 2. Design Calculations: Calculate requirements for selecting seismic restraints.
 3. Detail fabrication, including anchorages and attachments to structure and to supported cable trays.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

- A. Coordination Drawings: Floor plans and sections, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Include scaled cable tray layout and relationships between components and adjacent structural, electrical, and mechanical elements.
 2. Vertical and horizontal offsets and transitions.
 3. Clearances for access above and to side of cable trays.
 4. Vertical elevation of cable trays above the floor or below bottom of ceiling structure.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548 "Vibration and Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

- B. Seismic Qualification Certificates: For cable trays, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- C. Field quality-control reports.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design cable tray supports and seismic bracing.

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

- B. Seismic Performance: Cable trays and supports shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification.

1. The term "withstand" means "the cable trays will remain in place without separation of any parts when subjected to the seismic forces specified."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [1.5] [1.0].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. <Insert requirements for Component Amplification Factor and Component Response Modification Factor>.

- C. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes in cable tray installed outdoors.

Differential values in "Temperature Change" Subparagraph below (for aluminum in particular) are suitable for most of the U.S.

1. Temperature Change: [120 deg F (67 deg C), ambient; 180 deg F (100 deg C), material surfaces] <Insert temperature change>.

2.2 GENERAL REQUIREMENTS FOR CABLE TRAYS

If cable trays are identified for use via listing, then follow listing requirements. This may require that all interconnected cable trays be from single manufacturer. Some tray types may not be capable of being interconnected.

- A. Cable Trays and Accessories: Identified as defined in NFPA 70 and marked for intended location, application, and grounding.
 - 1. Source Limitations: Obtain cable trays and components from single manufacturer.

If using multiple types, sizes, or ratings of cable trays on a project, consider adding a table to Drawings.

- B. Sizes and Configurations: See the Cable Tray Schedule on Drawings for specific requirements for types, materials, sizes, and configurations.

Wire-basket cable trays cannot support the concentrated loads imposed on other tray types and can only support spans of 72 to 96 inches (1800 to 2400 mm) maximum.

- C. Structural Performance: See articles for individual cable tray types for specific values for the following parameters:

See "Load/Span Classification System" Article in the Evaluations.

- 1. Uniform Load Distribution: Capable of supporting a uniformly distributed load on the indicated support span when supported as a simple span and tested according to NEMA VE 1.
- 2. Concentrated Load: A load applied at midpoint of span and centerline of tray.
- 3. Load and Safety Factors: Applicable to both side rails and rung capacities.

2.3 LADDER CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

Retain "Basis-of-Design Product" Paragraph and list of manufacturers below to identify a specific product or a comparable product from manufacturers listed. Retain option and delete insert note if manufacturer's name and model number are indicated on Drawings.

- B. Basis-of-Design Product: Subject to compliance with requirements, provide **[product indicated on Drawings] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - 1. Allied Tube & Conduit; a Tyco International Ltd. Co.
 - 2. Chalfant Manufacturing Company.

3. Cooper B-Line, Inc.
4. Mono-Systems, Inc.
5. MP Husky.
6. Niedax-Kleinhuis USA, Inc.
7. <Insert manufacturer's name>.

C. Description:

1. Configuration: Two I-beam side rails with transverse rungs welded to side rails.
2. Rung Spacing: [6 inches (150 mm)] [9 inches (225 mm)] [12 inches (300 mm)] [18 inches (450 mm)] o.c.
3. Radius-Fitting Rung Spacing: 9 inches (225 mm) at center of tray's width.
4. Minimum Cable-Bearing Surface for Rungs: 7/8-inch (22-mm) width with radius edges.
5. No portion of the rungs shall protrude below the bottom plane of side rails.
6. Structural Performance of Each Rung: Capable of supporting a maximum cable load, with a safety factor of 1.5, plus a 200-lb (90-kg) concentrated load, when tested according to NEMA VE 1.
7. Minimum Usable Load Depth: [3 inches (75 mm)] [4 inches (100 mm)] [5 inches (125 mm)] [6 inches (150 mm)].
8. Straight Section Lengths: [10 feet (3 m)] [12 feet (3.6 m)] [20 feet (6 m)] [24 feet (7.4 m)] except where shorter lengths are required to facilitate tray assembly.
9. Width: [6 inches (150 mm)] [9 inches (225 mm)] [12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)] [30 inches (750 mm)] [36 inches (900 mm)] unless otherwise indicated on Drawings.
10. Fitting Minimum Radius: [12 inches (300 mm)] [24 inches (600 mm)] [36 inches (900 mm)] [48 inches (1200 mm)].

The maximum uniform load and the support span are indicated by the cable tray class.

11. Class Designation: Comply with NEMA VE 1, [Class 12B] [Class 12C] [Class 20B] [Class 20C] <Insert designation>.
12. Splicing Assemblies: Bolted type using serrated flange locknuts.
13. Hardware and Fasteners: [ASTM F 593 and ASTM F 594 stainless steel, Type 316] [Steel, zinc plated according to ASTM B 633].
14. Splice Plate Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.

2.4 WIRE-BASKET CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, [provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:

Retain "Basis-of-Design Product" Paragraph and list of manufacturers below to identify a specific product or a comparable product from manufacturers listed. Retain option and delete insert note if manufacturer's name and model number are indicated on Drawings.

B. Basis-of-Design Product: Subject to compliance with requirements, provide [**product indicated on Drawings**] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. Allied Tube & Conduit; a Tyco International Ltd. Co.
2. Cablofil/Legrande.
3. Chalfant Manufacturing Company.
4. Cooper B-Line, Inc.
5. Enduro Systems, Inc.
6. Mono-Systems, Inc.
7. MP Husky.
8. Niedax-Kleinhuis USA, Inc.
9. Snaketray.
10. Wiremaid Products Division; Vutec Corporation.
11. <Insert manufacturer's name>.

C. Description:

1. Configuration: Wires are formed into a standard **2-by-4-inch** (50-by-100-mm) wire mesh pattern with intersecting wires welded together. Mesh sections must have at least one bottom longitudinal wire along entire length of section.
2. Materials: High-strength-steel longitudinal wires with no bends.
3. Safety Provisions: Wire ends along wire-basket sides (flanges) rounded during manufacturing to maintain integrity of cables and installer safety.
4. Sizes:
 - a. Straight sections shall be furnished in standard **118-inch** (3000-mm) lengths.

Retain one or more of four "Wire-Basket Depth" subparagraphs below. If retaining more than one, show tray depth on Drawings.

- b. Wire-Basket Depth: **1-inch** (25-mm) usable loading depth by [**4 inches** (100 mm)] [**12 inches** (300 mm)] wide.
 - c. Wire-Basket Depth: **2-inch** (50-mm) usable loading depth by [**4 inches** (100 mm)] [**6 inches** (150 mm)] [**8 inches** (200 mm)] [**12 inches** (300 mm)] [**18 inches** (450 mm)] [**24 inches** (600 mm)] wide.
 - d. Wire-Basket Depth: **4-inch** (100-mm) usable loading depth by [**8 inches** (200 mm)] [**12 inches** (300 mm)] [**18 inches** (450 mm)] [**24 inches** (600 mm)] wide.
 - e. Wire-Basket Depth: **6-inch** (150-mm) usable loading depth by [**8 inches** (200 mm)] [**12 inches** (300 mm)] [**18 inches** (450 mm)] [**24 inches** (600 mm)] wide.
5. Connector Assemblies: Bolt welded to plate shaped to fit around adjoining tray wires and mating plate. Mechanically joins adjacent tray wires to splice sections together or to create horizontal fittings.
 6. Connector Assembly Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.
 7. Hardware and Fasteners: [**ASTM F 593 and ASTM F 594 stainless steel, Type 316**] [**Steel, zinc plated according to ASTM B 633**].

2.5 SINGLE-RAIL CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

Retain "Basis-of-Design Product" Paragraph and list of manufacturers below to identify a specific product or a comparable product from manufacturers listed. Retain option and delete insert note if manufacturer's name and model number are indicated on Drawings.

- B. Basis-of-Design Product: Subject to compliance with requirements, provide **[product indicated on Drawings] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:

1. Allied Tube & Conduit; a Tyco International Ltd. Co.
2. Cooper B-Line, Inc.
3. Mono-Systems, Inc.
4. MP Husky.
5. **<Insert manufacturer's name>**.

- C. Description:

1. Configuration: Center rail with extruded-aluminum rungs arranged symmetrically about the center rail.
2. Construction: Aluminum rungs mechanically connected to aluminum center rail in at least two places, with ends finished to protect installers and cables.
3. Rung Spacing: **[6 inches (150 mm)] [9 inches (225 mm)] [12 inches (300 mm)]** o.c.
4. Radius-Fitting Rung Spacing: **9 inches (225 mm)** at center of tray's width.
5. Straight Section Lengths: **[10 feet (3 m)] [12 feet (3.6 m)]** except where shorter lengths are required to facilitate tray assembly.
6. Width: **[6 inches (150 mm)] [9 inches (225 mm)] [12 inches (300 mm)] [18 inches (450 mm)] [24 inches (600 mm)]** unless otherwise indicated on Drawings.
7. Support Point: Splice fittings shall be hanger support point.
8. Support Spacing: Support each section at midpoint. Support wall-mounted sections a maximum of one-sixth of the section length from each end.
9. Loading Depth: **[3 inches (75 mm)] [4 inches (100 mm)] [6 inches (150 mm)]**.
10. Maximum Loads: **[25 lb/ft. (37 kg/m)] [50 lb/ft. (74 kg/m)]**.

Maintaining cable tray rungs within six degrees of horizontal is for aesthetic reasons. The tray looks uneven when tilted more than this. Support variations are available to allow varying levels of unbalanced loads while not exceeding the maximum tilt.

11. Unbalanced Loads: Maintain cable tray rungs within six degrees of horizontal under all loading conditions.
12. Splicing Assemblies: Bolted type using serrated flange locknuts.
13. Splicing Assembly Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.
14. Hardware and Fasteners: **[ASTM F 593 and ASTM F 594 stainless steel, Type**

316] [Steel, zinc plated according to ASTM B 633].

15. Splices and Connectors: Protect cables from edges of center rail and do not intrude into cable fill area.

2.6 TROUGH CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, **[provide products by the following] [provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

Retain "Basis-of-Design Product" Paragraph and list of manufacturers below to identify a specific product or a comparable product from manufacturers listed. Retain option and delete insert note if manufacturer's name and model number are indicated on Drawings.

- B. Basis-of-Design Product: Subject to compliance with requirements, provide **[product indicated on Drawings] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:

1. Allied Tube & Conduit; a Tyco International Ltd. Co.
2. Chalfant Manufacturing Company.
3. Cooper B-Line, Inc.
4. Mono-Systems, Inc.
5. MP Husky.
6. Niedax-Kleinhuis USA, Inc.
7. **<Insert manufacturer's name>**.

- C. Description:

1. Configuration: Two longitudinal members (side rails) with a solid sheet over rungs exposed on the interior of the trough, or corrugated sheet with both edges welded to the side rails.
2. Rung Spacing: Rungs or corrugations shall be spaced a maximum of **6 inches** (150 mm) o.c. and have a minimum flat bearing surface of **2 inches** (50 mm).
3. Radius-Fitting Rung Spacing: **9 inches** (225 mm) at center of tray's width.
4. Structural Performance: Capable of supporting a maximum cable load, with a safety factor of 1.5, plus a**200-lb** (90-kg) concentrated load, when tested according to NEMA VE 1.
5. Minimum Usable Load Depth: **[3 inches** (75 mm)] **[4 inches** (100 mm)] **[5 inches** (125 mm)] **[6 inches** (150 mm)].
6. Straight Section Lengths: **[10 feet** (3 m)] **[12 feet** (3.6 m)] **[20 feet** (6 m)] **[24 feet** (7.4 m)] except where shorter lengths are required to facilitate tray assembly.
7. Width: **[6 inches** (150 mm)] **[9 inches** (225 mm)] **[12 inches** (300 mm)] **[18 inches** (450 mm)] **[24 inches** (600 mm)] **[30 inches** (750 mm)] **[36 inches** (900 mm)] unless otherwise indicated on Drawings.
8. Fitting Minimum Radius: **[12 inches** (300 mm)] **[24 inches** (600 mm)] **[36 inches** (900 mm)] **[48 inches** (1200 mm)].

The maximum uniform load and the support span are indicated by the cable tray class.

9. Class Designation: Comply with NEMA VE 1, [**Class 12B**] [**Class 12C**] [**Class 20B**] [**Class 20C**] <Insert designation>.
10. Splicing Assemblies: Bolted type using serrated flange locknuts.
11. Splicing Assembly Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.
12. Hardware and Fasteners: [**ASTM F 593 and ASTM F 594 stainless steel, Type 316**] [**Steel, zinc plated according to ASTM B 633**].

2.7 FIBERGLASS CABLE TRAYS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

Retain "Basis-of-Design Product" Paragraph and list of manufacturers below to identify a specific product or a comparable product from manufacturers listed. Retain option and delete insert note if manufacturer's name and model number are indicated on Drawings.

- B. Basis-of-Design Product: Subject to compliance with requirements, provide [**product indicated on Drawings**] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:

1. Allied Tube & Conduit; a Tyco International Ltd. Co.
2. Cooper B-Line, Inc.
3. Enduro Systems, Inc.
4. Mono-Systems, Inc.
5. MP Husky.
6. <Insert manufacturer's name>.

- C. Description:

1. Configuration: Two longitudinal members with rounded edges and smooth surfaces, complying with NEMA FG 1.
2. Materials: Straight section structural elements; side rails, rungs, and splice plates shall be pultruded from glass-fiber-reinforced [**polyester**] [**vinyl ester**] resin, complying with NEMA FG 1 and UL 568.
3. Fasteners: Fiberglass-encapsulated, ASTM F 593 and ASTM F 594 stainless steel, Type 316. Design fasteners so that no metal is visible when fully assembled and tightened. Fastener encapsulation shall not be damaged when torqued to manufacturer's recommended value.
4. Minimum Usable Load Depth: [**1 inch** (25 mm)] [**2 inches** (50 mm)] [**3 inches** (75 mm)] [**5 inches** (125 mm)] [**7 inches** (175 mm)] according to NEMA FG 1.
5. Straight Section Lengths: [**10 feet** (3 m)] [**20 feet** (6 m)].
6. Width: [**6 inches** (150 mm)] [**9 inches** (225 mm)] [**12 inches** (300 mm)] [**18 inches** (450 mm)] [**24 inches** (600 mm)] [**30 inches** (750 mm)] [**36 inches** (900 mm)] unless

otherwise indicated on Drawings.

The maximum uniform load and the support span are indicated by the cable tray class.

7. Class Designation: Comply with NEMA VE 1, [Class 12B] [Class 12C] [Class 20B] [Class 20C] <Insert designation>.

See "Load/Span Classification System" Article in the Evaluations for discussion of temperature effects.

8. Temperature Rating: Reduce the load rating of tray exposed to temperatures above 75 deg F (24 deg C) according to Table 4-3, "Working Loads," in NEMA FG 1.
9. Fitting Minimum Radius: [12 inches (300 mm)] [24 inches (600 mm)].
10. Splicing Assemblies: Minimum four nuts and bolts per plate. Splice plates shall be furnished with straight sections and fittings.
11. Splicing Assembly Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.

2.8 MATERIALS AND FINISHES

Retain one or more of "Steel," "Aluminum," and "Stainless Steel" paragraphs below. If using more than one type of cable tray material for Project, consider using a schedule to detail the specific requirements in each area. See "Cable Tray Materials" Article in the Evaluations.

A. Steel:

ASTM A 1011/A 1011M is for 14 gage and thicker; ASTM A 1008/A 1008M is for 16 gage and thinner. Both have structural-steel (SS) and high-strength, low-alloy steel (HSLAS) designations.

1. Straight Section and Fitting Side Rails and Rungs: Steel complies with the minimum mechanical properties of [ASTM A 1011/A 1011M, SS, Grade 33] [ASTM A 1008/A 1008M, Grade 33, Type 2].
2. Steel Tray Splice Plates: ASTM A 1011/A 1011M, HSLAS, Grade 50, Class 1.
3. Fasteners: Steel complies with the minimum mechanical properties of ASTM A 510/A 510M, Grade 1008.

Retain one of six "Finish" subparagraphs below or insert a different finish.

4. Finish: Mill galvanized before fabrication.
 - a. Standard: Comply with ASTM A 653/A 653M, G90 (Z275).

Retain one option in "Hardware" Subparagraph below.

- b. Hardware: [Galvanized, ASTM B 633] [Chromium-zinc plated, ASTM F 1136].
5. Finish: Electrogalvanized before fabrication.
 - a. Standard: Comply with ASTM B 633.
 - b. Hardware: Galvanized, ASTM B 633.
6. Finish: Hot-dip galvanized after fabrication.

- a. Standard: Comply with ASTM A 123/A 123M, Class B2.

Retain one option in "Hardware" Subparagraph below.

- b. Hardware: [**Chromium-zinc plated, ASTM F 1136**] [**Stainless steel, Type 316, ASTM F 593 and ASTM F 594**].

7. Finish: [**Epoxy-resin**] [**Powder-coat enamel**] paint.

- a. Powder-Coat Enamel: Cable tray manufacturer's recommended primer and corrosion-inhibiting treatment, with factory-applied powder-coat paint.
- b. Epoxy-Resin Prime Coat: Cold-curing epoxy primer, MPI# 101.
- c. Epoxy-Resin Topcoat: Epoxy, cold-cured, gloss, MPI# 77.

Retain one option in "Hardware" Subparagraph below.

- d. Hardware: [**Chromium-zinc plated, ASTM F 1136**] [**Stainless steel, Type 316, ASTM F 593 and ASTM F 594**].

8. Finish: Factory-standard primer, ready for field painting, with chromium-zinc-plated hardware according to ASTM F 1136.
9. Finish: Black oxide finish for support accessories and miscellaneous hardware according to ASTM D 769.
10. <Insert finish>.

B. Aluminum:

1. Materials: Alloy 6063-T6 according to ANSI H 35.1/H 35.1M for extruded components and [**Alloy 5052-H32**] [or] [**Alloy 6061-T6**] according to ANSI H 35.1/H 35.1M for fabricated parts.
2. Hardware: [**Chromium-zinc-plated steel, ASTM F 1136**] [**Stainless steel, Type 316, ASTM F 593 and ASTM F 594**].
3. Hardware for Aluminum Cable Tray Used Outdoors: Stainless steel, Type 316, ASTM F 593 and ASTM F 594.

C. Stainless Steel:

1. Materials: Low-carbon, passivated, stainless steel, [**Type 304L**] [or] [**Type 316L**], ASTM F 593 and ASTM F 594.
2. Hardware for Stainless-Steel Cable Tray Used Outdoors: Stainless steel, Type 316, ASTM F 593 and ASTM F 594.

2.9 CABLE TRAY ACCESSORIES

- A. Fittings: Tees, crosses, risers, elbows, and other fittings as indicated, of same materials and finishes as cable tray.

If more than one cable tray cover type is required, delete "Covers" Paragraph below and indicate type on Drawings or in a schedule. Retain paragraph if cable tray covers are required. See "Cable Tray Covers" Article in the Evaluations.

- B. Covers: [**Solid**] [**Louvered**] [**Ventilated-hat**] [**2-in-3 pitch**] type made of same

materials and with same finishes as cable tray.

Indicate required locations for barrier strips on Drawings.

- C. Barrier Strips: Same materials and finishes as for cable tray.
- D. Cable tray supports and connectors, including bonding jumpers, as recommended by cable tray manufacturer.

2.10 WARNING SIGNS

Insert different lettering size in "Lettering" Paragraph below to suit 25-foot (7.6-m) viewing distance.

- A. Lettering: [1-1/2-inch- (40-mm-)] <Insert dimension> high, black letters on yellow background with legend "Warning! Not To Be Used as Walkway, Ladder, or Support for Ladders or Personnel."
- B. Comply with requirements for fasteners in Section 260553 "Identification for Electrical Systems."

2.11 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect cable trays according to [NEMA FG 1] [NEMA VE 1].

PART 3 - EXECUTION

3.1 CABLE TRAY INSTALLATION

NEMA FG 1 applies to fiberglass cable trays only. NEMA VE 2 applies to all metallic cable trays.

- A. Install cable trays according to [NEMA FG 1] [NEMA VE 2].
- B. Install cable trays as a complete system, including fasteners, hold-down clips, support systems, barrier strips, adjustable horizontal and vertical splice plates, elbows, reducers, tees, crosses, cable dropouts, adapters, covers, and bonding.
- C. Install cable trays so that the tray is accessible for cable installation and all splices are accessible for inspection and adjustment.
- D. Remove burrs and sharp edges from cable trays.
- E. Join aluminum cable tray with splice plates; use four square neck-carriage bolts and locknuts.
- F. Fasten cable tray supports to building structure[and install seismic restraints].

Retain first paragraph below if deleting "Delegated Design" Paragraph in "Performance Requirements" Article. Delete below if retaining "Delegated Design" Paragraph.

- G. Design fasteners and supports to carry cable tray, the cables, and a concentrated load of 200 lb (90 kg). Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems." [**Comply with seismic-restraint details according to Section 260548 "Vibration and Seismic Controls for Electrical Systems."**]
- H. Place supports so that spans do not exceed maximum spans on schedules and provide clearances shown on Drawings. Install intermediate supports when cable weight exceeds the load-carrying capacity of the tray rungs.
- I. Construct supports from channel members, threaded rods, and other appurtenances furnished by cable tray manufacturer. Arrange supports in trapeze or wall-bracket form as required by application.
- J. Support bus assembly to prevent twisting from eccentric loading.
- K. Install center-hung supports for single-rail trays designed for 60 versus 40 percent eccentric loading condition, with a safety factor of 3.
- L. Locate and install supports according to [**NEMA FG 1**] [**NEMA VE 2**]. Do not install more than one cable tray splice between supports.

Retain one of first two paragraphs below.

- M. Support wire-basket cable trays with [**center support hangers**] [**trapeze hangers**] [**wall brackets**].
- N. Support [**center support hangers**] [**trapeze hangers**] for wire-basket trays with [1/4-inch- (6-mm-)] [3/8-inch- (10-mm-)] diameter rods.

Retain first paragraph below if cable trays connect to equipment.

- O. Make connections to equipment with flanged fittings fastened to cable trays and to equipment. Support cable trays independent of fittings. Do not carry weight of cable trays on equipment enclosure.

Retain first paragraph below if expansion fittings are required.

- P. Install expansion connectors where cable trays cross building expansion joints and in cable tray runs that exceed dimensions recommended in [**NEMA FG 1**] [**NEMA VE 2**]. Space connectors and set gaps according to applicable standard.
- Q. Make changes in direction and elevation using manufacturer's recommended fittings.
- R. Make cable tray connections using manufacturer's recommended fittings.
- S. Seal penetrations through fire and smoke barriers. Comply with requirements in Section 078413 "Penetration Firestopping."

If cable trays are sized for future cables, specify provisions for penetrations with sleeves through fire-rated partitions or use "repairable" firestop-sealing material. Include this Section's specific firestopping requirements in a schedule developed in Section 078413 "Penetration Firestopping."

- T. Install capped metal sleeves for future cables through firestop-sealed cable tray penetrations of fire and smoke barriers.
- U. Install cable trays with enough workspace to permit access for installing cables.

Retain first paragraph below if systems are mixed in a single cable tray.

- V. Install barriers to separate cables of different systems, such as power, communications, and data processing; or of different insulation levels, such as 600, 5000, and 15 000 V.

See "Cable Tray Covers" Article in the Evaluations.

- W. Install permanent covers, if used, after installing cable. Install cover clamps according to NEMA VE 2.
- X. Clamp covers on cable trays installed outdoors with heavy-duty clamps.
- Y. Install warning signs in visible locations on or near cable trays after cable tray installation.

3.2 CABLE TRAY GROUNDING

- A. Ground cable trays according to NFPA 70 unless additional grounding is specified. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Cable trays with communications cable shall be bonded together with splice plates listed for grounding purposes or with listed bonding jumpers.
- C. Cable trays with control conductors shall be bonded together with splice plates listed for grounding purposes or with listed bonding jumpers.
- D. When using epoxy- or powder-coat painted cable trays as a grounding conductor, completely remove coating at all splice contact points or ground connector attachment. After completing splice-to-grounding bolt attachment, repair the coated surfaces with coating materials recommended by cable tray manufacturer.
- E. Bond cable trays to power source for cables contained within with bonding conductors sized according to NFPA 70, Article 250.122, "Size of Equipment Grounding Conductors."

3.3 CABLE INSTALLATION

- A. Install cables only when each cable tray run has been completed and inspected.

Fastening cables on horizontal runs is beyond the requirements of NFPA 70 in most cases. See Evaluations.

- B. Fasten cables on horizontal runs with cable clamps or cable ties according to NEMA VE 2. Tighten clamps only enough to secure the cable, without indenting the cable jacket. Install cable ties with a tool that includes an automatic pressure-limiting device.
- C. Fasten cables on vertical runs to cable trays every 18 inches (450 mm).

Length of unsupported cable is dependent on the cable diameter. See "Cable Installations" Article in the Evaluations.

- D. Fasten and support cables that pass from one cable tray to another or drop from cable trays to equipment enclosures. Fasten cables to the cable tray at the point of exit and support cables independent of the enclosure. The cable length between cable trays or between cable tray and enclosure shall be no more than 72 inches (1800 mm).
- E. Tie MI cables down every 36 inches (900 mm) where required to provide a 2-hour fire rating and every 72 inches (1800 mm) elsewhere.
- F. In existing construction, remove inactive or dead cables from cable trays.

3.4 CONNECTIONS

- A. Remove paint from all connection points before making connections. Repair paint after the connections are completed.
- B. Connect pathways to cable trays according to requirements in NEMA VE 2 and NEMA FG 1.

3.5 FIELD QUALITY CONTROL

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- A. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. After installing cable trays and after electrical circuitry has been energized, survey for compliance with requirements.
 2. Visually inspect cable insulation for damage. Correct sharp corners, protuberances in cable trays, vibrations, and thermal expansion and contraction conditions, which may cause or have caused damage.
 3. Verify that the number, size, and voltage of cables in cable trays do not exceed that permitted by NFPA 70. Verify that communications or data-processing circuits are separated from power circuits by barriers or are installed in separate cable trays.
 4. Verify that there are no intruding items such as pipes, hangers, or other equipment in the cable tray.

5. Remove dust deposits, industrial process materials, trash of any description, and any blockage of tray ventilation.
6. Visually inspect each cable tray joint and each ground connection for mechanical continuity. Check bolted connections between sections for corrosion. Clean and retorque in suspect areas.
7. Check for improperly sized or installed bonding jumpers.
8. Check for missing, incorrect, or damaged bolts, bolt heads, or nuts. When found, replace with specified hardware.
9. Perform visual and mechanical checks for adequacy of cable tray grounding; verify that all takeoff raceways are bonded to cable trays. Test entire cable tray system for continuity. Maximum allowable resistance is 1 ohm.

B. Prepare test and inspection reports.

3.6 PROTECTION

A. Protect installed cable trays and cables.

1. Install temporary protection for cables in open trays to safeguard exposed cables against falling objects or debris during construction. Temporary protection for cables and cable tray can be constructed of wood or metal materials and shall remain in place until the risk of damage is over.
2. Repair damage to galvanized finishes with zinc-rich paint recommended by cable tray manufacturer.
3. Repair damage to paint finishes with matching touchup coating recommended by cable tray manufacturer.

END OF SECTION 270536

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SECTION 270544 - SLEEVES AND SLEEVE SEALS FOR COMMUNICATIONS PATHWAYS AND CABLING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

- 1. Sleeves for pathway and cable penetration of non-fire-rated construction walls and floors.
- 2. Sleeve-seal systems.
- 3. Sleeve-seal fittings.
- 4. Grout.
- 5. Silicone sealants.

- B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 078413 "Penetration Firestopping" for penetration firestopping installed in fire-resistance-rated walls, horizontal assemblies, and smoke barriers, with and without penetrating items.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in

this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include data substantiating that materials comply with requirements.
- B. LEED Submittals:

"Product Data for Credit EQ 4.1" Subparagraph below applies to LEED-NC, LEED-CI, and LEED-CS; coordinate with requirements for sealants.

- 1. Product Data for Credit EQ 4.1: For sealants, documentation including printed statement of VOC content.

"Laboratory Test Reports for Credit EQ 4" Subparagraph below applies to LEED for Schools.

- 2. Laboratory Test Reports for Credit EQ 4: For sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

C. CONSTRUCTION WASTE MANAGEMENT

- 1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 SLEEVES

- A. Wall Sleeves:

Retain "Steel Pipe Sleeves" or "Cast-Iron Pipe Sleeves" Subparagraph below for penetrations through

exterior walls above and below grade.

1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

Retain "Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies" Paragraph below when required by authorities having jurisdiction. NFPA 70 does not contain requirements for sleeves. The requirement below is from International Building Code, Section 712, "Penetrations."

- B. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies: Galvanized-steel sheet; 0.0239-inch (0.6-mm) minimum thickness; round tube closed with welded longitudinal joint, with tabs for screw-fastening the sleeve to the board.

PVC sleeves in "PVC-Pipe Sleeves" and "Molded-PVC Sleeves" paragraphs below may be prohibited by authorities having jurisdiction.

- C. PVC-Pipe Sleeves: ASTM D 1785, Schedule 40.
- D. Molded-PVC Sleeves: With nailing flange for attaching to wooden forms.
- E. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.
- F. Sleeves for Rectangular Openings:
1. Material: Galvanized-steel sheet.
 2. Minimum Metal Thickness:
 - a. For sleeve cross-section rectangle perimeter less than 50 inches (1270 mm) and with no side larger than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
 - b. For sleeve cross-section rectangle perimeter 50 inches (1270 mm) or more and one or more sides larger than 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).
- G. Sleeves for Vertical (Backbone) Communications Pathways:
1. Vertical Communications Pathways are facilities used to distribute and support cable between MDF and IDF rooms. These pathways may include conduit, cable tray and sleeves between vertically aligned rooms.
 2. Sleeves -Vertically aligned IDF and MDF rooms shall be linked with a series of 4-inch rigid metallic sleeves. Sleeves shall be attached to the wall above and below the floor slab with length of unistrut and appropriate clamp. Sleeves must not obstruct wall terminating space. All sleeves must be constructed in accordance with the National Electrical Code (NEC) and local fire codes. Sleeves shall be provided with a minimum of a 4 inch high chamfered curb as measured from the finished floor. All sleeves shall be fire safed in accordance with DEN standards.

3. The following table provides general guidelines for determining the number of 4 in. sleeves required, based on ANSI/EIA/TIAA-569:

Total Square Feet Served	Qty of Sleeves
Up to 50,000	3
50,000 to 100,000	4
100,000 to 300,000	5-8
300,000 to 500,000	9-12

2.2 SLEEVE-SEAL SYSTEMS

Sleeve-seal systems in this article are used for conduit penetrations in slabs-on-grade and below grade in exterior walls.

- A. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and pathway or cable.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advance Products & Systems, Inc.
 - b. CALPICO, Inc.
 - c. Metraflex Company (The).
 - d. Pipeline Seal and Insulator, Inc.
 - e. Proco Products, Inc.
 - f. <Insert manufacturer>
 - g. or approved equal.

Retain first option in "Sealing Elements" Subparagraph below unless Nitrile (Buna N) rubber gasket material is required because hydrocarbons are present in the soil.

2. Sealing Elements: [EPDM] [Nitrile (Buna N)] rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
3. Pressure Plates: [Carbon steel] [Plastic] [Stainless steel].
4. Connecting Bolts and Nuts: [Carbon steel, with corrosion-resistant coating,] [Stainless steel] of length required to secure pressure plates to sealing elements.

2.3 SLEEVE-SEAL FITTINGS

Sleeve-seal fittings in this article are used for conduit penetrations in slabs-on-grade and in exterior walls. These fittings are made to match conduit OD, so they must be selected to match the penetrating piping size. They are available for NPS 1/2 to 6 (DN 15 to 150) piping.

- A. Description: Manufactured plastic, sleeve-type, waterstop assembly made for embedding in concrete slab or wall. Unit shall have plastic or rubber waterstop collar with center opening to match piping OD.

Retain "Manufacturers" Subparagraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Presealed Systems.
 - b. <Insert manufacturer>
 - c. or approved equal.

2.4 GROUT

- A. Description: Nonshrink; recommended for interior and exterior sealing openings in non-fire-rated walls or floors.
- B. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- C. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

Retain "Silicone Sealants" Article below when use of silicone sealants and silicone foams is permitted as an alternative to grout in sealing of conduit or cable penetrations in gypsum wallboard walls.

2.5 SILICONE SEALANTS

- A. Silicone Sealants: Single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below.
1. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces that are not fire rated.

Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit EQ 4.1.

2. Sealant shall have VOC content of [250] <Insert value> g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools Credit EQ 4.

3. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

- B. Silicone Foams: Multicomponent, silicone-based liquid elastomers that, when mixed, expand and cure in place to produce a flexible, nonshrinking foam.

2.6 CABLE TRAY PENETRATIONS THROUGH FIRE RATED PARTITIONS

- A. Cable trays requiring penetration through fire rated partitions shall terminate on each side of the rated partition. Furnish and install STI EZ-PATH series re-enterable fire and smoke seal modules through rated partition with an area equal to the capacity of the cable tray. Modules shall be UL classified and/or FM Systems Approved and tested to the requirements of ASTM E814 (UL 1479).

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION FOR NON-FIRE-RATED ELECTRICAL PENETRATIONS

- A. Comply with NECA 1.
- B. Comply with NEMA VE 2 for cable tray and cable penetrations.
- C. Sleeves for Conduits Penetrating Above-Grade Non-Fire-Rated Concrete and Masonry-Unit Floors and Walls:
1. Interior Penetrations of Non-Fire-Rated Walls and Floors:
 - a. Seal annular space between sleeve and pathway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Section 079200 "Joint Sealants."
 - b. Seal space outside of sleeves with mortar or grout. Pack sealing material solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect material while curing.
 2. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
 3. Size pipe sleeves to provide [1/4-inch (6.4-mm)] **<Insert dimension>** annular clear space between sleeve and pathway or cable unless sleeve seal is to be installed[**or unless seismic criteria require different clearance**].
 4. Install sleeves for wall penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of walls. Cut sleeves to length for mounting flush with both surfaces of walls. Deburr after cutting.

Retain subparagraph below when unsleeved core-drilled openings in concrete floors are not allowed.

5. Install sleeves for floor penetrations. Extend sleeves installed in floors [2 inches (50 mm)] **<Insert dimension>** above finished floor level. Install sleeves during erection of floors.
- D. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies:
1. Use circular metal sleeves unless penetration arrangement requires rectangular sleeved opening.
 2. Seal space outside of sleeves with approved joint compound for gypsum board assemblies.

3. 4" Conduits shall be secured to both sides of the wall with unistrut and 4-inch unistrut clamps.
- E. Roof-Penetration Sleeves: Seal penetration of individual pathways and cables with flexible boot-type flashing units applied in coordination with roofing work.
- F. Aboveground, Exterior-Wall Penetrations: Seal penetrations using [steel] [cast-iron] pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
- G. Underground, Exterior-Wall and Floor Penetrations: Install cast-iron pipe sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between pathway or cable and sleeve for installing sleeve-seal system.

3.2 SLEEVE-SEAL-SYSTEM INSTALLATION

Sleeve-seal systems in this article are used in slabs-on-grade and in below-grade exterior concrete walls for a watertight seal around service-piping entries into the building. These systems require installation in a sleeve for proper operation.

- A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at pathway entries into building.
- B. Install type and number of sealing elements recommended by manufacturer for pathway or cable material and size. Position pathway or cable in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pathway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

3.3 SLEEVE-SEAL-FITTING INSTALLATION

Sleeve-seal fittings in this article are used above and below grade in concrete slabs and in concrete walls for a watertight seal around piping. These fittings do not require a sleeve.

- A. Install sleeve-seal fittings in new walls and slabs as they are constructed.
- B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.
- C. Secure nailing flanges to concrete forms.
- D. Using grout, seal the space around outside of sleeve-seal fittings.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 270544

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SECTION 271100 - COMMUNICATIONS EQUIPMENT ROOM FITTINGS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

- 1. Telecommunications mounting elements.
- 2. Backboards.
- 3. Telecommunications equipment racks and cabinets.
- 4. Grounding.

- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 260536 "Cable Trays for Electrical Systems" for cable trays and accessories.
- 2. Section 271300 "Communications Backbone Cabling" for voice and data cabling associated with system panels and devices, and Intermediate Distribution Facilities.
- 3. Section 271500 "Communications Horizontal Cabling" for voice and data cabling associated with system panels and devices.
- 4. Section 280513 "Conductors and Cables for Electronic Safety and Security" for voice and data cabling associated with system panels and devices.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. BICSI: Building Industry Consulting Service International.
- B. IDF: Intermediate Distribution Facility.
- C. LAN: Local area network.
- D. RCDD: Registered Communications Distribution Designer.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for equipment racks and cabinets.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For communications equipment room fittings. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Equipment Racks and Cabinets: Include workspace requirements and access for cable connections.
 - 3. Grounding: Indicate location of grounding bus bar and its mounting detail showing standoff insulators and wall mounting brackets.

1.5 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For **[Contractor]** **[Installer]**, qualified layout technician, installation

supervisor, and field inspector.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Sections specifying telecommunications equipment supports and seismic controls. See ASCE/SEI 7 for certification requirements for equipment and components.

Coordinate seismic requirements with DEN Project Manager.

- B. Seismic Qualification Certificates: For equipment frames from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions. Base certification on the maximum number of components capable of being mounted in each rack type. Identify components on which certification is based.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.6 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

- A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

BICSI is an industry trade association. See Editing Instruction No. 2 in the Evaluations for summaries of qualifications for registration.

- A. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
1. Layout Responsibility: Preparation of Shop Drawings shall be under the direct supervision of [RCDD] [RCDD/NTS] **[Commercial Installer, Level 2]**.
 2. Installation Supervision: Installation shall be under the direct supervision of **[Registered Technician] [Level 2 Installer]**, who shall be present at all times when Work of this Section is performed at Project site.
 3. Field Inspector: Currently registered by BICSI as [RCDD] **[Commercial Installer, Level 2]** to perform the on-site inspection.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

B. CONSTRUCTION WASTE MANAGEMENT

1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall

be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate seismic requirements with structural engineer and DEN Project Manager.

- A. Seismic Performance: Equipment frames shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

2.2 BACKBOARDS

- A. Backboards: Plywood, [fire-retardant treated,]3/4 by 48 by 96 inches (19 by 1220 by 2440 mm). Comply with requirements for plywood backing panels specified in Section 061000 "Rough Carpentry."

2.3 EQUIPMENT FRAMES

Delete this article if all cross-connects and patch panels are mounted on backboards.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. ADC.
 2. Belden Inc.
 3. Cooper B-Line.
 4. Emerson Network Power Connectivity Solutions.
 5. Hubbell Premise Wiring.

6. Leviton Commercial Networks Division.
 7. Middle Atlantic Products, Inc.
 8. Ortronics, Inc.
 9. Panduit Corp.
 10. Siemon Co. (The).
 11. Tyco Electronics Corporation; AMP Products.
 12. **<Insert manufacturer>**
 13. or approved equal.
- B. General Frame Requirements:
1. Distribution Frames: Freestanding and wall-mounting, modular-steel units designed for telecommunications terminal support and coordinated with dimensions of units to be supported.
 2. Module Dimension: Width compatible with EIA 310-D standard, **19-inch** (480-mm) panel mounting.
 3. Finish: Manufacturer's standard, baked-polyester powder coat.
- C. Floor-Mounted Racks: Modular-type, steel construction.
1. Vertical and horizontal cable management channels, top and bottom cable troughs, grounding lug[, **and a power strip**].
 2. Baked-polyester powder coat finish.
- D. Modular Freestanding Cabinets:
1. Removable and lockable side panels.
 2. Hinged and lockable front and rear doors.
 3. Adjustable feet for leveling.
 4. Screened ventilation openings in the roof and rear door.
 5. Cable access provisions in the roof and base.
 6. Grounding bus bar.
 7. **[Rack] [Roof]**-mounted, **550-cfm** (260-L/s) fan with filter.
 8. Power strip.
 9. Baked-polyester powder coat finish.
 10. All cabinets keyed alike.
- E. Modular Wall Cabinets:
1. Wall mounting.
 2. **[Steel] [Aluminum] [Steel or aluminum]** construction.
 3. Treated to resist corrosion.
 4. Lockable front[**and rear**] doors.
 5. Louvered side panels.
 6. Cable access provisions top and bottom.
 7. Grounding lug.
 8. **[Rack] [Roof]**-mounted, **250-cfm** (118-L/s) fan.
 9. Power strip.
 10. All cabinets keyed alike.

F. Cable Management for Equipment Frames:

1. Metal, with integral wire retaining fingers.
2. Baked-polyester powder coat finish.
3. Vertical cable management panels shall have front and rear channels, with covers.
4. Provide horizontal crossover cable manager at the top of each relay rack, with a minimum height of two rack units each.

2.4 POWER STRIPS

A. Power Strips: Comply with UL 1363.

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Rack mounting.
3. **[Six] <Insert number>, [15-A, 120-V ac, NEMA WD 6, Configuration 5-15R] [20-A, 120-V ac, NEMA WD 6, Configuration 5-20R]** receptacles.
4. LED indicator lights for power and protection status.
5. LED indicator lights for reverse polarity and open outlet ground.

Retain one of first two subparagraphs below.

6. Circuit Breaker and Thermal Fusing: When protection is lost, circuit opens and cannot be reset.
7. Circuit Breaker and Thermal Fusing: Unit continues to supply power if protection is lost.
8. **[Close-coupled, direct plug-in] [Cord connected with 15-foot (4.5-m)]** line cord.
9. Rocker-type on-off switch, illuminated when in on position.

Retain two subparagraphs below if power strips contain surge protection. In first subparagraph, retain 33 kA for high exposure and cost, 26 kA for medium exposure and cost, and 13 kA for low exposure and cost.

10. Peak Single-Impulse Surge Current Rating: **[33] [26] [13]** kA per phase.
11. Protection modes shall be line to neutral, line to ground, and neutral to ground. UL 1449 clamping voltage for all three modes shall be not more than **[330 V] <Insert value>**.

2.5 GROUNDING

A. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems" for grounding conductors and connectors.

B. Telecommunications Main Bus Bar:

1. Connectors: Mechanical type, cast silicon bronze, solderless **[compression] [exothermic]**-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.
2. Ground Bus Bar: Copper, minimum **1/4 inch thick by 4 inches wide** (6 mm thick by 100 mm wide) with **9/32-inch (7.14-mm)** holes spaced **1-1/8 inches (28 mm)** apart.

3. Stand-Off Insulators: Comply with UL 891 for use in switchboards, 600 V. Lexan or PVC, impulse tested at 5000 V.

- C. Comply with J-STD-607-A.

2.6 LABELING

- A. Comply with TIA/EIA-606-A and UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.

PART 3 - EXECUTION

3.1 ENTRANCE FACILITIES

Retain first paragraph below if demarcation point and service entrance cabling are by telecommunications service provider.

- A. Contact DEN Project Manager and arrange for installation of demarcation point, protected entrance terminals, and a housing when so directed by DEN Project Manager.
- B. Comply with requirements in Section 270528 "Pathways for Communications Systems" for materials and installation requirements for **[underground]** **[buried]** **[aerial]** pathways.

3.2 INSTALLATION

- A. Comply with NECA 1.
- B. Comply with BICSI TDMM for layout and installation of communications equipment rooms.
- C. Bundle, lace, and train conductors and cables to terminal points without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

Revise two paragraphs below to specify coordination with other parties involved in finalizing communications equipment room work. See Editing Instruction No. 3 in the Evaluations.

- D. Coordinate layout and installation of communications equipment with Owner's telecommunications and LAN equipment and service suppliers. Coordinate service entrance arrangement with local exchange carrier.
 1. Meet jointly with telecommunications and LAN equipment suppliers, local exchange carrier representatives, and Owner to exchange information and agree on details of equipment arrangements and installation interfaces.
 2. Record agreements reached in meetings and distribute them to other participants.

3. Adjust arrangements and locations of distribution frames, cross-connects, and patch panels in equipment rooms to accommodate and optimize arrangement and space requirements of telephone switch and LAN equipment.
 4. Adjust arrangements and locations of equipment with distribution frames, cross-connects, and patch panels of cabling systems of other communications, electronic safety and security, and related systems that share space in the equipment room.
- E. Coordinate location of power raceways and receptacles with locations of communications equipment requiring electrical power to operate.

3.3 SLEEVE AND SLEEVE SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling."

3.4 FIRESTOPPING

- A. Comply with requirements in Section 078413 "Penetration Firestopping."
- B. Comply with TIA-569-B, Annex A, "Firestopping."
- C. Comply with BICSI TDMM, "Firestopping Systems" Article.

3.5 GROUNDING

- A. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
- B. Comply with J-STD-607-A.
- C. Locate grounding bus bar to minimize the length of bonding conductors. Fasten to wall allowing at least **2-inch (50-mm)** clearance behind the grounding bus bar. Connect grounding bus bar with a minimum No. 4 AWG grounding electrode conductor from grounding bus bar to suitable electrical building ground.
- D. Bond metallic equipment to the grounding bus bar, using not smaller than No. 6 AWG equipment grounding conductor.

Retain subparagraph below if screened twisted-pair cables and coaxial cables are in communications equipment rooms.

1. Bond the shield of shielded cable to the grounding bus bar in communications rooms and spaces.

3.6 IDENTIFICATION

- A. Identify system components, wiring, and cabling complying with TIA/EIA-606-A. Comply with requirements in Section 260553 "Identification for Electrical Systems."
- B. Comply with requirements in Section 099123 "Interior Painting" for painting backboards. For fire-resistant plywood, do not paint over manufacturer's label.

See Section 271500 "Communications Horizontal Cabling" for additional identification requirements. See Evaluations for discussion of TIA/EIA standard as it applies to this Section.

- C. Paint and label colors for equipment identification shall comply with TIA/EIA-606-A for [Class 2] [Class 3] [Class 4] level of administration[**including optional identification requirements of this standard**].
- D. Labels shall be preprinted or computer-printed type.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 271100

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SECTION 271300 - COMMUNICATIONS BACKBONE CABLING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

- 1. Pathways.
- 2. UTP cable.
- 3. Single Mode Fiber Optic Cable 9/125 micrometer.
- 4. Cable connecting hardware, patch panels, and cross-connects.
- 5. Cabling identification products.

- B. Related Sections:

Retain subparagraph below for requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 260536 "Cable Trays for Electrical Systems" for cable trays.
- 2. Section 260553 "Identification for Electrical Systems" for identification of cable systems and components.
- 3. Section 270528 "Pathways for Communication Systems" for wire pathways, wireways, conduit and fittings.
- 4. Section 280513 "Conductors and Cables for Electronic Safety and Security" for voice and data cabling associated with system panels and devices.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. BICSI: Building Industry Consulting Service International.
- B. Cross-Connect: A facility enabling the termination of cable elements and their interconnection or cross-connection.
- C. EMI: Electromagnetic interference.
- D. IDC: Insulation displacement connector.
- E. LAN: Local area network.
- F. RCDD: Registered Communications Distribution Designer.
- G. UTP: Unshielded twisted pair.

1.4 BACKBONE CABLING DESCRIPTION

- A. Backbone cabling system shall provide interconnections between communications equipment rooms, main terminal space, and entrance facilities in the telecommunications cabling system structure. Cabling system consists of backbone cables, intermediate and main cross-connects, mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross-connection.
- B. Backbone cabling cross-connects may be located in communications equipment rooms or at entrance facilities. Bridged taps and splitters shall not be used as part of backbone cabling.
- C. All work designed and constructed under this section shall comply with EIA/TIA 568, 569, 606 and relevant Building Industry Construction Service, Inc. (BICSI Standards).
- D. Designers are required to submit a complete set of plans and specifications for their projects to the DEN Telecommunications Department for review and approval. Designers are also required to meet with representatives from the DEN Telecommunications Department at one or more times during the course of design to work out specific interface details prior to the final submittal.
- E. Work shall consist of furnishing all labor, equipment, supplies, and materials, unless otherwise specified, necessary for the installation of complete system of telecommunications pathways, spaces and cabling as required by the specifications

and as shown on the Drawings, subject to the terms and conditions of the contract. The Work shall also include the completion of those details of work not mentioned or shown which are necessary for the successful operation of all telecommunications systems.

- F. Backbone copper and fiber cabling at DEN are assigned unique numbers that allow cabling pair and strand assignments to be managed by the DEN cable management system. Backbone (BB) and Inter-Building (IB) cable number assignments shall be coordinated with the DEN Technologies to ensure that numerical assignments do not conflict with existing cable designations used elsewhere in the airport.

1.5 PERFORMANCE REQUIREMENTS

- A. General Performance: Backbone cabling system shall comply with transmission standards in TIA/EIA-568-B.1, when tested according to test procedures of this standard.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.6 ACTION SUBMITTALS

- A. Product Data: Provide complete product data for each element of cabling, and equipment proposed. Where a data sheet covers multiple items specifically mark items proposed for use on the Project.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:

Retain one of first two subparagraphs below.

- 1. System Labeling Schedules: Electronic copy of labeling schedules, in software and format selected by Owner.
- 2. System Labeling Schedules: Electronic copy of labeling schedules that are part of the cabling and asset identification system of the software.
- 3. Cabling administration drawings and printouts.
- 4. Wiring diagrams to show typical wiring schematics including the following:
 - a. Cross-connects.
 - b. Patch panels.
 - c. Patch cords.
- 5. Cross-connects and patch panels. Detail mounting assemblies, and show elevations and physical relationship between the installed components.
- 6. Cable tray layout, showing cable tray route to scale, with relationship between the tray and adjacent structural, electrical, and mechanical elements. Include the following:

- a. Vertical and horizontal offsets and transitions.
- b. Clearances for access above and to side of cable trays.
- c. Vertical elevation of cable trays above the floor or bottom of ceiling structure.
- d. Load calculations to show dead and live loads as not exceeding manufacturer's rating for tray and its support elements.

1.7 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For Contractor, installer, qualified layout technician, installation supervisor, and field inspector.
- B. Source quality-control reports.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.
- D. Maintenance Data: For splices and connectors to include in maintenance manuals.

1.8 CLOSEOUT SUBMITTALS

Retain paragraph below for PC-based, cabling administration systems.

- A. Software and Firmware Operational Documentation:
 1. Complete test records for all cable tests.
 2. Diagrams indicating route, cable types, pair or strand count and cable ID numbers used in the Project.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Provide complete as-built drawings for all IDF rooms, backbone conduit routes and tray routes indicating actual routing.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.9 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with

protective covering for storage and identified with labels describing contents.

1. Patch-Panel Units: **[One (1)] <Insert number>** of each type.
2. Connecting Blocks: **[One (1)] <Insert number>** of each type.

1.10 QUALITY ASSURANCE

BICSI is an industry trade association. See Editing Instruction No. 2 in the Evaluations for summaries of qualifications for registration.

- A. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
1. Layout Responsibility: Preparation of Shop Drawings[**and Cabling Administration Drawings**][, **Cabling Administration Drawings, and field testing program development**] by an RCDD.
 2. Installation Supervision: Installation shall be under the direct supervision of **[Registered Technician] [Level 2 Installer]**, who shall be present at all times when Work of this Section is performed at Project site.

Delete subparagraph below if Contractor performs field quality-control testing.

3. Testing Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.

Retain first paragraph below if Contractor or manufacturer selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- B. Testing Agency Qualifications: An NRTL.
1. Testing Agency's Field Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.
- C. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
1. Flame-Spread Index: **[25] <Insert value>** or less.
 2. Smoke-Developed Index: **[50] [450] <Insert value>** or less.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Telecommunications Pathways and Spaces: Comply with TIA/EIA-569-A.
- F. Grounding: Comply with ANSI-J-STD-607-A.

1.11 DELIVERY, STORAGE, AND HANDLING

According to BICSI ITSIM, cables should be tested upon receipt.

- A. Test cables upon receipt at Project site.

Retain one or both of first two subparagraphs below.

1. Test optical fiber cable to determine the continuity of the strand end to end. Use **[optical fiber flashlight] [or] [optical loss test set] <Insert test instrument>**.
2. Test optical fiber cable while on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector, including the loss value of each. Retain test data and include the record in maintenance data.
3. Test each pair of UTP cable for open and short circuits.

1.12 PROJECT CONDITIONS

- A. Environmental Limitations: Do not deliver or install cables and connecting materials until wet work in spaces is complete and dry, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.
- B. Verify that field measurements are as shown on Drawings.
- C. Where wire and cable routing is not shown, and destination only is indicated, determine exact routing and lengths required by field verification.

1.13 COORDINATION

Revise this article to specify coordination with other parties involved in finalizing communications equipment room work. See Editing Instruction No. 3 in the Evaluations.

- A. Coordinate layout and installation of telecommunications pathways and cabling with Owner's telecommunications and LAN equipment and service suppliers, and with DEN Project Manager.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

B. CONSTRUCTION WASTE MANAGEMENT

1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All metal conductors shall be copper.
- B. All building wire and cable shall be installed in approved raceways.
- C. Materials and Equipment: Acceptable to the authority having jurisdiction and suitable for the use intended, except where more stringent requirements are indicated as described herein.

2.2 PATHWAYS

- A. General Requirements: Comply with TIA/EIA-569-A.
- B. Reference Section 270528 "Pathways for Communication Systems" for wire pathways, wireways, conduit and fittings.

Retain first paragraph below if cable support brackets are used in communications equipment rooms.

- C. Cable Support: NRTL labeled for support of Category 6 cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.
 - 1. Support brackets with cable tie slots for fastening cable ties to brackets.
 - 2. Lacing bars, spools, J-hooks, and D-rings.
 - 3. Straps and other devices.
- D. Cable Trays:
 - 1. Comply with requirements in Section 260536 "Cable Trays for Electrical Systems"
- E. Conduit and Boxes: Comply with requirements in Section 260533 "Raceway and Boxes for Electrical Systems." [**Flexible metal conduit shall not be used.**]
 - 1. Outlet boxes shall be no smaller than **2 inches** (50 mm) wide, **3 inches** (75 mm) high, and **2-1/2 inches** (64 mm) deep.

2.3 BACKBOARDS

- A. Backboards: Plywood, fire-retardant treated, **3/4 by 48 by 96 inches** (19 by 1220 by 2440 mm). Comply with requirements in Section 061000 "Rough Carpentry" for plywood backing panels.

2.4 UTP CABLE

Copy this article and re-edit for each product.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Belden CDT Inc.; Electronics Division.
 2. Berk-Tek; a Nexans company.
 3. CommScope, Inc.
 4. Draka USA.
 5. Genesis Cable Products; Honeywell International, Inc.
 6. KRONE Incorporated.
 7. Mohawk; a division of Belden CDT.
 8. Nordex/CDT; a subsidiary of Cable Design Technologies.
 9. Superior Essex Inc.
 10. SYSTIMAX Solutions; a CommScope Inc. brand.
 11. 3M.
 12. Tyco Electronics/AMP Netconnect; Tyco International Ltd.
 13. <Insert manufacturer's name>.
 14. or approved equal.
- B. Description: 100-ohm, [100] <Insert number>-pair UTP, formed into 25-pair binder groups covered with a[gray] thermoplastic jacket[and overall metallic shield].
1. Comply with ICEA S-90-661 for mechanical properties.
 2. Comply with TIA/EIA-568-B.1 for performance specifications.
 3. Comply with TIA/EIA-568-B.2, [Category 5e] [Category 6].
 4. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 for the following types:

Type requirements in subparagraphs below are minimum requirements and may be revised to suit Project. Retain options if "permitted substitutions," as defined in NFPA 70, are appropriate for this Project.

- a. Communications, General Purpose: Type CM or CMG[; or **MPP, CMP, MPR, CMR, MP, or MPG**].
- b. Communications, Plenum Rated: Type CMP[or **MPP**], complying with NFPA 262.
- c. Communications, Riser Rated: Type CMR[; or **MPP, CMP, or MPR**], complying with UL 1666.
- d. Communications, Limited Purpose: Type CMX[; or **MPP, CMP, MPR, CMR, MP, MPG, CM, or CMG**].
- e. Multipurpose: Type MP or MPG[; or **MPP or MPR**].
- f. Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
- g. Multipurpose, Riser Rated: Type MPR[or **MPP**], complying with UL 1666.

2.5 UTP CABLE HARDWARE

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. American Technology Systems Industries, Inc.
 2. Dynacom Corporation.
 3. Hubbell Premise Wiring.
 4. KRONE Incorporated.
 5. Leviton Voice & Data Division.
 6. Molex Premise Networks; a division of Molex, Inc.
 7. Nordex/CDT; a subsidiary of Cable Design Technologies.
 8. Panduit Corp.
 9. Siemon Co. (The).
 10. Tyco Electronics/AMP Netconnect; Tyco International Ltd.
 11. **<Insert manufacturer's name>**.
 12. or approved equal.

See Editing Instruction No. 4 in the Evaluations for discussion about 110-style IDC connectors and connector blocks.

- B. General Requirements for Cable Connecting Hardware: Comply with TIA/EIA-568-B.2, IDC type, with modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of same category or higher.
- C. Connecting Blocks: **[110-style IDC for Category 5e] [110-style IDC for Category 5E or Category 6]** . Provide blocks for the number of cables terminated on the block, plus **[25] <Insert number>** percent spare. Integral with connector bodies, including plugs and jacks where indicated.

Delete first paragraph below if cross-connection is accomplished exclusively on patch panels.

- D. Cross-Connect: Modular array of connecting blocks arranged to terminate building cables and permit interconnection between cables.

Coordinate subparagraph below with Drawings for quantity of fields.

1. Number of Terminals per Field: **[One] <Insert number>** for each conductor in assigned cables.
- E. Patch Panel: Modular panels housing multiple-numbered jack units with IDC-type connectors at each jack for permanent termination of pair groups of installed cables.

Coordinate subparagraph below with Drawings for quantity of fields.

1. Number of Jacks per Field: One for each four-pair **[UTP cable indicated] [conductor group of indicated cables, plus spares and blank positions adequate to suit specified expansion criteria]**.

- F. Jacks and Jack Assemblies: Modular, color-coded, eight-position modular receptacle units with integral IDC-type terminals.

Cords are generally available in lengths to 20 feet (6 m) and longer in 24-inch (600-mm) increments.

- G. Patch Cords: Factory-made, 4-pair cables in [36-inch (900-mm)] [48-inch 1200-mm] <Insert length> lengths; terminated with 8-position modular plug at each end. Termination sequence shall be EIA/TIA 568B.

Retain one of two subparagraphs below; retain first for Category 6, second for Category 5e patch cords.

1. Patch cords shall have bend-relief-compliant boots and color-coded icons to ensure Category 6 performance. Patch cords shall have latch guards to protect against snagging.
2. Patch cords shall have color-coded boots for circuit identification.

2.6 OPTICAL FIBER CABLE

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Berk-Tek; a Nexans company.
 2. CommScope, Inc.
 3. Corning Cable Systems.
 4. General Cable Technologies Corporation.
 5. Mohawk; a division of Belden CDT.
 6. Nordex/CDT; a subsidiary of Cable Design Technologies.
 7. Optical Connectivity Solutions Division; Emerson Network Power.
 8. Superior Essex Inc.
 9. SYSTIMAX Solutions; a CommScope Inc. brand.
 10. 3M.
 11. Tyco Electronics/AMP Netconnect; Tyco International Ltd.
 12. <Insert manufacturer's name>.
 13. or approved equal.
- B. Description: Multimode, [50/125] [62.5/125]-micrometer, [24] <Insert number>-fiber, [nonconductive,]tight buffer, optical fiber cable.

Retain first subparagraph below for indoor cable. ICEA standard for outside plant is ICEA S-87-640.

1. Comply with ICEA S-83-596 for mechanical properties.
2. Comply with TIA/EIA-568-B.3 for performance specifications.

Retain first option in first subparagraph below for 50/125-micrometer cable; retain second for 62.5/125-micrometer cable.

3. Comply with [TIA/EIA-492AAAA-B] [TIA/EIA-492AAAA-A] for detailed specifications.

4. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:

Type requirements in first six subparagraphs below are minimum requirements and may need to be revised to suit Project. OFC, OFCR, OFCG, and OFCP are conductive optical fiber cables that might have application in industrial settings. Retain options if "permitted substitutions," as defined in NFPA 70, are appropriate for this Project.

- a. General Purpose, Nonconductive: Type OFN or OFNG[, or **OFNR, OFNP**].
- b. Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
- c. Riser Rated, Nonconductive: Type OFNR[or **OFNP**], complying with UL 1666.
- d. General Purpose, Conductive: Type OFC or OFCG[; or **OFNG, OFN, OFCR, OFNR, OFCP, or OFNP**].
- e. Plenum Rated, Conductive: Type OFCP[or **OFNP**], complying with NFPA 262.
- f. Riser Rated, Conductive: Type OFCR[; or **OFNR, OFCP, or OFNP**], complying with UL 1666.

Retain first subparagraph below even if nonconductive cable is specified above. If both conductive and nonconductive cables are specified, indicate locations of each on Drawings.

5. Conductive cable shall be [**steel**] [**aluminum**] armored type.
6. Maximum Attenuation: <Insert number> dB/km at 850 nm; [**1.5**] <Insert number> dB/km at 1300 nm for multi-mode fiber.
7. Single Mode fiber shall be type SMF28E.
8. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm for multi-mode fiber.

C. Jacket:

1. Jacket Color: [**Aqua for 50/125-micrometer cable**][**Orange for 62.5/125-micrometer cable**] [**Yellow for Single Mode Fiber**].
2. Cable cordage jacket, fiber, unit, and group color shall be according to TIA/EIA-598-B.
3. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed **40 inches** (1000 mm).

2.7 OPTICAL FIBER CABLE HARDWARE

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. ADC.
 2. American Technology Systems Industries, Inc.
 3. Berk-Tek; a Nexans company.
 4. Corning Cable Systems.

5. Dynacom Corporation.
6. Hubbell Premise Wiring.
7. Molex Premise Networks; a division of Molex, Inc.
8. Nordex/CDT; a subsidiary of Cable Design Technologies.
9. Optical Connectivity Solutions Division; Emerson Network Power.
10. Siemon Co. (The).
11. Superior Modular Products.
12. **<Insert manufacturer's name>**.
13. or approved equal.

- B. Cross-Connects and Patch Panels: Modular panels housing multiple-numbered cable connectors. Connector type for all strands except those used for analog services shall be type LC. Strands used for analog services such as DEN TV and Distributed Antenna Systems shall be terminated with APC high return loss terminations.

Coordinate subparagraph below with Drawings for quantity of fields.

1. Number of Connectors per Field: **[One (1)] <Insert number>** for each fiber of cable or cables assigned to field, plus spares and blank positions adequate to suit specified expansion criteria.
- C. Patch Cords: Factory-made, single or dual-fiber cables in **36-inch** (900-mm) incremental lengths.
- D. Cable Connecting Hardware:
1. Comply with Optical Fiber Connector Intermateability Standards (FOCIS) specifications of TIA/EIA-604-2, TIA/EIA-604-3-A, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.

Type SC is a subscriber connector and Type ST is a straight-tip, single-fiber connector; both are in common use. Recently developed connectors are Type LC, which is an upgraded version of either Type SC or Type ST with a lower insertion loss, and Type MT-RJ, which is a no-epoxy, no-polish connector.

2. Quick-connect, simplex and duplex, **[Type SC] [Type ST] [Type LC]** connectors. Insertion loss not more than 0.75 dB.
3. Type SFF connectors may be used in termination racks, panels, and equipment packages.

2.8 GROUNDING

- A. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems" for grounding conductors and connectors.
- B. Comply with ANSI-J-STD-607-A.

2.9 IDENTIFICATION PRODUCTS

- A. Comply with TIA/EIA-606-A and UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.

- B. Reference Section 260553 "Identification for Electrical Systems" for identification of cable systems and components.

2.10 SOURCE QUALITY CONTROL

Retain first paragraph below if required. Independent certification may be acceptable to authorities having jurisdiction without further monitoring of plant's quality-control and testing program by Owner.

- A. Testing Agency: Engage a qualified testing agency to evaluate cables.
- B. Factory test cables on reels according to TIA/EIA-568-B.1.
- C. Factory test UTP cables according to TIA/EIA-568-B.2.
- D. Factory test multimode optical fiber cables according to TIA/EIA-526-14-A and TIA/EIA-568-B.3.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. Cable will be considered defective if it does not pass tests and inspections.
- F. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 GENERAL

- A. All Work to be coordinated with and approved by DEN Telecommunications Department and DEN Project Manager.
- B. All Work to be coordinated with existing systems at DEN.

3.2 ENTRANCE FACILITIES

Retain this article if service entrance cabling and demarcation point are provided by communications service provider.

- A. Coordinate backbone cabling with the protectors and demarcation point provided by communications service provider.

3.3 WIRING METHODS

Retain one of first two paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings.

- A. Verify pathways are open, continuous and clear of debris before installing cables.

- B. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters. Conceal raceway and cables except in unfinished spaces.

Retain first subparagraph below if retaining unenclosed wiring method option in paragraph above.

1. Install plenum cable in environmental air spaces, including plenum ceilings.
2. Comply with requirements for raceways and boxes specified in Section 260533 "Raceway and Boxes for Electrical Systems."
3. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems".

- C. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.

- D. Wiring within Enclosures: Bundle, lace, and train cables within enclosures. Connect to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

3.4 INSTALLATION OF PATHWAYS

- A. Cable Trays:

1. Comply with NEMA VE 2 and TIA/EIA-569-A.
2. Comply with Section 260536 "Cable Trays for Electrical Systems".

Coordinate cable connection hardware installations and specialty arrangements with layout drawings and with requirements specified for communications equipment rooms. If Drawings are explicit enough, these requirements may be reduced or omitted.

- B. Comply with requirements for demarcation point, pathways, cabinets, and racks specified in Section 271100 "Communications Equipment Room Fittings." Drawings indicate general arrangement of pathways and fittings.

- C. Comply with TIA/EIA-569-A for pull-box sizing and length of conduit and number of bends between pull points.

- D. Comply with requirements in Section 260533 "Raceway and Boxes for Electrical Systems" for installation of conduits and wireways.

- E. Install manufactured conduit sweeps and long-radius elbows whenever possible.

- F. Pathway Installation in Communications Equipment Rooms:

1. Secure conduits to backboard when entering room from overhead.
2. Extend conduits [3 inches (76 mm)] <Insert dimension> above finished floor.
3. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.

- G. Backboards: Install backboards with 96-inch (2440-mm) dimension vertical. Butt

adjacent sheets tightly, and form smooth gap-free corners and joints.

- H. Install wire in raceway after interior of building has been physically protected from the weather and all mechanical work likely to injure conductors has been completed.
- I. Completely and thoroughly swab raceway system before installing conductors.
- J. Conductors shall not be pulled in concrete encased conduits before concrete is placed.

3.5 INSTALLATION OF CABLES

- A. Comply with NECA 1.
- B. Provide protection for exposed cables where subject to damage.
- C. Use suitable cable fittings and connectors.
- D. All cable shall be racked and supported in manholes.
- E. Pulling winches and other necessary pulling equipment shall be of adequate capacity to ensure a continuous pull on the cable. Strain gages shall be used to monitor the cable pulling tension.
- F. Cable and Wire pulling lubricants that are non-corrosive and harmless to hands and clothes shall be used. Lubricants shall be compatible with cable jackets and insulation.
- G. General Requirements for Cabling:
 - 1. Comply with TIA/EIA-568-B.1.
 - 2. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."
 - 3. Install 110-style IDC termination hardware unless otherwise indicated.
 - 4. Terminate all conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, cross-connects, and patch panels.
 - 5. Cables may not be spliced except at locations noted on the contract drawings.
 - 6. Secure and support cables at intervals not exceeding **30 inches** (760 mm) and not more than **6 inches** (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
 - 7. Install lacing bars to restrain cables, to prevent straining connections, and to prevent bending cables to smaller radii than minimums recommended by manufacturer.
 - 8. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Use lacing bars and distribution spools.
 - 9. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
 - 10. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.

11. In the communications equipment room, install a **10-foot-** (3-m-) long service loop on each end of cable.
12. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.

H. UTP Cable Installation:

1. Comply with TIA/EIA-568-B.2.
2. Do not untwist UTP cables more than **1/2 inch** (12 mm) from the point of termination to maintain cable geometry.

I. Optical Fiber Cable Installation:

1. Comply with TIA/EIA-568-B.3.
2. Cable may be terminated on connecting hardware that is rack or cabinet mounted.

J. Open-Cable Installation:

1. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
2. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.

K. Installation of Cable Routed Exposed under Raised Floors:

1. Install plenum-rated cable only.
2. Install cabling after the flooring system has been installed in raised floor areas.
3. Coil cable [**6 feet** (1800 mm)] **<Insert size>** long not less than [**12 inches** (300 mm)] **<Insert size>** in diameter below each feed point.

L. Group connecting hardware for cables into separate logical fields.

See Editing Instruction No. 5 in the Evaluations for discussion about EMI.

M. Separation from EMI Sources:

1. Comply with BICSI TDMM and TIA/EIA-569-A recommendations for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.
2. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: A minimum of **5 inches** (127 mm).
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **12 inches** (300 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **24 inches** (610 mm).

3. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: A minimum of **2-1/2 inches** (64 mm).
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **6 inches** (150 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **12 inches** (300 mm).
4. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: No requirement.
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **3 inches** (76 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **6 inches** (150 mm).
5. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of **48 inches** (1200 mm).
6. Separation between Communications Cables and Fluorescent Fixtures: A minimum of **5 inches** (127 mm).

3.6 FIRESTOPPING

- A. Comply with requirements in Section 078413 "Penetration Firestopping."
- B. Comply with TIA/EIA-569-A, Annex A, "Firestopping."
- C. Comply with BICSI TDMM, "Firestopping Systems" Article.

3.7 GROUNDING

- A. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
- B. Comply with ANSI-J-STD-607-A.
- C. Locate grounding bus bar to minimize the length of bonding conductors. Fasten to wall allowing at least **2-inch** (50-mm) clearance behind the grounding bus bar. Connect grounding bus bar with a minimum No. 4 AWG grounding electrode conductor from grounding bus bar to suitable electrical building ground.
- D. Bond metallic equipment to the grounding bus bar, using not smaller than No. 6 AWG equipment grounding conductor.

3.8 IDENTIFICATION

- A. Identify system components, wiring, and cabling using backbone and inter-building cable numbers as assigned by DEN Technologies Premise Wiring & Communications.
 - 1. Color-code cross-connect fields and apply colors to voice and data service backboards, connections, covers, and labels.
- B. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- C. Comply with requirements in Section 099123 "Interior Painting" for painting backboards. For fire-resistant plywood, do not paint over manufacturer's label.

See Section 271500 "Communications Horizontal Cabling" for additional identification requirements. See Evaluations for discussion about TIA/EIA standard as it applies to this Section.

- D. Paint and label colors for equipment identification shall comply with TIA/EIA-606-A for [Class 2] [Class 3] [Class 4] level of administration[**including optional identification requirements of this standard**].
- E. Comply with requirements in Section 271500 "Communications Horizontal Cabling" for cable and asset management software.
- F. Cabling Administration Drawings: Show building floor plans with cabling administration-point labeling. Identify labeling convention and show labels for telecommunications closets, [**backbone pathways and cables,**] [**entrance pathways and cables,**] terminal hardware and positions, horizontal cables, work areas and workstation terminal positions, grounding buses and pathways, and equipment grounding conductors.
- G. Cable and Wire Identification:
 - 1. Label each cable within 4 inches (100 mm) of each termination and tap, where it is accessible in a cabinet or junction or outlet box, and elsewhere as indicated.
 - 2. Each wire connected to building-mounted devices is not required to be numbered at device if color of wire is consistent with associated wire connected and numbered within panel or cabinet.
 - 3. Label each terminal strip and screw terminal in each cabinet, rack, or panel.
 - a. Individually number wiring conductors connected to terminal strips and identify each cable or wiring group being extended from a panel or cabinet to a building-mounted device with name and number of particular device as shown.
 - b. Label each unit and field within distribution racks and frames.
 - 4. Identification within Connector Fields in Equipment Rooms and Wiring Closets: Label each connector and each discrete unit of cable-terminating and connecting hardware.
- H. Labels shall be preprinted or computer-printed type with printing area and font color

that contrasts with cable jacket color but still complies with requirements in TIA/EIA 606-A, for the following:

1. Cables use flexible vinyl or polyester that flexes as cables are bent.

3.9 FIELD QUALITY CONTROL

- A. Inspect wire and cable for physical damage and proper connection.
- B. Torque conductor connections and terminations to manufacturer's recommended values. Provide torque report if requested by DEN Project Manager.
- C. Verify cables are colored coded and labeled according to contract documents.

Retain one of first two paragraphs below to identify who shall perform tests and inspections. If retaining second option in first paragraph, or if retaining second paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

- D. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

- E. Perform tests and inspections.

Retain first paragraph below to describe tests and inspections to be performed.

- F. Tests and Inspections:
 1. Visually inspect UTP and optical fiber jacket materials for NRTL certification markings. Inspect cabling terminations in communications equipment rooms for compliance with color-coding for pin assignments, and inspect cabling connections for compliance with TIA/EIA-568-B.1.
 2. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.

Retain first subparagraph below if verification of quality is to be performed before completing horizontal cabling. Otherwise, specify testing of the transmission performance of cabling system in Section 271500 "Communications Horizontal Cabling"

3. Test UTP copper cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not cross-connection.
 - a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.

Retain subparagraph below if verification of quality is to be performed before completing horizontal cabling. Otherwise, specify testing of the transmission performance of cabling system in Section 271500 "Communications Horizontal Cabling" for voice and data cabling associated with system panels and devices.

4. Optical Fiber Cable Tests:

- a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
- b. Link End-to-End Attenuation Tests - Single Mode:
 - 1) Perform an optical loss test of each strand using an optical power meter and calibrated light source at both 1310nm and 1550nm..
 - 2) Perform an Optical Time Domain Reflectometer test from both ends of each fiber strand at both 1310nm and 1550nm.

- G. Data for each measurement shall be documented. Data for submittals shall be printed in a summary report that is formatted similar to Table 10.1 in BICSI TDMM, or transferred from the instrument to the computer, saved as text files, and printed and submitted.
- H. Remove and replace cabling where test results indicate that they do not comply with specified requirements.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- I. End-to-end cabling will be considered defective if it does not pass tests and inspections.
- J. Prepare test and inspection reports.

PART 4 - PART 4- MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PART 5- PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 271300

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SECTION 271500 - COMMUNICATIONS HORIZONTAL CABLING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

1. UTP cabling.
2. **[50/125] [62.5/125]**-micrometer, optical fiber cabling.
3. Coaxial cable.
4. Multiuser telecommunications outlet assemblies.
5. Cable connecting hardware, patch panels, and cross-connects.
6. Telecommunications outlet/connectors.
7. Cabling system identification products.
8. Cable management system.

- B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 270528 "Pathways for Communications Systems" for pathways.
2. Section 260536 "Cable Trays for Electrical Systems" for cable tray systems.
3. Section 271300 "Communications Backbone Cabling" for voice and data cabling associated with system panels and devices.
4. Section 280513 "Conductors and Cables for Electronic Safety and Security" for voice and data cabling associated with system panels and devices.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 GENERAL DESCRIPTION

- A. Denver International Airport (DEN) owns and operates a private telecommunications infrastructure that provides voice, data and video services to all airport, airline and tenant facilities throughout the fifty-three square mile site. Tenants developing leasehold spaces or facilities on ground-leased sites are required to design their horizontal wiring pathways in accordance with these guidelines. Horizontal wiring pathways include all types of raceway systems to support voice, data, LAN, CATV and fiber cabling between DEN telecommunications rooms and outlets in the tenant, public or City areas
- B. Designers are required to submit a complete set of plans and specifications for their projects to the DEN Telecommunications Department for review and approval. Designers are also encouraged to meet with representatives from the DEN Telecommunications Department at one or more times during the course of design to work out specific interface details prior to the final submittal.

1.4 DEN TELECOMMUNICATIONS HORIZONTAL CABLING POLICY

- A. Tenants and designers of new DEN facilities are required to install raceways, outlet boxes and pull cords for all communications outlets in accordance with the worksheets that accompany these guidelines.
- B. Tenants and designers are encouraged to utilize the services of the current DEN Premise Wiring and Communications System (PWCS) contractor for installation of all horizontal cabling, outlets and termination. The City's contract with this contractor stipulates that all wiring and other components installed by the PWCS contractor be serviced and maintained by that contractor as part of the ongoing PWCS system maintenance agreement.
- C. A tenant may elect to install a privately owned and maintained system of horizontal wiring within it's leasehold space. This wiring would extend from outlets within the leasehold area to a designated point of demarcation with the DEN PWCS system. In this configuration, circuits ordered through the PWCS contractor or regulated telephone company will be terminated and tagged at the designated point of demarcation. Responsibility for cross connecting these circuits from the point of demarcation to their final destination remains the responsibility of the tenant. The PWCS contractor will troubleshoot any reported problems with a circuit only as far as the designated point of demarcation.
- D. Any tenant vacating their leasehold space shall leave any horizontal wiring in place and in serviceable condition. This shall include outlets, horizontal wiring and termination blocks at the telecommunications equipment room.

1.5 HORIZONTAL WIRING PATHWAYS

- A. Reference Section 270528 "Pathways for Communication Systems" and Section 260536 "Cable Trays for Electrical Systems" for pathways and cable trays for communication systems.
- B. Horizontal wiring pathways consist of structures that conceal, protect, and support horizontal cables between the communications workstation outlet and the horizontal cross-connect in the serving telecommunications room, cabinet or closet. Horizontal communications pathways are used to distribute and support horizontal cable and connecting hardware between the workstation outlet and the telecommunications closet. These pathways & spaces are the "container" for the horizontal cabling.
- C. It is the responsibility of the designer to review all proposed Horizontal Distribution Systems with the DEN Telecommunications Department to ensure the systems design:
 - 1. Makes optimum use of the ability of the horizontal cabling system to accommodate change.
 - 2. Is as unconstrained as possible by vendor-dependence.
 - 3. Compliance with ANSI/NFPA 70 Local, State, and Federal Codes.
 - 4. Compliance with ANSI/EIA-TIA-568 and 569.

1.6 ELECTROMAGNETIC INTERFERENCE (EMI)

- A. EMI causes severe problems with electronic equipment, telecommunications and data communications, avoidance of all potential sources or, electromagnetic interference must be a primary consideration when designing a horizontal distribution system. To avoid electromagnetic interference, all distribution pathways should provide clearances of at least:
 - 1. Four (4) ft. (1.2 m) from large motors and/or transformers.
 - 2. One (1) ft. (0.3 m) from conduit and cables used for electrical power distribution.
 - 3. Five (5) in. (12 cm) from fluorescent lighting
- B. Note: Horizontal Distribution Pathways should cross perpendicular to fluorescent lighting and electrical power cables or conduits.
- C. For additional clearance requirements, see ANSI/EIA-TIA-569 and ANSI/NFPA 70.

1.7 TYPES OF HORIZONTAL WIRING PATHWAY SYSTEMS

- A. Many types of horizontal wiring pathway systems are acceptable for installation at DEN. Many buildings may require two or more of the following systems to meet all distribution needs. The acceptable types of horizontal pathways are:
 - 1. Unlimited access (raised floors).
 - 2. Conduit.
 - 3. Cable tray.

1.8 OTHER HORIZONTAL DISTRIBUTION SYSTEMS

- A. Other types of horizontal distribution systems may be used. These include, but are not limited to:
 - 1. Unlimited access (raised floors).
 - 2. Conduit.
- B. Due to the individuality, complexity and the broad scope of requirements for these systems, DEN Telecommunications will review each of these specified systems on a case-by-case basis.

1.9 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

- A. BICSI: Building Industry Consulting Service International.
- B. Consolidation Point: A location for interconnection between horizontal cables extending from building pathways and horizontal cables extending into furniture pathways.
- C. Cross-Connect: A facility enabling the termination of cable elements and their interconnection or cross-connection.
- D. EMI: Electromagnetic interference.
- E. IDC: Insulation displacement connector.
- F. LAN: Local area network.
- G. MUTOA: Multiuser telecommunications outlet assembly, a grouping in one location of several telecommunications outlet/connectors.
- H. Outlet/Connectors: A connecting device in the work area on which horizontal cable or outlet cable terminates.
- I. RCDD: Registered Communications Distribution Designer.
- J. UTP: Unshielded twisted pair.

1.10 ADMINISTRATIVE REQUIREMENTS

Revise this article to specify coordination with other parties involved in finalizing communications equipment room work. See Editing Instruction No. 3 in the Evaluations.

- A. Coordinate layout and installation of telecommunications cabling with Owner's telecommunications and LAN equipment and service suppliers.

- B. Coordinate telecommunications outlet/connector locations with location of power receptacles at each work area.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.11 ACTION SUBMITTALS

- A. Product Data: For each type of product submit a complete data sheet indicating physical properties and performance characteristics.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:

Retain one of two "System Labeling Schedules" subparagraphs below.

- 1. System Labeling Schedules: Electronic copy of labeling schedules, in software and format selected by Owner.
- 2. System Labeling Schedules: Electronic copy of labeling schedules that are part of the cabling and asset identification system of the software.
- 3. Cabling administration drawings and printouts.
- 4. Wiring diagrams to show typical wiring schematics, including the following:
 - a. Cross-connects.
 - b. Patch panels.
 - c. Patch cords.
- 5. Cross-connects and patch panels. Detail mounting assemblies, and show elevations and physical relationship between the installed components.

Retain "Samples" Paragraph below when workstation outlet faceplates have critical features needing hands-on appraisal.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager. Coordinate sample requirements with DEN Project Manager.

- C. Samples: For workstation outlets, jacks, jack assemblies, **[in specified finish, one for each size and outlet configuration] [and faceplates for color selection and evaluation of technical features].**

1.12 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For **[Installer,]**qualified layout technician, installation supervisor, and field inspector.
- B. Source quality-control reports.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1.13 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For splices and connectors to include in maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.14 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Patch-Panel Units: **[One (1)] <Insert number>** of each type.
 2. Connecting Blocks: **[One (1)] <Insert number>** of each type.
 3. Device Plates: **[One (1)] <Insert number>** of each type.
 4. Multiuser Telecommunications Outlet Assemblies: **[One (1)] <Insert number>** of each type.

1.15 QUALITY ASSURANCE

BICSI is an industry trade association. See Editing Instruction No. 2 in the Evaluations for summaries of qualifications for registration.

- A. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
 1. Layout Responsibility: Preparation of Shop Drawings[**and Cabling Administration Drawings**][, **Cabling Administration Drawings, and field testing program development**] by an RCDD.
 2. Installation Supervision: Installation shall be under the direct supervision of **[Registered Technician] [Level 2 Installer]**, who shall be present at all times when Work of this Section is performed at Project site.

Delete "Testing Supervisor" Subparagraph below if Contractor performs field quality control.

3. Testing Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.

Retain "Testing Agency Qualifications" Paragraph below if Contractor or manufacturer selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also defines "NRTL" (nationally recognized testing laboratory).

- B. Testing Agency Qualifications: An NRTL.
 - 1. Testing Agency's Field Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.

1.16 PROJECT CONDITIONS

- A. Verify that field measurements are as shown on Drawings.
- B. Where wire and cable routing is not shown, and destination only is indicated, determine exact routing and lengths required by field verification.

1.17 DELIVERY, STORAGE, AND HANDLING

According to BICSI ITSIM, cables should be tested upon receipt.

- A. Test cables upon receipt at Project site.

Retain one or both of first two subparagraphs below.

- 1. Test optical fiber cables to determine the continuity of the strand end to end. Use **[optical loss test set]** <Insert test>.
- 2. Test optical fiber cables while on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector; including the loss value of each. Retain test data and include the record in maintenance data.
- 3. Test each pair of UTP cable for open and short circuits.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

- B. CONSTRUCTION WASTE MANAGEMENT
 - 1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 HORIZONTAL CABLING DESCRIPTION

- A. Horizontal cable and its connecting hardware provide the means of transporting signals between the telecommunications outlet/connector and the horizontal cross-connect located in the communications equipment room. This cabling and its connecting hardware are called a "permanent link," a term that is used in the testing protocols.
1. TIA/EIA-568-B.1 requires that a minimum of two telecommunications outlet/connectors be installed for each work area.
 2. Horizontal cabling shall contain no more than one transition point or consolidation point between the horizontal cross-connect and the telecommunications outlet/connector.
 3. Bridged taps and splices shall not be installed in the horizontal cabling.
 4. Splitters shall not be installed as part of the optical fiber cabling.
- B. The maximum allowable horizontal cable length is **295 feet (90 m)**. This maximum allowable length does not include an allowance for the length of **16 feet (4.9 m)** to the workstation equipment or in the horizontal cross-connect.
- C. All metal conductors shall be copper.
- D. All building wire and cable shall be installed in an approved raceway.

2.2 PERFORMANCE REQUIREMENTS

- A. General Performance: Horizontal cabling system shall comply with transmission standards in TIA/EIA-568-B.1 when tested according to test procedures of this standard.
- B. Surface-Burning Characteristics: Comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
1. Flame-Spread Index: **[25] <Insert value>** or less.
 2. Smoke-Developed Index: **[50] [450] <Insert value>** or less.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Grounding: Comply with J-STD-607-A.

2.3 BACKBOARDS

- A. Backboards: Plywood, **[fire-retardant treated,]3/4 by 48 by 96 inches (19 by 1220 by 2440 mm)**. Comply with requirements in Section 061000 "Rough Carpentry" for plywood backing panels.

2.4 UTP CABLE

Copy this article and re-edit for each product.

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [ADC](#).
 2. [Belden Inc.](#)
 3. [Berk-Tek; a Nexans company](#).
 4. [CommScope, Inc.](#)
 5. [Draka Cableteq USA](#).
 6. [Genesis Cable Products; Honeywell International, Inc.](#)
 7. [Mohawk; a division of Belden Networking, Inc.](#)
 8. [Superior Essex Inc.](#)
 9. [SYSTIMAX Solutions; a CommScope, Inc. brand](#).
 10. [3M Communication Markets Division](#).
 11. [Tyco Electronics Corporation; AMP Products](#).
 12. <Insert manufacturer's name>.
 13. or approved equal.
- B. Description: 100-ohm, four-pair UTP, formed into 25-pair, binder groups covered with a blue thermoplastic jacket.
1. Comply with ICEA S-90-661 for mechanical properties.
 2. Comply with TIA/EIA-568-B.1 for performance specifications.
 3. Comply with TIA/EIA-568-B.2, [**Category 5e**] [**Category 6**].
 4. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 for the following types:

Type requirements in subparagraphs below are minimum requirements and may be revised to suit Project. Retain options if "permitted substitutions," as defined in NFPA 70, are appropriate for this Project.

- a. Communications, General Purpose: Type CM or CMG[; or **MPP, CMP, MPR, CMR, MP, or MPG**].
- b. Communications, Plenum Rated: Type CMP[or **MPP**], complying with NFPA 262.
- c. Communications, Riser Rated: Type CMR[; or **MPP, CMP, or MPR**], complying with UL 1666.
- d. Communications, Limited Purpose: Type CMX[; or **MPP, CMP, MPR, CMR, MP, MPG, CM, or CMG**].
- e. Multipurpose: Type MP or MPG[; or **MPP or MPR**].
- f. Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
- g. Multipurpose, Riser Rated: Type MPR[or **MPP**], complying with UL 1666.

2.5 UTP CABLE HARDWARE

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [ADC](#).
 2. [American Technology Systems Industries, Inc.](#)
 3. [Belden Inc.](#)
 4. [Dynacom Inc.](#)
 5. [Hubbell Premise Wiring](#).
 6. [Leviton Commercial Networks Division](#).
 7. [Molex Premise Networks; a division of Molex, Inc.](#)
 8. [Panduit Corp.](#)
 9. [Siemon Co. \(The\)](#).
 10. [Tyco Electronics Corporation; AMP Products](#).
 11. **<Insert manufacturer's name>**.
 12. or approved equal.

See Editing Instruction No. 4 in the Evaluations for discussion about 110-style IDC connectors and connector blocks.

- B. General Requirements for Cable Connecting Hardware: Comply with TIA/EIA-568-B.2, IDC type, with modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of same category or higher.
- C. Connecting Blocks: **[110-style IDC for Category 5e] [110-style IDC for Category 6] [66-style IDC for Category 5e]**. Provide blocks for the number of cables terminated on the block, plus **[25] <Insert number>** percent spare. Integral with connector bodies, including plugs and jacks where indicated.

Delete "Cross-Connect" Paragraph below if cross-connection is accomplished exclusively on patch panels.

- D. Cross-Connect: Modular array of connecting blocks arranged to terminate building cables and permit interconnection between cables.

Coordinate "Number of Terminals per Field" Subparagraph below with Drawings for quantity of terminals.

1. Number of Terminals per Field: **[One] <Insert number>** for each conductor in assigned cables.
- E. Patch Panel: Modular panels housing multiple-numbered jack units with IDC-type connectors at each jack for permanent termination of pair groups of installed cables.

Coordinate "Number of Jacks per Field" Subparagraph below with Drawings for quantity of fields.

1. Number of Jacks per Field: **[One]** <Insert number> for each four-pair **[UTP cable indicated]** **[conductor group of indicated cables, plus spares and blank positions adequate to suit specified expansion criteria]**.

- F. Jacks and Jack Assemblies: Modular, color-coded, eight-position modular receptacle units with integral IDC-type terminals.

Cords are generally available in lengths to 20 feet (6 m) and longer in 24-inch (600-mm) increments.

- G. Patch Cords: Factory-made, four-pair cables in **[36-inch (900 mm)]** **[48-inch 1200-mm]** <Insert length> lengths; terminated with eight-position modular plug at each end.

Retain one of two subparagraphs below; retain first for Category 6, second for Category 5e patch cords.

1. Patch cords shall have bend-relief-compliant boots and color-coded icons to ensure Category 6 performance. Patch cords shall have latch guards to protect against snagging.
2. Patch cords shall have color-coded boots for circuit identification.

2.6 OPTICAL FIBER CABLE

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Belden Inc.](#)
2. [Berk-Tek; a Nexans company.](#)
3. [CommScope, Inc.](#)
4. [Corning Cable Systems.](#)
5. [CSI Technologies Inc.](#)
6. [General Cable Technologies Corporation.](#)
7. [Mohawk; a division of Belden Networking, Inc.](#)
8. [Superior Essex Inc.](#)
9. [SYSTIMAX Solutions; a CommScope, Inc. brand.](#)
10. [3M Communication Markets Division.](#)
11. [Tyco Electronics Corporation; AMP Products.](#)
12. <Insert manufacturer's name>.
13. or approved equal.

- B. Description: Multimode, **[50/125]** **[62.5/125]**-micrometer, **[24]** <Insert number>-fiber, **[nonconductive,**]tight buffer, optical fiber cable.

Retain first subparagraph below for indoor cable. ICEA standard for outside plant is ICEA S-87-640.

1. Comply with ICEA S-83-596 for mechanical properties.
2. Comply with TIA/EIA-568-B.3 for performance specifications.

Retain first option in first subparagraph below for 50/125-micrometer cable; retain second for 62.5/125-micrometer cable.

3. Comply with [TIA-492AAAB] [TIA-492AAAA-A] for detailed specifications.
4. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:

Type requirements in first six subparagraphs below are minimum requirements and may need to be revised to suit Project. Types OFC, OFCR, OFCG, and OFCP are conductive optical fiber cables that might have application in industrial settings. Retain options if "permitted substitutions," as defined in NFPA 70, are appropriate for this Project.

- a. General Purpose, Nonconductive: Type OFN or OFNG[, or **OFNR, OFNP**].
- b. Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
- c. Riser Rated, Nonconductive: Type OFNR[or **OFNP**], complying with UL 1666.
- d. General Purpose, Conductive: Type OFC or OFCG[; or **OFNG, OFN, OFCR, OFNR, OFCP, or OFNP**].
- e. Plenum Rated, Conductive: Type OFCP[or **OFNP**], complying with NFPA 262.
- f. Riser Rated, Conductive: Type OFCR[; or **OFNR, OFCP, or OFNP**], complying with UL 1666.

Retain first subparagraph below even if nonconductive cable is specified in subparagraphs above. If both conductive and nonconductive cables are specified, indicate locations of each on Drawings.

5. Conductive cable shall be [**steel**] [**aluminum**] armored type.
6. Maximum Attenuation: [**3.50**] <Insert number> dB/km at 850 nm; [**1.5**] <Insert number> dB/km at 1300 nm.
7. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.

C. Jacket:

1. Jacket Color: [**Aqua for 50/125-micrometer cable**] [**Orange for 62.5/125-micrometer cable**].
2. Cable cordage jacket, fiber, unit, and group color shall be according to TIA-598-C.
3. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed 40 inches (1000 mm).

2.7 OPTICAL FIBER CABLE HARDWARE

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. ADC.
 2. American Technology Systems Industries, Inc.
 3. Belden Inc.

4. [Berk-Tek; a Nexans company.](#)
5. [Corning Cable Systems.](#)
6. [CSI Technologies Inc.](#)
7. [Dynacom Inc.](#)
8. [Hubbell Premise Wiring.](#)
9. [Molex Premise Networks; a division of Molex, Inc.](#)
10. [Siemon Co. \(The\).](#)
11. **<Insert manufacturer's name>.**
12. or approved equal.

- B. Cross-Connects and Patch Panels: Modular panels housing multiple-numbered, duplex cable connectors.

Coordinate "Number of Connectors per Field" Subparagraph below with Drawings for quantity of connectors.

1. Number of Connectors per Field: [**One**] **<Insert number>** for each fiber of cable or cables assigned to field, plus spares and blank positions adequate to suit specified expansion criteria.

- C. Patch Cords: Factory-made, single or dual-fiber cables in **36-inch** (900-mm) incremental lengths.

- D. Cable Connecting Hardware:

1. Comply with Optical Fiber Connector Intermateability Standards (FOCIS) specifications of TIA-604-2-B, TIA-604-3-B, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.

Type SC is a subscriber connector, Type ST is a straight-tip, single-fiber connector; both are in common use. Recently developed connectors are Type LC, which is an upgraded version of either Type SC or ST connector with a lower insertion loss, and Type MT-RJ, which is a no-epoxy, no-polish connector.

2. Quick-connect, simplex and duplex, [**Type SC**] [**Type ST**] [**Type LC**] [**Type MT-RJ**] connectors. Insertion loss not more than 0.75 dB.
3. Type SFF connectors may be used in termination racks, panels, and equipment packages.

2.8 COAXIAL CABLE

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. [Alpha Wire Company.](#)
2. [Belden Inc.](#)
3. [Coleman Cable, Inc.](#)
4. [CommScope, Inc.](#)
5. [Draka Cableteq USA.](#)

6. <Insert manufacturer's name>.
7. or approved equal.

See Evaluations for discussion about coaxial cables. Indicate location of each type on Drawings.

- B. Cable Characteristics: Broadband type, recommended by cable manufacturer specifically for broadband data transmission applications. Coaxial cable and accessories shall have 75-ohm nominal impedance with a return loss of 20 dB maximum from 7 to 806 MHz.

Cable types in first five paragraphs below are typical.

- C. RG-11/U: NFPA 70, Type CATV.

1. [No. 14] <Insert size> AWG, solid, copper-covered steel conductor.
2. Gas-injected, foam-PE insulation.
3. Double shielded with 100 percent aluminum polyester tape and 60 percent aluminum braid.
4. Jacketed with sunlight-resistant, black PVC or PE.
5. Suitable for outdoor installations in ambient temperatures ranging from minus 40 to plus 85 deg C.

- D. RG-6/U: NFPA 70, Type CATV or CM.

1. [No. 16] <Insert size> AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
2. Double shielded with 100 percent aluminum-foil shield and 60 percent aluminum braid.
3. Jacketed with black PVC or PE.
4. Suitable for indoor installations.

Paragraph below is typical of NFPA 70 cable types. See NFPA 70, "Community Antenna Television and Radio Distribution Systems" and "Network-Powered Broadband Communications Systems" Articles for other types that may be added to the list.

- E. NFPA and UL compliance, listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 1655 and with NFPA 70 "Radio and Television Equipment" and "Community Antenna Television and Radio Distribution" Articles. Types are as follows:

1. CATV Cable: Type CATV[, or **CATVP** or **CATVR**].
2. CATV Plenum Rated: Type CATVP, complying with NFPA 262.
3. CATV Riser Rated: Type CATVR[; or **CATVP**, **CATVR**, or **CATV**], complying with UL 1666.
4. CATV Limited Rating: Type CATVX.

2.9 COAXIAL CABLE HARDWARE

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Emerson Network Power Connectivity Solutions.
 2. [Leviton Commercial Networks Division](#).
 3. [Siemon Co. \(The\)](#).
 4. **<Insert manufacturer's name>**.
 5. or approved equal.
- B. Coaxial-Cable Connectors: Type BNC, 75 ohms.

2.10 CONSOLIDATION POINTS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. [American Technology Systems Industries, Inc.](#)
 2. [Belden Inc.](#)
 3. [Chatsworth Products, Inc.](#)
 4. [Dynacom Inc.](#)
 5. [Hubbell Premise Wiring](#).
 6. [Molex Premise Networks; a division of Molex, Inc.](#)
 7. [Ortronics, Inc.; a subsidiary of Legrand Group](#).
 8. [Panduit Corp.](#)
 9. [Siemon Co. \(The\)](#).
 10. **<Insert manufacturer's name>**.
 11. or approved equal.
- B. Description: Consolidation points shall comply with requirements for cable connecting hardware.

Coordinate "Number of Terminals per Field" Subparagraph below with Drawings for quantity of terminals.

1. Number of Terminals per Field: **[One (1)] <Insert number>** for each conductor in assigned cables.

Coordinate "Number of Connectors per Field" Subparagraph below with Drawings for quantity of connectors.

2. Number of Connectors per Field:
 - a. **[One (1)] <Insert number>** for each four-pair UTP cable indicated.
 - b. **[One (1)] <Insert number>** for each four-pair conductor group of indicated cables, plus **[25] <Insert number>** percent spare positions.
3. Mounting: **[Recessed in ceiling] [Wall] [Desk] [Furniture]**.
4. NRTL listed as complying with UL 50 and UL 1863.

5. When installed in plenums used for environmental air, NRTL listed as complying with UL 2043.

2.11 MULTIUSER TELECOMMUNICATIONS OUTLET ASSEMBLY (MUTOA)

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. [Belden Inc.](#)
 2. [Chatsworth Products, Inc.](#)
 3. [Hubbell Premise Wiring.](#)
 4. [Molex Premise Networks; a division of Molex, Inc.](#)
 5. [Ortronics, Inc.; a subsidiary of Legrand Group.](#)
 6. [Panduit Corp.](#)
 7. [Siemon Co. \(The\).](#)
 8. **<Insert manufacturer's name>.**
 9. or approved equal.
- B. Description: MUTOAs shall meet the requirements for cable connecting hardware.

Coordinate "Number of Terminals per Field" Subparagraph below with Drawings for quantity of terminals.

1. Number of Terminals per Field: **[One (1)] <Insert number>** for each conductor in assigned cables.

Coordinate "Number of Connectors per Field" Subparagraph below with Drawings for quantity of connectors.

2. Number of Connectors per Field:
 - a. **[One (1)] <Insert number>** for each four-pair UTP cable indicated.
 - b. **[One (1)] <Insert number>** for each four-pair conductor group of indicated cables, plus **[25] <Insert number>** percent spare positions.
3. Mounting: **[Recessed in ceiling] [Wall] [Desk] [Furniture]**.
4. NRTL listed as complying with UL 50 and UL 1863.
5. Label shall include maximum length of work area cords, based on TIA/EIA-568-B.1.
6. When installed in plenums used for environmental air, NRTL listed as complying with UL 2043.

2.12 TELECOMMUNICATIONS OUTLET/CONNECTORS

- A. Jacks: 100-ohm, balanced, twisted-pair connector; four-pair, eight-position modular. Comply with TIA/EIA-568-B.1.

Coordinate "Workstation Outlets" Paragraph below with other items specified to be mounted in workstation faceplates. Revise paragraph if faceplate elevations are on Drawings.

- B. Workstation Outlets: **[Two (2)][Four (4)]<Insert number of ports>**-port-connector assemblies mounted in **[single] [or] [multigang]** faceplate.

Retain "Plastic Faceplate" or "Metal Faceplate" Subparagraph below, or retain both as required to match Section 262726 "Wiring Devices."

1. Plastic Faceplate: High-impact plastic. Coordinate color with Section 262726 "Wiring Devices."
2. Metal Faceplate: **[Stainless steel] [Brass] <Insert description>**, complying with requirements in Section 262726 "Wiring Devices."
3. For use with snap-in jacks accommodating any combination of UTP, optical fiber, and coaxial work area cords.
 - a. Flush mounting jacks, positioning the cord at a 45-degree angle.

Retain one of three "Legend" subparagraphs below; retain first for metal faceplates.

4. Legend: Factory labeled by silk-screening or engraving **[for] [stainless steel] [brass] <Insert description> [faceplates]**.
5. Legend: Machine printed, in the field, using adhesive-tape label.
6. Legend: Snap-in, clear-label covers and machine-printed paper inserts.

2.13 GROUNDING

- A. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems" for grounding conductors and connectors.
- B. Comply with J-STD-607-A.
- C. Horizontal Pathways must be grounded and bonded in accordance with the requirements specified in ANSI/NFPA 70, except where other codes or local authorities impose more stringent requirements.

2.14 IDENTIFICATION PRODUCTS

- A. Comply with TIA/EIA-606-A and UL 969 for labeling materials, including label stocks, laminating adhesives, and inks used by label printers.
- B. Comply with requirements in Section 260553 "Identification for Electrical Systems."
- C. Standard schematic methods and procedures for labeling and managing horizontal pathways. Locate markings so that they are clearly visible after installation, and easily distinguishable from any markings that appear on individual components. For more details on guidelines and requirements for the administration of horizontal pathways and spaces, see BICSI TDM Manual Chapter 4 and ANSI/TIA/EIA-606.

- D. Electrical or telecommunications drawings produced as part of any tenant or facility design shall include labeling for each outlet location. Labeling shall include the room number, outlet letter designator and outlet type. Please refer to the details that accompany this guideline for a complete listing of standard outlet types and their designations.

2.15 CABLE MANAGEMENT SYSTEM

- A. Provide a spreadsheet list of all horizontal cabling in Microsoft Excel format suitable for importation into the DEN cable management system. Data shall include outlet location by building and room, connected device type and other information as requested by DEN Telecommunications.

2.16 SOURCE QUALITY CONTROL

Retain "Testing Agency" Paragraph below if required. Independent certification may be acceptable to authorities having jurisdiction without further monitoring of plant's quality-control and testing program by Owner.

- A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to evaluate cables.
- B. Factory test UTP and optical fiber cables on reels according to TIA/EIA-568-B.1.
- C. Factory test UTP cables according to TIA/EIA-568-B.2.
- D. Factory test multimode optical fiber cables according to TIA-526-14-A and TIA/EIA-568-B.3.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- E. Factory-sweep test coaxial cables at frequencies from 5 MHz to 1 GHz. Sweep test shall test the frequency response, or attenuation over frequency, of a cable by generating a voltage whose frequency is varied through the specified frequency range and graphing the results.
- F. Cable will be considered defective if it does not pass tests and inspections.
- G. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 GENERAL

- A. Coordinate Work with DEN Telecommunications Department and DEN Project Manager.

- B. Coordinate Work with existing systems at DEN.

3.2 ENTRANCE FACILITIES

Retain this article if service entrance cabling and demarcation point are provided by communications service provider and horizontal cabling connects to the demarcation point. Normally, unless this is for a small single-story facility, communications horizontal cable interfaces with backbone cabling in communications rooms or spaces at cross-connects and patch panels.

- A. Coordinate backbone cabling with the protectors and demarcation point provided by communications service provider.

3.3 WIRING METHODS

Retain one of first two paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings.

- A. Verify cable pathways are open, continuous and clear of debris before installing cables.
- B. Install cables in pathways and cable trays except within consoles, cabinets, desks, and counters. Conceal pathways and cables except in unfinished spaces.

Retain first subparagraph below if retaining unenclosed wiring method option in paragraph above.

- 1. Install plenum cable in environmental air spaces, including plenum ceilings.
- 2. Comply with requirements in Section 260536 "Cable Trays for Electrical Systems" for cable trays.
- 3. Comply with requirements in Section 270528 "Pathways for Communications Systems."
- C. Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
- D. Wiring within Enclosures:
 - 1. Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii.
 - 2. Install lacing bars and distribution spools.
 - 3. Install conductors parallel with or at right angles to sides and back of enclosure.

3.4 INSTALLATION OF CABLES

- A. Comply with NECA 1.
- B. General Requirements for Cabling:
 - 1. Comply with TIA/EIA-568-B.1.

2. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."
 3. Install 110-style IDC termination hardware unless otherwise indicated.
 4. MUTOA shall not be used as a cross-connect point.
 5. Consolidation points may be used only for making a direct connection to telecommunications outlet/connectors:
 - a. Do not use consolidation point as a cross-connect point, as a patch connection, or for direct connection to workstation equipment.
 - b. Locate consolidation points for UTP at least **49 feet (15 m)** from communications equipment room.
 6. Terminate conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, cross-connects, and patch panels.
 7. Cables may not be spliced. Secure and support cables at intervals not exceeding **30 inches (760 mm)** and not more than **6 inches (150 mm)** from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
 8. Install lacing bars to restrain cables, to prevent straining connections, and to prevent bending cables to smaller radii than minimums recommended by manufacturer.
 9. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
 10. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
 11. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
 12. In the communications equipment room, install a **10-foot- (3-m-)** long service loop on each end of cable.
 13. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.
- C. UTP Cable Installation:
1. Comply with TIA/EIA-568-B.2.
 2. Do not untwist UTP cables more than **1/2 inch (12 mm)** from the point of termination to maintain cable geometry.
- D. Optical Fiber Cable Installation:
1. Comply with TIA/EIA-568-B.3.
 2. Cable may be terminated on connecting hardware that is rack or cabinet mounted.
- E. Open-Cable Installation:
1. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.

2. Suspend UTP cable not in a wireway or pathway a minimum of **8 inches** (200 mm) above ceilings by cable supports not more than [**60 inches** (1524 mm)] **<Insert dimension>** apart.
3. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.

F. Installation of Cable Routed Exposed under Raised Floors:

1. Install plenum-rated cable only.
2. Install cabling after the flooring system has been installed in raised floor areas.
3. Coil cable [**6 feet** (1800 mm)] **<Insert size>** long not less than [**12 inches** (300 mm)] **<Insert size>** in diameter below each feed point.

G. Group connecting hardware for cables into separate logical fields.

See Editing Instruction No. 5 in the Evaluations for discussion about EMI.

H. Separation from EMI Sources:

1. Comply with BICSI TDMM and TIA-569-B for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.
2. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: A minimum of **5 inches** (127 mm).
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **12 inches** (300 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **24 inches** (610 mm).
3. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: A minimum of **2-1/2 inches** (64 mm).
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **6 inches** (150 mm).
 - c. Electrical Equipment Rating More Than 5 kVA: A minimum of **12 inches** (300 mm).
4. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
 - a. Electrical Equipment Rating Less Than 2 kVA: No requirement.
 - b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of **3 inches** (76 mm).

- c. Electrical Equipment Rating More Than 5 kVA: A minimum of **6 inches** (150 mm).
5. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of **48 inches** (1200 mm).
6. Separation between Communications Cables and Fluorescent Fixtures: A minimum of **5 inches** (127 mm).

3.5 FIRESTOPPING

- A. Comply with requirements in Section 078413 "Penetration Firestopping."
- B. Comply with TIA-569-B, Annex A, "Firestopping."
- C. Comply with BICSI TDMM, "Firestopping Systems" Article.
- D. All horizontal pathways that penetrate fire-rated barriers must be firestopped in accordance with DEN standards and all applicable codes.

3.6 GROUNDING

- A. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
- B. Comply with J-STD-607-A.
- C. Locate grounding bus bar to minimize the length of bonding conductors. Fasten to wall allowing at least **2-inch** (50-mm) clearance behind the grounding bus bar. Connect grounding bus bar with a minimum No. 4 AWG grounding electrode conductor from grounding bus bar to suitable electrical building ground.
- D. Bond metallic equipment to the grounding bus bar, using not smaller than No. 6 AWG equipment grounding conductor.

3.7 IDENTIFICATION

Retain one of first two paragraphs below.

- A. Identify system components, wiring, and cabling complying with TIA/EIA-606-A. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

See Evaluations for discussion about designating the class of cabling plant administration and color-coding of cross-connect fields.

1. Administration Class: **[1] [2] [3] [4]**.
2. Color-code cross-connect fields. Apply colors to voice and data service backboards, connections, covers, and labels.

- B. Comply with requirements in Section 099123 "Interior Painting" for painting backboards. For fire-resistant plywood, do not paint over manufacturer's label.

See Evaluations for discussion about TIA/EIA standard as it applies to this Section.

- C. Paint and label colors for equipment identification shall comply with TIA/EIA-606-A for [Class 2] [Class 3] [Class 4] level of administration[, **including optional identification requirements of this standard**].
- D. Cabling Administration Drawings: Show building floor plans with cabling administration-point labeling. Identify labeling convention and show labels for telecommunications closets, [**backbone pathways and cables,**] [**entrance pathways and cables,**] terminal hardware and positions, horizontal cables, work areas and workstation terminal positions, grounding buses and pathways, and equipment grounding conductors. Follow convention of TIA/EIA-606-A. Furnish electronic record of all drawings, in software and format selected by Owner.
- E. Cable and Wire Identification:
1. Label each cable within 4 inches (100 mm) of each termination and tap, where it is accessible in a cabinet or junction or outlet box, and elsewhere as indicated.
 2. Each wire connected to building-mounted devices is not required to be numbered at device if color of wire is consistent with associated wire connected and numbered within panel or cabinet.
 3. Label each terminal strip and screw terminal in each cabinet, rack, or panel.
 - a. Individually number wiring conductors connected to terminal strips, and identify each cable or wiring group being extended from a panel or cabinet to a building-mounted device shall be identified with name and number of particular device as shown.
 - b. Label each unit and field within distribution racks and frames.
 4. Identification within Connector Fields in Equipment Rooms and Wiring Closets: Label each connector and each discrete unit of cable-terminating and connecting hardware. Where similar jacks and plugs are used for both voice and data communication cabling, use a different color for jacks and plugs of each service.
 5. Uniquely identify and label work area cables extending from the MUTOA to the work area. These cables may not exceed the length stated on the MUTOA label.
- F. Labels shall be preprinted or computer-printed type with printing area and font color that contrasts with cable jacket color but still complies with requirements in TIA/EIA-606-A.
1. Cables use flexible vinyl or polyester that flex as cables are bent.

3.8 FIELD QUALITY CONTROL

- A. General:
1. Inspect wire and cable for physical damage and proper connections.

2. Torque conductor connections and terminations to manufacturer's recommended values. Provide torque report if requested by DEN Project Manager.
3. Verify cables are colored coded and labeled according to contract documents.

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

- B. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

- C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

- D. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
1. Visually inspect UTP and optical fiber cable jacket materials for NRTL certification markings. Inspect cabling terminations in communications equipment rooms for compliance with color-coding for pin assignments, and inspect cabling connections for compliance with TIA/EIA-568-B.1.
 2. Visually confirm [**Category 5e,**] [**Category 6,**] marking of outlets, cover plates, outlet/connectors, and patch panels.
 3. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.
 4. Test UTP backbone copper cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not cross-connection.
 - a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
 5. Optical Fiber Cable Tests:
 - a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.

- b. Link End-to-End Attenuation Tests:
 - 1) Horizontal multimode link measurements: Test at 850 or 1300 nm in 1 direction according to TIA-526-14-A, Method B, One Reference Jumper.
 - 2) Attenuation test results for backbone links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.
6. UTP Performance Tests:
 - a. Test for each outlet and MUTOA. Perform the following tests according to TIA/EIA-568-B.1 and TIA/EIA-568-B.2:
 - 1) Wire map.
 - 2) Length (physical vs. electrical, and length requirements).
 - 3) Insertion loss.
 - 4) Near-end crosstalk (NEXT) loss.
 - 5) Power sum near-end crosstalk (PSNEXT) loss.
 - 6) Equal-level far-end crosstalk (ELFEXT).
 - 7) Power sum equal-level far-end crosstalk (PSELFEXT).
 - 8) Return loss.
 - 9) Propagation delay.
 - 10) Delay skew.
7. Optical Fiber Cable Performance Tests: Perform optical fiber end-to-end link tests according to TIA/EIA-568-B.1 and TIA/EIA-568-B.3.

Retain "Coaxial Cable Tests" Subparagraph below when cable is used for broadband closed-circuit television applications. Revise to suit tests to verify cable performance for other systems using coaxial cable.

8. Coaxial Cable Tests: Conduct tests according to Section 274133 "Master Antenna Television System."

Retain "Final Verification Tests" Subparagraph below if Owner intends to use Contractor in final testing after its personnel have assumed the operation of communications system.

9. Final Verification Tests: Perform verification tests for UTP[**and optical fiber**] systems after the complete communications cabling and workstation outlet/connectors are installed.
- E. Document data for each measurement. Data for submittals shall be printed in a summary report that is formatted similar to Table 10.1 in BICSI TDMM, or transferred from the instrument to the computer, saved as text files, and printed and submitted.
- See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.
- F. End-to-end cabling will be considered defective if it does not pass tests and inspections.
 - G. Prepare test and inspection reports.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel in cable-plant management operations, including changing signal pathways for different workstations, rerouting signals in failed cables, and keeping records of cabling assignments and revisions when extending wiring to establish new workstation outlets. **[Include training in cabling administration software.]**
- B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - PART 4- MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PART 5- PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 271500

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SECTION 272100 - LOCAL AREA NETWORKS (LANS)

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

IMPORTANT: PARTS LISTS MUST BE SPECIFICALLY COORDINATED FOR ALL PROJECTS. ENSURE THAT ALL REQUIRED COORDINATION WITH DEN STAFF IS COMPLETED IN A TIMELY MANNER. REFER TO DESIGNER NOTES CONTAINED IN PART 2 OF THIS SECTION FOR MORE INFORMATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Denver International Airport operates three Local Area Networks (LANs). The enterprise network is the largest of these networks supporting services ranging from city desktops, flight information, common use departure control equipment to building automation and in some cases tenant networks. The enterprise network is a large three layer network consisting of core switches, pairs of distribution switches in each major building and access layer switches located in Intermediate Distribution Frame (IDF) rooms throughout the buildings.
- B. The Emergency Communications System, or ECS, is a stand-alone network that supports public address communications. This network utilizes smaller switches in a core, distribution and access layer configuration that allows public address CobraNet audio to traverse locally in each network region while allowing client to server communications to traverse between buildings to reach the system servers. The ECS network also utilizes a small layer two network to allow inter-building CobraNet audio to traverse between buildings.

- C. The Security Access Control Network, or SACN, is also a separate network. This network is dedicated exclusively to security access control including communications to door controllers, door related intercom and door security cameras.
- D. Work Includes:
1. Enterprise Network Distribution and Access Layer Switches.
 2. ECS Network Distribution and Access Layer Switches.
 3. SACN Network Distribution and Access Layer Switches.
- E. Contractors shall be required to purchase specific equipment as listed on the bill of materials including SmartNet warranty coverage where indicated. All equipment shall be procured through a Cisco certified value added reseller. Gray market equipment procured through non-certified sources shall not be acceptable.
- F. This equipment shall be assembled and installed at designated locations throughout the project with fiber uplinks to distribution and core switches. DEN Technologies will provide a basic configuration to be applied to each switch by the contractor. The contractor shall apply this configuration to each network device including the IP address, subnet mask and default gateway.
- G. Once the network devices are installed and connectivity is tested, DEN Technologies will activate core and/ or distribution switch ports to join the new network devices to the production networks. The DEN Technologies staff will then apply a permanent configuration on each network device and will thereafter operate and maintain these devices.
- H. Related Sections:
1. Section 260400 "Basic Electrical Requirements".
 2. Section 270526 "Grounding and Bonding for Telecommunications Systems".
 3. Section 270528 "Pathways for Communications Systems".
 4. Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling".
 5. Section 271100 "Communications Equipment Room Fittings".
 6. Section 271300 "Communications Backbone Cabling".
 7. Section 271500 "Communications Horizontal Cabling".

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- I. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 SCOPE OF WORK

Retain terms that remain after this Section has been edited for a project.

- A. Furnish and install, complete with all accessories the network equipment for each network. Include all optical modules, stackwise and stack power links for a fully

functional extension of the respective networks

- B. Provide all required fiber jumpers and patching to join the new network components to assigned ports on the DEN production networks.
- C. Test connectivity of all new network devices by capturing a "Show CDP Neighbor" output from each network device. Once testing is complete, provide this output to the DEN Technologies' network staff.

1.4 REFERENCE STANDARDS

- A. General: The latest version of the following codes and standards shall be applicable:
 - 1. Code of Federal Regulations (CFR).
 - 2. 47 CFR 15 et seq.: Radio Frequency Devices.
 - 3. Institute of Electrical and Electronics Engineers (IEEE):
 - a. IEEE C2: National Electrical Safety Code.
 - b. IEEE 142: IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems.
 - c. IEEE C62.41-1991: Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
 - d. IEEE 802.3: Information Technology - Local and Metropolitan Area Networks - Part 3; Carrier Sense with Collision Detection (CSMA/CD) Access Methods and Physical Layer Specification.
 - e. IEEE 802.3u: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/s Operation.
 - f. IEEE 802.3x: Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Specification for 802.3 Full Duplex Operation Detection (CSMA/CD) Access Method & Physical Layer Specifications:
 - 1) Specification for 802.3 Full Duplex Operation.
 - 4. National Fire Protection Association (NFPA):
 - a. NFPA 70: National Electrical Code (NEC).
 - 5. Telecommunications Industry Association/Electronics Industry Association (TIA/EIA):
 - a. EIA-170: Electrical Performance Standards - Monochrome Television Studio Facilities.
 - b. EIA-310-D: Cabinets, Racks, Panels, and Associated Equipment
 - c. TIA/EIA-568-B: Commercial Building Telecommunications Cabling Standard.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT

PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. General: Comply with requirements of Section 013300 "Submittal Procedures"
- B. Product Data: For each type of product.
 - 1. Submit catalog cut sheets, technical data sheets, manufacturer's specifications and/or diagrams necessary to illustrate a product, material or system for some portion of the work. Product data literature is required on all items of material and equipment and should be clearly marked; identifying specific items proposed with a reference to the specification requirement(s) the item is being submitted for.
 - 2. Product data shall include adequate descriptive literature and catalog cut sheets required for the DEN Project Manager to ascertain that the proposed equipment and materials comply with Specifications requirements.
 - 3. Include data substantiating that materials comply with requirements.
- C. Shop Drawings:
 - 1. The shop drawings shall be approved by the DEN Project Manager prior to system installation.
 - 2. Floor plans detailing all devices, conduit and raceway systems.
 - 3. Equipment room layouts to scale including equipment cabinet elevations.
 - 4. Point-to-point wiring diagrams.

1.6 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For installer.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For Local Area Networks to include in emergency, operation, and maintenance manuals.
 - 1. Include operating instructions, and maintenance and repair procedures. Procedures shall include shop manuals and schematic drawings to allow repair of equipment.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Contractor shall maintain on site accurate as-built drawings indicating dimensioned locations of constructed raceway, box and device locations. Any modifications to work depicted on the Engineered shop drawings shall be noted. Documents shall be updated daily and shall at all times be available for DEN review.

Edit below to suit Project, or delete Article if no maintenance material submittals.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1.9 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.
- B. Contractor shall be fully responsible for daily quality control of all system installation, coordination with trades, and coordination with DEN Maintenance and Engineering.

1.10 DELIVERY, STORAGE AND HANDLING

- A. Deliver products to site under provisions of Division 1.
- B. Store and protect products under provisions of Division 1.

1.11 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

- A. All components, parts and assemblies provided by the Contractor shall be guaranteed against defects in materials and workmanship for a period of 24 months following acceptance. Submit warranty per Division 1 requirements.
- B. Warranty service shall be provided by a trained specialist of the equipment manufacturer, who shall be based in a fully staffed, fully stocked (replacement parts and test equipment) office, located within 50 miles of the site.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

1.1 Bill of Materials

- A. Consultants are required to provide a complete bill of materials specific to the project, and coordinated with DEN technologies staff. The consultant shall produce a spreadsheet for submission to DEN for each of the three networks that includes the following information for each item of network connected equipment:
 - 1. Item Number.
 - 2. System Name.
 - 3. Device Type.
 - 4. Device Name.
 - 5. Room Number.
 - 6. Outlet & Jack Number.
 - 7. Serving IDF Room.
 - 8. Network (Enterprise, ECS or SACN).
 - 9. Power over Ethernet Required in Watts.
- B. Once the information above is compiled, submit the spreadsheet to the DEN Project Manager and request to arrange a meeting with DEN Technologies Network staff. The DEN Technologies staff will compile a detailed bill of materials for inclusion in the project specifications based on the equipment that is currently being procured and provide the bill of materials to the consultant. Designers shall include this bill of material in the network specifications for each of the three networks.
- C. DEN Technologies will also complete the network spreadsheet for each of the three networks including the following for each item of network connected equipment:
 - 1. Circuit ID Number.
 - 2. Switch Name.
 - 3. Switch Port Assignment.
 - 4. VLAN ID.
 - 5. IP Address.
 - 6. Subnet Mask.
 - 7. Default Gateway.
 - 8. Port Speed and Duplex.
 - 9. Circuit Cut Sheet.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 ENTERPRISE NETWORK

- A. Enterprise network distribution switches shall be provided in any new network region in a "red / blue configuration in physically diverse rooms. Each distribution switch shall be provided with 10G-Base-LR modules to support uplinks to the red and blue DEN enterprise core switches and between the distribution switches. Switches shall be provided with a supervisor engine to allow routing using Cisco EIGRP protocol.
- B. Enterprise Network Distribution Switches shall be configured using sufficient modules to support uplinks to the Enterprise Network core switches and redundant downlinks to the region access layer switches.
- C. Acceptable products for the distribution switches are listed below:

CISCO	C6807-XL	Catalyst 6807-XL 7-slot chassis, 10RU
CISCO	CON-SNT-C6807XLC	SMARTNET 8X5XNBD Catalyst 6807-XL7-s
CISCO	MEM-C6K-INTFL1GB	Internal 1G Compact Flash
CISCO	VS-F6K-PFC4	Cat 6k 80G Sys Daughter Board Sup2T PFC4
CISCO	VS-SUP2T-10G	Catalyst 6500 Supervisor Engine 2T
CISCO	MEM-SUP2T-2GB	Catalyst 6500 2GB memory for Sup2T and Sup2TXL
CISCO	S2TAEK9-15102SY	Cisco CAT6000-VS-S2T IOS ADV ENT SERVULL ENCRYPT
CISCO	WS-X6724-SFP	Catalyst 6500 24-port GigE Mod: fabric-enabled (Req. SFPs)
CISCO	MEM-XCEF720-256M	Catalyst 6500 256MB DDR, xCEF720 (67xx interface, DFC3A)
CISCO	WS-F6700-CFC	Catalyst 6500 Central Fwd Card for WS-X67xx modules
CISCO	WS-X6724-SFP	Catalyst 6500 24-port GigE Mod: fabric-enabled (Req. SFPs)
CISCO	MEM-XCEF720-256M	Catalyst 6500 256MB DDR, xCEF720 (67xx interface, DFC3A)
CISCO	WS-F6700-CFC	Catalyst 6500 Central Fwd Card for WS-X67xx modules
CISCO	WS-X6908-10G-2T	C6K 8 port 10 Gigabit Ethernet module with DFC4 (Trustsec)
CISCO	WS-F6K-DFC4-E	Cat 6k 80G Sys Daughter Board DFC4E
CISCO	WS-X6908-10G	Catalyst 6500 8 Port 10G SFP Baseboard
CISCO	C6800-XL-3KW-AC	Catalyst 6807-XL 3000W Power Supply
CISCO	CAB-C19-CBN	Cabinet Jumper Power Cord, 250 VAC 16A, C20-C19 Connectors
CISCO	C6807-XL-FAN	Catalyst 6807-XL Chassis Fan Tray
CISCO	C6800-XL-CVR	Catalyst 6807-XL line card slot cover
CISCO	C6800-CAMPUS-CORE	Catalyst 6800 Campus Core Deployment; For Tracking Only

CISCO	VS-S2T-10G	Cat 6500 Sup 2T with 2 x 10GbE and 3 x 1GbE with MSFC5 PFC4
CISCO	GLC-T 1000-Base-T	Copper SFP for Firewall Connections
CISCO	X2-10GB-LR	10GBASE-LR X2 Module

D. Enterprise Network access layer switches shall be provided in either a 24-port or 48-port configuration at each IDF room. Each access layer switch shall be provided with one 1000-base-LX/LH uplink to the red distribution switch with a second 1000-base-LX/LH uplink to the blue distribution switch. Locations requiring more than one switch shall be configured with stackwise and stackpower cables. Switches shall support Power over Ethernet

E. Acceptable components for 24-port access layer switches are:

CISCO	WS-C3850-24U-S	Cisco Catalyst 3850 24 Port UPOE IP Base
CISCO	PWR-C1-1100WAC	1100W AC Config 1 Power Supply
CISCO	CAB-C15-CBN	Cabinet Jumper Power Cord, 250 VAC 13A, C14-C15 Connectors
CISCO	PWR-C1-1100WAC/2	1100W AC Config 1 Secondary Power Supply
CISCO	C3850-NM-2-10G	Cisco Catalyst 3850 2 x 10GE Network Module
CISCO	GLC-LH-SMD=	1000BASE-LX/LH SFP transceiver module, MMF/SMF, 1310nm, DOM
CISCO	S3850UK9-33SE	CAT3850 Universal k9 image
CISCO	STACK-T1-50CM	50CM Type 1 Stacking Cable
CISCO	CAB-SPWR-30CM	Catalyst 3750X and 3850 Stack Power Cable 30 CM
CISCO	N/A	Limited Lifetime Warranty

F. Acceptable components for 48-port access layer switches are:

CISCO	WS-C3850-48U-S	Cisco Catalyst 3850 48 Port UPOE IP Base
CISCO	CAB-C15-CBN	Cabinet Jumper Power Cord, 250 VAC 13A, C14-C15 Connectors
CISCO	PWR-C1-1100WAC/2	1100W AC Config 1 Secondary Power Supply
CISCO	C3850-NM-2-10G	Cisco Catalyst 3850 2 x 10GE Network Module
CISCO	S3850UK9-33SE	CAT3850 Universal k9 image
CISCO	STACK-T1-50CM	50CM Type 1 Stacking Cable
CISCO	GLC-LH-SMD=	1000BASE-LX/LH SFP transceiver module, MMF/SMF, 1310nm, DOM
CISCO	CAB-SPWR-30CM	Catalyst 3750X and 3850 Stack Power Cable 30 CM
CISCO	PWR-C1-1100WAC	1100W AC Config 1 Power Supply
CISCO	N/A	Limited Lifetime Warranty

G. Enterprise network access layer switches at un-conditioned spaces such as roadway cabinets, exterior parking locations, etc. shall be environmentally hardened. Acceptable components for switches in these locations are:

CISCO	IE-3000-8TC-E	IE 3000 8-Port Base Switch w/ Layer 3
CISCO	SIESISK9T-15002EY	Cisco IE 3000 IP SERVICES WITH WEB BASED DEV MGR

CISCO	PWR-IE3000-AC=	IE 3000 Power transformer
CISCO	STK-RACKMNT-2955=	19 in Rack mount kit for Catalyst 2955
CISCO	GLC-LH-SMD=	1000BASE-LX/LH SFP transceiver module, MMF/SMF, 1310nm, DOM
CISCO	CON-SNT-IE30008	Smartnet 8x5xNBD

2.2 ECS NETWORK

A. ECS distribution switches shall be deployed in a red / blue configuration in physically separate rooms. Switches shall be 12-port SFP based configuration with 1000-base-BXU uplinks from each switch to the ECS “red” core switch and “blue” core switch. 1000-base-BXD downlink modules shall be provided for the core switch interfaces. An additional pair of BXU BXD modules shall be used for a link between distribution switches. In locations requiring more than nine (9) ECS access layer switches more than one 12-port SFP switch shall be utilized in a stackwise configuration.

B. Acceptable components for ECS distribution switches are:

CISCO	WS-C3750X-12S-E	Catalyst 3750X 12 Port GE SFP IP Services
CISCO	CAB-C15-CBN	Cabinet Jumper Power Cord, 250 VAC 13A, C14-C15 Connectors
CISCO	C3KX-PWR-350WAC/2	Catalyst 3K-X 350W AC Secondary Power Supply
CISCO	S375XVK9T-15002SE	CAT 3750X IOS UNIVERSAL WITH WEB BASE DEV MGR
CISCO	C3KX-NM-10G	Catalyst 3K-X 10G Network Module option PID
CISCO	CAB-STACK-50CM	Cisco StackWise 50CM Stacking Cable
CISCO	CAB-SPWR-30CM	Catalyst 3750X and 3850 Stack Power Cable 30 CM
CISCO	C3KX-PWR-350WAC	Catalyst 3K-X 350W AC Power Supply

C. ECS access layer switches shall be provided at IDF rooms that support public address microphone stations and other items of public address equipment. These switches shall provide PoE power to operate microphone stations. Switches shall be provided with 1000-base-BXU uplink modules to link to the red and blue ECS distribution switches with 1000-base-BXD modules at the distribution switch location.

D. Acceptable components for the ECS access layer switches are:

CISCO	WS-C3850-24U-S	Cisco Catalyst 3850 24 Port UPOE IP Base
CISCO	CAB-C15-CBN	Cabinet Jumper Power Cord, 250 VAC 13A, C14-C15 Connectors
CISCO	PWR-C1-1100WAC/2	1100W AC Config 1 Secondary Power Supply
CISCO	C3850-NM-2-10G	Cisco Catalyst 3850 2 x 10GE Network Module
CISCO	S3850UK9-33SE	CAT3850 Universal k9 image
CISCO	STACK-T1-50CM	50CM Type 1 Stacking Cable
CISCO	CAB-SPWR-30CM	Catalyst 3750X and 3850 Stack Power Cable 30 CM
CISCO	PWR-C1-1100WAC	1100W AC Config 1 Power Supply
CISCO	GLC-LH-BXU	1000-BASE-BXU Uplink Module 1-strand SM

CISCO	GLC-LH-BXD	1000-BASE-BXD Downlink Module 1-strand SM
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2.3 SACN NETWORK

- A. SACN distribution switches shall be deployed in a red / blue configuration in physically separate rooms. Switches shall be 12-port SFP based configuration with 1000-base-LX/LH uplinks from each switch to the SACN “red” core switch and “blue” core switch. 1000-base-LX/LH downlink modules shall be provided for the core switch interfaces. An additional pair of 1000-base-LX/LH modules shall be used for a link between distribution switches. In locations requiring more than nine (9) SACN access layer switches more than one 12-port SFP switch shall be utilized in a stackwise configuration.
- B. Acceptable components for SACN distribution switches are:

CISCO	WS-C3750X-12S-E	Catalyst 3750X 12 Port GE SFP IP Services
CISCO	CAB-C15-CBN	Cabinet Jumper Power Cord, 250 VAC 13A, C14-C15 Connectors
CISCO	C3KX-PWR-350WAC/2	Catalyst 3K-X 350W AC Secondary Power Supply
CISCO	S375XVK9T-15002SE	CAT 3750X IOS UNIVERSAL WITH WEB BASE DEV MGR
CISCO	C3KX-NM-10G	Catalyst 3K-X 10G Network Module option PID
CISCO	CAB-STACK-50CM	Cisco StackWise 50CM Stacking Cable
CISCO	CAB-SPWR-30CM	Catalyst 3750X and 3850 Stack Power Cable 30 CM
CISCO	C3KX-PWR-350WAC	Catalyst 3K-X 350W AC Power Supply

- C. SACN access layer switches shall be provided at IDF rooms that support access control equipment. These switches shall be provided in pairs of two switches in a stackwise configuration. The top switch in the stack is considered the active switch and cables from access control equipment are normally connected to this switch. The bottom switch is configured as a hot spare for security to use in the event the top switch fails. . Switches shall be provided with 1000-base-BXU uplink modules to link to the red and blue ECS distribution switches with 1000-base-BXD modules at the distribution switch location.
- D. Acceptable components for the SACN access layer switches are:

CISCO	WS-C3850-24U-S	Cisco Catalyst 3850 24 Port UPOE IP Base
CISCO	CAB-C15-CBN	Cabinet Jumper Power Cord, 250 VAC 13A, C14 -C15 Connectors
CISCO	PWR-C1-1100WAC/2	1100W AC Config 1 Secondary Power Supply
CISCO	C3850-NM-2-10G	Cisco Catalyst 3850 2 x 10GE Network Module
CISCO	S3850UK9-33SE	CAT3850 Universal k9 image
CISCO	STACK-T1-50CM	50CM Type 1 Stacking Cable
CISCO	CAB-SPWR-30CM	Catalyst 3750X and 3850 Stack Power Cable 30 CM
CISCO	PWR-C1-1100WAC	1100W AC Config 1 Power Supply
CISCO	GLC-LH-BXU	1000-BASE-BXU Uplink Module 1-strand SM
CISCO	GLC-LH-BXD	1000-BASE-BXD Downlink Module 1-strand SM

- E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- F. Comply with NFPA 70.

2.4 NO SUBSTITUTIONS

- A. Substitution on network equipment is not permitted as these devices must interoperate with existing DEN networks.
- B. Source Limitations: Obtain Local Area Network components from single source and from single manufacturer for each component type.

PART 3 - EXECUTION

3.1 GENERAL

- A. The Work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly factory trained and qualified for this Work.
- B. Raceways: Raceways shall be installed in accordance with Division 26 and as augmented by applicable Division 27 sections.

3.2 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing and Reports:
 - 1. The Contractor shall provide all personnel, equipment, instrumentation, and supplies necessary to perform all testing.
 - 2. Design Engineer and Airport representatives will witness all field tests.
 - 3. When installation is complete, the system shall be tested by the Contractor and DEN representatives. A representative of the installing Contractor shall submit a written report of the findings to the DEN Project Manager.
 - 4. Report shall consist of a complete listing of every device and feature, the date it was tested and by whom, the results, and the date retested (if failure occurred during any previous tests). The final test reports shall indicate that every device tested successfully.
 - 5. Submit two (2) typed copies of the test reports in a neatly bound folder to the Owner's Representative for approval.
 - 6. Also, submit electronic copies of test reports in pdf format.
 - 7. Failure to comply will result in a delay of final testing and acceptance.
- B. The field testing shall as a minimum include:

1. Verification that the data transmission media and any signal or control cabling has been installed, tested, and approved.
2. Verification that the new equipment is fully functional and that all other ancillary equipment is functioning properly.

3.3 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 1. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
 2. Complete installation and startup checks according to manufacturer's written instructions.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the local area network (LANS) and equipment. Refer to Section 017900 "Demonstration and Training."
 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 272100

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SECTION 272101 - PUBLIC WIRELESS LAN (WIFI)

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

IMPORTANT: TECHNOLOGIES PARTS LISTS MUST BE SPECIFICALLY COORDINATED FOR ALL PROJECTS. ENSURE THAT ALL REQUIRED COORDINATION WITH DEN STAFF IS COMPLETED IN A TIMELY MANNER. REFER TO DESIGNER NOTES CONTAINED IN THIS SECTION FOR MORE INFORMATION.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Consultant Coordination Requirements

1. Consultants are required to coordinate WiFi design with DEN during design as described below.
 - a. Consultant shall review the general design guidelines below and develop a preliminary design. After preliminary design is complete, coordinate with the DEN Project Manager to arrange a meeting with the consultant and DEN Technologies WIFI group to review the preliminary design and confirm the specific locations and configuration of WIFI access points, antennas and pods.
 - b. Low density areas such as curbside, bag claim and similar areas will require individual 802.11a/b/g/n access points and patch antennas. A WIFI device coming into the proximity of the access point will be queried by the WIFI network controller to determine whether the device is 802.11a capable. If so, the controller will assign the device to one of several 802.11a channels. If not the device will be assigned to one of the 802.11b/g/n channels. High density locations will require pods of WIFI access points. A

pod consists of three 802.11a/b/g/n antennas and access points. Antennas are ceiling mounted in an equilateral triangular arrangement that is seven (7) feet on a side. A WIFI device coming into a high density area will be queried to verify 802.11a compatibility and if so, assigned to an 802.11a channel in the nearest pod. If not, the network.

Edit to suit Project.

- B. The Contractor shall provide a physically complete and fully functional extension of the airport public wireless LAN system throughout all public areas of the project. This equipment shall fully integrate with the DEN enterprise wired network and with existing airport WIFI controllers. Provide all labor and products required for installation of the equipment. Programming shall be performed by Denver International Airport (DEN) representatives. Test and checkout of the WIFI equipment shall be done jointly with the Contractor and DEN personnel. Coordinate all work by DEN staff through the DEN Project Manager.
- C. Work Includes:
 - 1. WIFI Access Points.
 - 2. WIFI Antennas.
 - 3. Cabling from access points to DEN enterprise network switches.
 - 4. Power Injectors for non-PoE switch connections.
 - 5. Access Point enclosures, access panels and other misc. hardware.
- D. Provide system documentation, submittals and warranty support.
- E. Comply with codes, ordinances, regulations, and other legal requirements of public authorities that bear on installation and performance of Work.
- F. The Work described in this section includes engineering, design, labor, materials, equipment, installation and services necessary for physically complete and functional system. Materials, equipment, appurtenances, or labor not specifically mentioned in this specification, or not shown on the Contract Drawings, but required for proper installation, performance, and operation of the equipment or systems, shall be provided by the Contractor.
- G. The Work shown in the Contract Drawings is diagrammatic in nature and the Contractor is responsible for determining the final equipment locations, arrangements, and installation to meet site-specific requirements.
- H. Related Sections:
 - 1. Section 260400 "Basic Electrical Requirements".
 - 2. Section 270526 "Grounding and Bonding for Telecommunications Systems".
 - 3. Section 270528 "Pathways for Communications Systems".
 - 4. Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling".
 - 5. Section 271100 "Communications Equipment Room Fittings".
 - 6. Section 271300 "Communications Backbone Cabling".

7. Section 271500 "Communications Horizontal Cabling".

Verify requirements for as-built plans with DEN Project Manager.

- I. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.3 SCOPE OF WORK

- A. The Contractor shall provide in-ceiling or above-ceiling enclosures for access points. Access points are not plenum rated. It is essential that the access points be readily accessible after installation for maintenance purposes.
- B. Ethernet communications between the access points and enterprise network access layer switches using a PoE Ethernet connection. Refer to the Contract Drawings for the location of each Ethernet access layer switch.
- C. Once access points are installed and connected to the public WIFI network DEN Technologies will configure the access points to work with the existing DEN WIFI controllers. DEN Technologies will provide an IP address, subnet mask and default gateway address for each access point. These must be configured on the access points prior to their installation.

1.4 REFERENCE STANDARDS

- A. General: The latest version of the following codes and standards shall be applicable:
 1. Code of Federal Regulations (CFR).
 2. 47 CFR 15 et seq.: Radio Frequency Devices.
 3. Institute of Electrical and Electronics Engineers (IEEE):
 - a. IEEE C2: National Electrical Safety Code.
 - b. IEEE 142: IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems.
 - c. IEEE C62.41-1991: Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
 - d. IEEE 802.3: Information Technology - Local and Metropolitan Area Networks - Part 3; Carrier Sense with Collision Detection (CSMA/CD) Access Methods and Physical Layer Specification.
 - e. IEEE 802.3u: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/s Operation.
 - f. IEEE 802.3x: Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Specification for 802.3 Full Duplex Operation Detection (CSMA/CD) Access Method & Physical Layer Specifications:

- 1) Specification for 802.3 Full Duplex Operation.
4. National Fire Protection Association (NFPA):
 - a. NFPA 70: National Electrical Code (NEC).
5. Telecommunications Industry Association/Electronics Industry Association (TIA/EIA):
 - a. EIA-170: Electrical Performance Standards - Monochrome Television Studio Facilities.
 - b. EIA-310-D: Cabinets, Racks, Panels, and Associated Equipment
 - c. TIA/EIA-568-B: Commercial Building Telecommunications Cabling Standard.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. General: Comply with requirements of Section 013300 "Submittal Procedures".
- B. Product Data: For each type of product.
 1. Submit catalog cut sheets, technical data sheets, manufacturer's specifications and/or diagrams necessary to illustrate a product, material or system for some portion of the work. Product data literature is required on all items of material and equipment and should be clearly marked; identifying specific items proposed with a reference to the specification requirement(s) the item is being submitted for.
 2. Product data shall include adequate descriptive literature and catalog cut sheets required for the DEN Project Manager to ascertain that the proposed equipment and materials comply with Specifications requirements.
 3. Include data substantiating that materials comply with requirements.
- C. Shop Drawings:
 1. The shop drawings shall be approved by the DEN Project Manager prior to system installation.
 2. Floor plans detailing all devices, conduit and raceway systems.
 3. Equipment room layouts to scale including equipment cabinet elevations.
 4. Point-to-point wiring diagrams.

1.6 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For installer.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For public wireless LAN (WIFI) systems to include in emergency, operation, and maintenance manuals.
 - 1. Include operating instructions, and maintenance and repair procedures. Procedures shall include shop manuals and schematic drawings to allow repair of equipment.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Contractor shall maintain on site accurate as-built drawings indicating dimensioned locations of constructed raceway, box and device locations. Any modifications to work depicted on the Engineered shop drawings shall be noted. Documents shall be updated daily and shall at all times be available for DEN review.

Edit below to suit Project, or delete Article if no maintenance material submittals.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1.9 QUALITY ASSURANCE

- A. Contractor shall be fully responsible for daily quality control of all system installation, coordination with trades, and coordination with DEN Maintenance and Engineering.

1.10 DELIVERY, STORAGE AND HANDLING

- A. Deliver products to site under provisions of Division 1.
- B. Store and protect products under provisions of Division 1.

1.11 WARRANTY

- A. All components, parts and assemblies provided by the Contractor shall be guaranteed against defects in materials and workmanship for a period of 24 months following acceptance. Submit warranty per Division 1 requirements.
- B. Warranty service shall be provided by a trained specialist of the equipment manufacturer, who shall be based in a fully staffed, fully stocked (replacement parts and test equipment) office, located within 50 miles of the site.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Designers are required to coordinate all equipment lists with DEN Technologies staff during design. Edit this section as required to suit project. Refer to designer notes contained in Part 1 for more information.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

- A. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - 1. WIFI Access Point:
 - a. Meru AP332 Dual Radio, Dual Band Three Stream Radio with six external antenna connections.
 - 2. WIFI Antenna (One per Access Point):
 - a. Meru ANT-6ABGN Dual band mini-MIMO ceiling mount omnidirectional antenna. Each antenna is equipped with six (6) 36-inch cables with RP-SMA plugs for connection to the associated access point.
 - 3. Substitutions:

- a. Substitution on WIFI equipment is not permitted, as these devices must interoperate with existing DEN WIFI controllers.
 - b. Designers are required to meet with DEN Technologies WIFI staff during the design phase of the Project to ensure there have been no changes in equipment types.
- B. Source Limitations: Obtain public wireless LAN (WIFI) system from single source from single manufacturer.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with NFPA 70.

PART 3 - EXECUTION

3.1 GENERAL

- A. The Work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly factory trained and qualified for this Work.
- B. Programming of the system WIFI controllers shall be performed by DEN Technologies.
- C. Raceways: Raceways shall be installed in accordance with Division 26 and as augmented by applicable Division 27 sections.

3.2 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing and Reports:
 - 1. The Contractor shall provide all personnel, equipment, instrumentation, and supplies necessary to perform all testing.
 - 2. Design Engineer and Airport representatives will witness all field tests.
 - 3. When installation is complete, the system shall be tested by the Contractor and DEN representatives. A representative of the installing Contractor shall submit a written report of the findings to the DEN Project Manager.
 - 4. Report shall consist of a complete listing of every device and feature, the date it was tested and by whom, the results, and the date retested (if failure occurred during any previous tests). The final test reports shall indicate that every device tested successfully.
 - 5. Submit two (2) typed copies of the test reports in a neatly bound folder to the Owner's Representative for approval.
 - 6. Also submit electronic copies of test reports in pdf format.
 - 7. Failure to comply will result in a delay of final testing and acceptance.

- B. The field testing shall as a minimum include:
1. Verification that the data transmission media and any signal or control cabling has been installed, tested, and approved.
 2. Verification that the new equipment is fully functional and that all other ancillary equipment is functioning properly.

3.3 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
1. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
 2. Complete installation and startup checks according to manufacturer's written instructions.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the public wireless LAN (WIFI) system and equipment. Refer to Section 017900 "Demonstration and Training."
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 272101

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SECTION 273200 - TELEPHONE SYSTEM

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes:

Edit to suit Project.

- 1. Tenant and Airline PABX Systems.
- 2. Courtesy Telephones.
- 3. Elevator Telephones.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DESCRIPTION

- A. Telephone service will consist of a variety of regulated services, airport PABX service and airline / tenant PABX services. These services will be provisioned over the DEN Premise Wiring and Communications backbone and horizontal cabling system to various outlets located throughout the facility.

- B. This section describes the general configuration required for airline / tenant telephone systems and specialized telephones that will interconnect to the DEN PABX system.
- C. Designers are required to submit a complete set of plans and specifications for their projects to the DEN Telecommunications Department for review and approval. Designers are also required to meet with representatives from the DEN Telecommunications Department at one or more times during the course of design to work out specific interface details prior to the final submittal.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment cabinets and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Cabling Diagrams: Single-line block diagrams showing cabling interconnection of all components for this specific equipment. Include cable type for each interconnection.
 - 3. Installation Details: For built-in equipment, dimensioned and to scale.

1.5 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- A. Qualification Data: For qualified Installer.
- B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For telephone equipment to include operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.7 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.
- B. Compatibility: System shall be capable of integration with any brand of phone system (wired or wireless), CCTV, and fire-alarm system.
- C. Electrical Components, Devices, and Accessories: Listed and labeled according to UL 1069 as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

D. CONSTRUCTION WASTE MANAGEMENT

- 1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 TENANT AND AIRLINE PABX SYSTEMS

- A. Tenant and Airline PABX systems shall be located within the Tenant or Airline leasehold area or, where space permits, in a locked cabinet within the tenant equipment room immediately adjacent to the DEN IDF room.
- B. Tie cables shall be utilized between the PABX location and the DEN IDF room. These cables shall be provided and installed by the DEN Premise Wiring and Communications System (PWCS) contractor at the expense of the airline or tenant. Incoming trunks and outgoing station circuits shall be extended to the PABX via this tie cable by the DEN PWCS contractor at airline or tenant expense under the airport's Move / Add / Change process.

2.2 COURTESY TELEPHONES

- A. Courtesy telephones shall be provided at pay telephone banks and other locations in a pattern matching courtesy telephone locations throughout existing portions of the facility.
- B. These telephones will connect as analog extensions on the DEN PABX system. All cross connects to support these telephones will be provided by the DEN PWCS contractor. All programming necessary to activate these telephones will be by the DEN Telecommunications staff.
- C. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ceeco Model: SSP 361-F, with optional white handset.
2. <Insert manufacturer>
3. or approved equal.

Retain first paragraph below if equipment connects with an existing system. Insert descriptions of specific operational sequences that must be achieved.

- D. Existing System Compatibility: Functionally and electrically compatible with existing system so components and wiring operate as an extension or upgrade of the existing system and existing or upgraded functional performance of the existing system applies to the entire final system. Colors, tones, and types, shall be common among new and existing systems.

2.3 ELEVATOR TELEPHONES

- A. Elevators installed at DEN must be equipped with an ADA compliant hands-free elevator telephone. These telephones are to be mounted inside the control station panel in each elevator cab. Special perforations are required for the telephone loudspeaker, microphone element and LED indicator.
- B. Provide one normally open auxiliary dry contact on the elevator alarm button in each elevator cab. The primary contact on this button shall ring the elevator alarm bell. The second contact shall cause the telephone to go off-hook causing the PABX to ring down the call to a designated receiving location.
- C. The standard DEN telephone also includes an ADA compliant legend plate that must be installed inside each elevator cab.
- D. The horizontal wiring distribution system shall include one ¾" conduit from the nearest IDF room to an interface cabinet near each elevator controller to support these telephones. Where multiple controllers are located in the same machine room, a single larger conduit may be utilized to a junction box in the machine room with separate ¾" conduits extending from this box to each elevator controller.
- E. Coordinate shielded traveling cable pair requirements with the elevator contractor
- F. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Talk-A-Phone ETP-103.
 2. Substitutions on these units shall not be considered as the telephones are polled several times per day by the Airport's Talk-A-Lert software and EB-200 base station.

2.4 AREA OF REFUGE TELEPHONES

- A. Furnish and install flush mount single button ADA compliant area of refuge telephones where shown on the contract drawings. These telephones shall flush mount in a flush backbox. Area of refuge telephones shall be provided with a front panel red button

marked emergency, call connected indicator and braille placard to assist the blind. Area of refuge telephones shall be connected to the airport PABX as analog stations. DEN Telecommunications will program the PABX to ring these telephones into the airport communications center when a call is placed.fl

B. Area of Refuge telephones shall be Talk-a-Phone model ETP-400

1. Substitutions on these units shall not be considered as the telephones are polled several times per day by the Airport's Talk-A-Lert software and EB-200 base station

2.5 GARAGE BLUE LIGHT TELEPHONES

A. Blue Light phones used at DEN shall be Talk-a-Phone model ETP-400D dual button hands free phones. The red button on the phone shall be marked Emergency with an ADA compliant braille label placard. This button is programmed to call the Denver Police position in the airport communications center. The black button on the phones are marked "Info" with an ADA compliant braille placard. This button is programmed to call the parking operator operations office. Phones connect to a standard analog PABX circuit.

B. Blue light phones shall be located adjacent to each stairwell. On lower levels of the garage Blue Light phones shall be installed in a Talk-a-Phone ETP-WM wall mount blue light enclosure. On the upper level of the garage, phones shall be mounted in a Talk-a-Phone ETP-MTE-72 tower enclosure. All phones will require both a telephone line connection and 120VAC power to power the blue light and strobe.

1. Substitutions on these units shall not be considered as the telephones are polled several times per day by the Airport's Talk-A-Lert software and EB-200 base station

2.6 HARDWARE, CONDUCTORS AND CABLE

A. Data Cable and Hardware: [**Category 5e**] UTP and UTP hardware. Comply with requirements in Section 271500 "Communications Horizontal Cabling."

B. Power Conductors and Cables: Power circuits and raceway to powered blue light telephones shall comply with relevant electrical sections of these specifications.

C. Grounding Conductors and Cables: Copper, stranded, No. 16 AWG. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Wiring Method:

1. Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters.
 - a. Install plenum cable in environmental air spaces, including plenum ceilings.
 - b. Conceal raceway and cables except in unfinished spaces.
2. Cable Trays: Comply with requirements in Section 260536 "Cable Trays for Electrical Systems" and Section 271500 "Communications Horizontal Cabling."
3. Conduit and Boxes: Comply with requirements in Section 260533 "Raceway and Boxes for Electrical Systems." [**Flexible metal conduit shall not be used.**]
 - a. Outlet boxes shall be no smaller than **2 inches (50 mm)** wide, **3 inches (75 mm)** high, and **2-1/2 inches (64 mm)** deep.

B. Install cables without damaging conductors, shield, or jacket.

C. Do not bend cables, while handling or installing, to radii smaller than as recommended by manufacturer.

D. Pull cables without exceeding cable manufacturer's recommended pulling tensions.

1. Pull cables simultaneously if more than one is being installed in same raceway.
2. Use pulling compound or lubricant if necessary. Use compounds that will not damage conductor or insulation.
3. Use pulling means, including fish tape, cable, rope, and basket-weave wire or cable grips, that will not damage media or raceway.

E. Install exposed raceways and cables parallel and perpendicular to surfaces or exposed structural members, and follow surface contours. Secure and support cables by straps, staples, or similar fittings designed and installed so as not to damage cables. Secure cable at intervals not exceeding **30 inches (760 mm)** and not more than **6 inches (150 mm)** from cabinets, boxes, or fittings.

F. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

G. Separation of Wires: Provide separation as recommended by equipment manufacturer for other conductors.

H. Splices, Taps, and Terminations: Make splices, taps, and terminations on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures. Install terminal cabinets where there are splices, taps, or terminations for eight or more conductors.

- I. Identification of Conductors and Cables: Comply with requirements in Section 271500 "Communications Horizontal Cabling" for cable administration, cable schedule, and cable and wire identification.
- J. Equipment Identification:
 - 1. Comply with requirements in Section 260553 "Identification for Electrical Systems" for equipment labels and signs and labeling installation requirements.
 - 2. Label stations, controls, and indications using approved consistent nomenclature.

3.2 EXISTING SYSTEMS

Retain this article if equipment being specified is to connect with existing equipment.

- A. Examine existing systems for proper operation, compatibility with new equipment, and deficiencies. If discrepancies or impairments to successful connection and operation of interconnected equipment are found, report them and do not proceed with installation until directed. Schedule existing systems' examination so there is reasonable time to resolve problems without delaying construction.

3.3 GROUNDING

- A. Ground cable shields and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other signal impairments.
- B. Signal Ground Terminal: Locate at main equipment cabinet. Isolate from power system and equipment grounding except at connection to main building ground bus.
- C. Grounding Provisions: Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.4 FIELD QUALITY CONTROL

Retain first paragraph below to require Contractor to perform tests and inspections.

- A. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

- 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist Contractor in testing.

Retain first paragraph below to describe tests and inspections to be performed.

- B. Tests and Inspections:

1. Schedule tests a minimum of seven days in advance.
 2. Report: Submit a written record of test results.
 3. Operational Test: Perform an operational system test and demonstrate proper operations of each installation.
- C. Inspection: Verify that units and controls are properly labeled and interconnecting wires and terminals are identified.
- D. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain telephone system.
1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 273200

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SECTION 274111 - VIDEO SURVEILLANCE AND ENVIRONMENTAL MONITORING SYSTEM (VSEMS)

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Consultant to provide responsibility matrix on drawings delineating scope of work for all parties.

Edit to suit Project.

- A. The Contractor shall provide a physically complete and fully functional Video Surveillance and Environmental Monitoring System (VSEMS) for monitoring of the DEM Intermediate Distribution Frame (IDF) rooms, the DEM MDF and other DEM Telecommunications as specified herein and detailed on the Contract Drawings. Provide all labor and products required for installation of the equipment. Programming shall be performed by Denver International Airport (DEM) representatives. Test and checkout of the VSEMS shall be done jointly with the Contractor and DEM personnel. Refer to the Contract Drawings including the responsibility matrix for further detail and delineation of the scope of work. Coordinate all work by DEM staff through the DEM Project Manager. Work of this Section Includes:

1. Monitoring Appliance.
2. Camera Pod.
3. Temperature Sensor.
4. Fluid Detector.
5. Cabling.
6. Software and License.

- B. The VSEMS communicates over the DEM Local Area Network on a dedicated Virtual Local Area Network (VLAN).
- C. Where the work of several trades is involved, coordinate all related work to provide each system complete and in proper operating order.
- D. Cooperate with all others involved in the Project, with due regard to their work, to promote rapid completion of the entire Project.
- E. Local conditions: The Contractor shall thoroughly familiarize itself with the work as well as the local conditions under which the work is to be performed. Schedule work with regard to seasons, weather, climatic conditions, and all other local conditions, which may affect the progress and quality of the Work.
- F. Provide system documentation, submittals and warranty support.
- G. Comply with all applicable codes, ordinances, regulations, and other legal requirements of public authorities that bear on installation and performance of Work.
- H. The Work described in this Section includes engineering, design, labor, materials, equipment, installation and services necessary for physically complete and functional system. Materials, equipment, appurtenances, or labor not specifically mentioned in this specification, or not shown on the Contract Drawings, but required for proper installation, performance, and operation of the equipment or systems, shall be provided by the Contractor.
- I. The Work shown in the Contract Drawings is diagrammatic in nature and the Contractor is responsible for determining the final equipment locations, arrangements, and installation to meet site-specific requirements.
- J. Related Sections:
 - 1. Section 260400 "Basic Electrical Requirements".
 - 2. Section 270526 "Grounding and Bonding for Telecommunications Systems".
 - 3. Section 270528 "Pathways for Communications Systems".
 - 4. Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling".
 - 5. Section 271100 "Communications Equipment Room Fittings".
 - 6. Section 271300 "Communications Backbone Cabling".

Verify requirements for as-built plans with DEM Project Manager.

- K. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.3 SCOPE OF WORK

Retain terms that remain after this Section has been edited for a Project.

- A. The Contractor shall provide a VSEMS for the video and environmental monitoring of the Intermediate Distribution Frame (IDF) rooms, the DEM MDF and other communications spaces as detailed on the Contract Drawings. The system shall consist of video and environmental monitoring appliances, software and all ancillary equipment and devices for a physically complete and fully functional system.
- B. Ethernet communications between the monitoring appliance and the existing server shall be via an Ethernet edge switch, provided by others, located within an equipment rack within each communications space. Refer to the Contract Drawings for the location of each Ethernet edge switch.
- C. The Contractor shall install a monitoring appliance with all accessories within each TR at a location as field coordinated with the Owner and Engineer. The monitoring device shall be connected to the Ethernet edge switch via a CAT 6 cable provided by the Premise Wiring and Communications (PWCS) Contractor. The Contractor shall provide all required power supplies and mounting hardware for installation of the monitoring appliance.
- D. The TR appliance shall provide monitoring of the following:
 - 1. Video.
 - 2. Ambient Room Temperature.
 - 3. Fluid Detection.
- E. System shall consist of the following:
 - 1. Monitoring Appliance.
 - 2. Camera Pod.
 - 3. Camera Lens - Varifocal.
 - 4. Temperature Sensor.
 - 5. Fluid Detector.
 - 6. Category 5e Jumper Cable, by PWCS Contractor.
 - 7. Ethernet Switch, by PWCS Contractor.
 - 8. Cable, Wire and Labels.

1.4 REFERENCE STANDARDS

- A. General: The latest version of the following codes and standards shall be applicable.
- B. Code of Federal Regulations (CFR).
 - 1. 47 CFR 15 et seq: Radio Frequency Devices
- C. Institute of Electrical and Electronics Engineers (IEEE):
 - 1. IEEE C2: National Electrical Safety Code.
 - 2. IEEE 142: IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems.
 - 3. IEEE C62.41-1991: Recommended Practice on Surge Voltages in Low-Voltage

- AC Power Circuits.
4. IEEE 802.3: Information Technology - Local and Metropolitan Area Networks - Part 3; Carrier Sense with Collision Detection (CSMA/CD) Access Methods and Physical Layer Specification.
 5. IEEE 802.3u: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/s Operation
 6. IEEE 802.3x: Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications:
 - a. Specification for 802.3 Full Duplex Operation.
- D. National Fire Protection Association (NFPA).
1. NFPA 70: National Electrical Code (NEC).
- E. Telecommunications Industry Association/Electronics Industry Association (TIA/EIA).
1. EIA-170: Electrical Performance Standards - Monochrome Television Studio Facilities.
 2. EIA-310-D: Cabinets, Racks, Panels, and Associated Equipment
 3. TIA/EIA-568-B: Commercial Building Telecommunications Cabling Standard

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEM PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. General: Comply with requirements of Section 013300 "Submittal Procedures".
- B. Product Data: For each type of product.
1. Submit catalog cut sheets, technical data sheets, manufacturer's specifications and/or diagrams necessary to illustrate a product, material or system for some portion of the work. Product data literature is required on all items of material and equipment and should be clearly marked; identifying specific items proposed with a reference to the specification requirement(s) the item is being submitted for.
 2. Product data shall include adequate descriptive literature and catalog cut sheets required for the DEM Project Manager to ascertain that the proposed equipment and materials comply with Specifications requirements.
 3. Include data substantiating that materials comply with requirements.
- C. Shop Drawings:
1. The shop drawings shall be approved by the DEM Project Manager prior to system installation.
 2. Floor plans detailing all devices, conduit and raceway systems.
 3. Equipment room layouts to scale including equipment cabinet elevations.
 4. Point-to-point wiring diagrams.

1.6 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- A. Qualification Data: For installer.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- B. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For video surveillance and environmental monitoring systems to include in emergency, operation, and maintenance manuals.

- 1. Include operating instructions, and maintenance and repair procedures. Procedures shall include shop manuals and schematic drawings to allow repair of equipment.

Verify requirements for as-built plans with DEM Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Contractor shall maintain on site accurate as-built drawings indicating dimensioned locations of constructed raceway, box and device locations. Any modifications to work depicted on the Engineered shop drawings shall be noted. Documents shall be updated daily and shall at all times be available for DEM review.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEM Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. The Contractor shall provide spare equipment as indicated in this Section.
- C. Spare parts shall be delivered in factory sealed cartons or packages with clearly marked model, part and serial numbers that match the invoice, packing slip and indication on packing carton, packages or container.
- D. Spare equipment and parts shall be new and unused and unopened.

- E. Spare equipment and parts shall be covered under the manufacturers 1 year warranty.
- F. Prior to delivery to the Owner, spare parts shall be stored in a controlled temperature and humidity environmental that meets the manufacturers recommendations.

Edit to suit project. Provide 5% spare for all equipment, minimum qty 1 per equipment type.

- G. Provide the following spare equipment:
 - 1. One (1) Netbotz 450 (1U Rack Mount Form Factor)

1.9 QUALITY ASSURANCE

- A. Contractor shall be fully responsible for daily quality control of all system installation, coordination with trades, and coordination with DEM Maintenance and Engineering.

1.10 DELIVERY, STORAGE AND HANDLING

- A. Deliver products to site under provisions of Division 1.
- B. Store and protect products under provisions of Division 1.

1.11 WARRANTY

Coordinate warranty requirements with DEM Project Manager.

- A. All components, parts and assemblies provided by the Contractor shall be guaranteed against defects in materials and workmanship for a period of 24 months following acceptance.
- B. Provide 21-month Bridge software and support agreement from the manufacturer for all devices and software licenses provided. Submit warranty per Division 1 requirements.
- C. Warranty service shall be provided by a trained specialist of the equipment manufacturer, who shall be based in a fully staffed, fully stocked (replacement parts and test equipment) office, located within 50 miles of the site.

Retain article below if required for Project. Coordinate requirements with DEM Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Each DEM IDF and the Main Distribution Frame Room (MDF) shall be equipped with a monitoring system that provides environmental and video monitoring of each space.
- B. Monitoring equipment deployed as part of the project shall be networked together over the DEM local area network.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.2 MANUFACTURERS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

Edit equipment to suit Project.

- A. **Manufacturers: Subject to compliance with requirements, provide products by the following:**
 - 1. **Base Station:**
 - a. Netbotz 450 rack mounted base station: Netbotz NBRK0451.
 - 1) Remote camera, including hardware for mounting camera to the cable ladder, shall meet the following requirements:
 - a) Resolution: 640 x 480.
 - b) Frame Rates: Up to 20 FPS.
 - c) Design Selection: Netbotz Camera Pod 160 #NBPD0160.
 - b. **<Insert manufacturer's name>.**
 - c. or approved equal.
 - 2. **Sensors:**
 - a. Fluid Detector: NBES0301.
 - b. Temperature Sensor: AP9335T.
 - c. **<Insert manufacturer's name>.**
 - d. or approved equal.
 - 3. **Software:**
 - a. Provide One (1) software license for each appliance, Model No. NBSP0131. Programming to be performed by others.

- b. Provide ISX Central Surveillance licenses, Model No. NBSV1005. Programming to be performed by others.
 - c. **<Insert manufacturer's name>**.
 - d. or approved equal.
- B. Provide connecting cables and mounting hardware to deploy and connect sensors to the base station.
- C. Source Limitations: Obtain system from single source from single manufacturer.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- E. Comply with NFPA 70.

PART 3 - EXECUTION

3.1 GENERAL

- A. Installation shall be supervised and tested by a representative of the manufacturer of the system equipment. The Work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly factory trained and qualified for this Work.
- B. Programming of the system headend and appliance settings shall be by DEM personnel.
- C. Raceways: Raceways shall be installed in accordance with Division 26 and as augmented by applicable Division 27 sections.

3.2 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEM Project Manager.

- A. Testing and Reports:
 - 1. The Contractor shall provide all personnel, equipment, instrumentation, and supplies necessary to perform all testing.
 - 2. Design Engineer and Airport representatives will witness all field tests.
 - 3. When installation is complete, the system shall be tested by the Contractor and DEM representatives. A representative of the installing Contractor shall submit a written report of the findings to the DEM Project Manager.
 - 4. Report shall consist of a complete listing of every device and feature, the date it was tested and by whom, the results, and the date retested (if failure occurred during any previous tests). The final test reports shall indicate that every device tested successfully.

5. Submit two (2) typed copies of the test reports in a neatly bound folder to the Owner's Representative for approval.
6. Also submit electronic copies of test reports in pdf format.
7. Failure to comply will result in a delay of final testing and acceptance.

B. The field testing shall as a minimum include:

1. Verification that the data transmission media and any signal or control cabling has been installed, tested, and approved.
2. Verification that the new equipment is fully functional.
3. Operation of all electrical, mechanical, and software controls and verification that the control performs the designed function.
4. Verification that all other ancillary equipment is functioning properly.

3.3 STARTUP SERVICE

A. Engage a factory-authorized service representative to assist Contractor and perform startup service.

1. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
2. Complete installation and startup checks according to manufacturer's written instructions.

3.4 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the video surveillance and environmental monitoring system (VSEMS) and equipment. Refer to Section 017900 "Demonstration and Training."

1. Schedule training with Owner, through DEM Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 274111

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SECTION 274133 - MASTER ANTENNA TELEVISION SYSTEM

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

- 1. Headend Description.
- 2. Optical Distribution.
- 3. IDF Room Nodes.
- 4. RF Distribution

- B. Related Sections:

Retain Sections in subparagraphs below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

- 1. Section 271300 "Communications Backbone Cabling" for coaxial, UTP, and fiber-optic cables and connectors.
- 2. Section 271500 "Communications Horizontal Cabling" for coaxial, UTP, and fiber-optic cables and connectors.
- 3. Section 282300 "Video Surveillance" for cameras, monitors, computers, and cabling for video surveillance systems.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- C. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. dBm: Decibels relative to one milliwatt (optical).
- B. dBmV: Decibels relative to 1 mV across 75 ohms. Zero dBmV is defined as 1 mV across 75 ohms. $\text{dBmV} = 20 \log_{10}(V_1/V_2)$ where V_1 is the measurement of voltage at a point having identical impedance to V_2 (0.001 V across 75 ohms).
- C. EDFA: Erbium Doped Fiber Amplifier.
- D. Headend: The central equipment for the DEN TV system, where incoming signals are amplified, converted, processed, and combined into a common cable along with any locally originated television signals, for transmission to user-interface points.
- E. L-Band: Frequencies down-converted at satellite antennas and fed to satellite receivers.
- F. MHz: Megahertz.
- G. Nm: Nanometers (wavelength of light).
- H. Optical Node: An appliance, generally located in DEN IDF rooms that accepts an optical input from the DEN TV Headend and provides a broadband radio frequency output to feed television receivers.
- I. QAM: Quadrature Amplitude Modulation (Cable TV Signal Format).

1.4 SYSTEM DESCRIPTION

Revise this article if locally originated television programs or CATV signals are to be added to headend.

- A. The DEN TV system is a two-tiered system fed from Dish Network equipment at the north terminal. The lower tier is a bulk, standard definition channel lineup to serve City and other non-tenant spaces such as conference rooms, break rooms and private offices. The second tier is a four channel L-band QAM feed which is run through the system above the lower tier channel lineup. Tenants such as bars and restaurants will utilize specialized satellite receivers at their television receivers to tune channels in this upper tier. High pass filters are installed on each tenant drop to prevent tenants from receiving the lower tier channels.

Retain one or more of four subparagraphs below based on type of system selected above. Revise to specify off-air signal reception and direct broadcast satellite service.

1. The headend for the system utilizes an optical transmitter that accepts the

- 50-860 MHz radio frequency output from the Dish Network equipment and from modulators that support locally originated channels. Operating wavelength from the transmitter is 1550nm.
2. Two Erbium Doped Fiber Amplifiers (EDFA) are used at the headend to amplify the forward television signal. Each EDFA provides eight (8) optical outputs at +21dBm.
 3. Outputs from the EDFA amplifiers are routed over APC terminated single mode fiber strands to 1 x 16 optical dividing networks located at the center core of each concourse, east and west side of the terminal and at other locations throughout the campus. These dividing networks attenuate the optical signal by 14.3 dB providing outputs for up to sixteen (16) optical nodes.
 4. IDF rooms shall be provided with optical nodes that accept an optical signal from the dividing networks. Optical input level for the nodes shall be attenuated to a level of 0dBm using a male-to-female fixed optical attenuator. The nodes will display a green LED bar on the center of the built-in optical power meter with red bars for power levels above and below 0dBm. Nodes are reverse path capable, however reverse path is not being used on the DEN TV system.
 5. Gain and slope controls on the optical nodes shall be adjusted to provide a sloped output of +37dBmV at 54mHz and 45dBmV at 860mHz.
 6. Optical nodes shall be connected through an 8dB fixed attenuator to the input of a sixteen-way splitter. At locations requiring more than sixteen coaxial drops the 8dB attenuator shall be replaced with a four-way splitter (also 8dB loss) which in turn feeds up to four sixteen-way splitters.
 7. Coaxial cable drops from the IDF splitters shall be either Quad shielded RG-6 (Circuit type TV06) or RG-11 (Circuit type TV11) depending on drop length. Tamper resistant 75-ohm terminators shall be installed on all unused splitter ports.
- B. Hardware Requirements: Optical dividing networks shall be one rack unit high and installed in existing 19-inch EIA racks at fiber aggregation points for each facility. IDF room optical nodes and splitters shall be wall mounted to plywood walls in the IDF room.

1.5 PERFORMANCE REQUIREMENTS

- A. Minimum acceptable performance of distribution system at all user-interface points shall be as follows:
1. RF Video-Carrier Level: Between 3 and 12 dBmV.
 2. Relative Video-Carrier Level: Within 3 dB to adjacent channel.
 3. Carrier Level Stability, Short Term: Level shall not change more than 0.5 dB during a 60-minute period.
 4. Carrier Level Stability, Long Term: Level shall not change more than 2 dB during a 24-hour period.
 5. Channel Frequency Response: Across any 6-MHz channel in the 54- to 860-MHz frequency range, referenced to video; signal amplitude shall be plus or minus 1 dB, maximum.
 6. Carrier-to-Noise Ratio: 45 dB or more.
 7. RF Visual Signal-to-Noise Ratio: 43 dB or more.

8. Antenna Combiner Insertion Loss: 40 dB maximum.
9. Signal Power Splitter and Isolation Tap Return Loss: 17 dB maximum.
10. Cable Connectors Attenuation: Less than 0.1 dB.

Tests in subparagraphs below require more expensive equipment than tests in subparagraphs above. Retain tests below for high-fidelity or high-definition systems.

11. Cross Modulation: Less than minus 50 dB.
12. Carrier-to-Echo Ratio: More than 40 dB.
13. Composite Triple Beat: Less than minus 53 dB.
14. Second Order Beat: Less than minus 60 dB.
15. Terminal Isolation from Television to Television: 25 dB, minimum.
16. Terminal Isolation between Television and FM: 35 dB, minimum.
17. Hum Modulation: 2 percent, maximum.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.6 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings: For headend and distribution system. Include plans, elevations, sections, details, and attachments to other work.
 1. Show fabrication and installation details for television equipment.
 2. Functional Block Diagram: Show single-line interconnections between components for headend and distribution system to user-interface points. Show cable types and sizes.

Retain first paragraph below if appearance and texture of device plate are important.

Delete sample requirement in paragraph below if project is of very limited scope, and deletion is approved by DEN Project Manager. Coordinate sample requirements with DEN Project Manager.

- C. Samples: Full size for each outlet device plate in required colors and textures.

Paragraph below is defined in Section 013300 "Submittal Procedures" as a "Delegated-Design Submittal." Retain if design responsibilities have been delegated to Contractor. Delete below if signal attenuation budget and losses are indicated on Drawings or if signal strength to user interfaces is indicated.

- D. Design Calculations: Calculate signal attenuation budget and show calculated line and equipment losses for the system based on the functional block diagram, to show that proposed system layout can be expected to perform up to specification.

1.7 INFORMATIONAL SUBMITTALS

Retain first paragraph below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

Coordinate requirements for coordination drawings with DEN Project Manager.

- A. Coordination Drawings: Include dimensioned plan and elevation views of components and enclosures. Show access and workspace requirements.
- B. Equipment List: Include each piece of equipment and include model number, manufacturer, serial number, location, and date of original installation. Insert testing record of each piece of adjustable equipment, listing name of person testing, date of test, and description of as-left set points.
- C. Field quality-control reports.

1.8 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For headend and distribution system to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1.9 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.10 PROJECT CONDITIONS

- A. Environmental Limitations: System components shall be equipped and rated for the environments in which they are installed.

Coordinate space conditioning requirements with mechanical engineer.

- B. Environmental Conditions: Capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability:

Revise to suit Project and specify features required to provide satisfactory service.

Coordinate requirements with DEN Project Manager.

1. Interior, Controlled Environment: System components, except central-station control unit, installed in interior environments shall be rated for continuous operation in ambient conditions of [36 to 122 deg F (2 to 50 deg C)] dry bulb and 20 to 90 percent relative humidity, noncondensing.
2. Interior, Uncontrolled Environment: System components installed in non- interior environments shall be rated for continuous operation in ambient conditions of [0 to 122 deg F (minus 18 to plus 50 deg C)] dry bulb and 20 to 90 percent relative humidity, noncondensing.
3. Exterior Environment: System components installed in locations exposed to weather shall be rated for continuous operation in ambient conditions of minus 30 to plus 122 deg F (minus 34 to plus 50 deg C)] dry bulb and 20 to 90 percent relative humidity, condensing. Rate for continuous operation when exposed to rain as specified in NEMA 250, winds up to 115 mph with gust factor of 1.3, [and snow cover up to 24 inches (610 mm) thick].
4. Altitude: 5,500 feet (1677 m) above sea level.

1.11 COORDINATION

- A. Coordinate size and location of raceway system and provisions for electrical power to equipment specified in this Section.
- B. Coordinate all work with existing DEN Systems.

1.12 MAINTENANCE SERVICE

Consider deleting this article for light or residential use; usually retain for critical units.

Review requirements with DEN Project Manager.

- A. Initial Maintenance Service: Beginning at Substantial Completion, provide twelve (12) months full maintenance by skilled employees of MATV system Installer. Include quarterly adjusting as required for optimum system performance. Provide parts and supplies the same as those used in the manufacture and installation of original equipment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

B. CONSTRUCTION WASTE MANAGEMENT

1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 OPTICAL DIVIDING NETWORK

- A. 1-input, x 16-output 19-inch rack mount.
- B. Connector type: SC/APC.
- C. Maximum Insertion Loss: 14.8dB 1310nm & 1550nm.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. See Section 016000 "Product Requirements".

- D. Basis of Design: Blonder Tongue Laboratories FOC-116U-SA.

2.2 OPTICAL ATTENUATORS

- A. Type: SC/APC Male to SC/APC Female.

Coordinate first paragraph below with the Drawings. Clear descriptions of signal sources used and programs distributed are critical to obtaining meaningful Contractor response to MATV system requirements.

- B. Attenuation: Fixed values from 1dB to 25dB in 1dB increments. Select value to provide 0dBm input to optical node
- C. Minimum Return Loss: 55dB.

2.3 OPTICAL NODES

- A. Forward Bandpass: 54-870mHz.
- B. Reverse Bandpass: 5-42 mHz.

Coordinate paragraph below with Drawings.

- C. Output Level: +37dBmV at 54mHz, +45dBmV at 870mHz.
- D. Composite Triple Beat: -72dB minimum.
- E. Composite Second Order Distortion: -65dBmv.
- F. Carrier to Noise: 53dB.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. See Section 016000 "Product Requirements".

- G. Basis of Design: ATX Networks QFMN870A-45G2W.

2.4 16-WAY SPLITTERS

- A. Bandpass: 5-1000mHz.
- B. Insertion Loss: 15dB maximum.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. See Section 016000 "Product Requirements".

- C. Basis of Design: Channel Vision HS-16.

2.5 TAMPER RESISTANT TERMINATORS

- A. Terminator Resistance: 75-ohm.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. See Section 016000 "Product Requirements".

- B. Basis of Design: Arrris/Regal

2.6 FIBER JUMPERS

- A. Fiber Type: Single Mode 9.5/125 single strand.
- B. Connector Type: SC/APC to FC/APC or other APC combination.

PART 3 - EXECUTION

3.1 OPTICAL LEVELS

- A. Measure and record 1550nm optical level at input to any new optical dividing network, at output of dividing network and at input to each optical node.
- B. Install correct value SC/APC optical attenuator to present exactly 0dBm to node forward path input.

3.2 RF LEVEL ADJUSTMENT

- A. Adjust gain and slope controls on each optical node to provide +37dBmV output at 54mHz and +45dBmV output at 870 mHz or on the highest visual carrier.

Coordinate paragraph below with Drawings and verify that Drawings properly indicate mounting heights.

- B. TERMINATORS
- C. Insure that tamper resistant terminators are installed and tightened on all unused splitter ports.

3.3 FIELD QUALITY CONTROL

Retain first paragraph below to require Contractor to perform tests and inspections.

- A. Distribution System Acceptance Tests:
1. Field-Strength Instrument: Rated for minus 40-dBmV measuring sensitivity and a frequency range of 54 to 1000 MHz, minimum. Provide documentation of recent calibration against recognized standards.
 2. Signal Level and Picture Quality: Use a field-strength meter or spectrum analyzer, and a standard television receiver to measure signal levels and check picture quality at **[100 percent of]** user-interface outlets.
 - a. Test the signal strength in dBmV at 55[, **151, 547,**] and 750 MHz.
 - b. Minimum acceptable signal level is +3 dBmV .
 - c. Maximum acceptable signal level over the entire bandwidth is 15 dBmV.
 - d. Television receiver shall show no evidence of cross-channel intermodulation, ghost images, or beat interference.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 274133

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SECTION 274219 - MULTI-USER FLIGHT INFORMATION SYSTEM (MUFIDS)

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Scope of Work provides installation of new flight information arrival and departure displays in locations as indicated on the Project Drawings.
- B. The extension of the MUFIDS systems will be an extension of the existing airport wide Multi User Flight Information Display System. The existing DEN MUFIDS system is based upon display software provided by SITA Com-Net™. All hardware and software for the extension of the MUFIDS expansion will be provided and installed as part of this Project. To maintain system compatibility and functionality with the existing MUFIDS system, software, software configuration, computer hardware, and all equipment and vendor specific equipment shall be provided by SITA Com-Net. MUFIDS signal carriage shall be over the DEN PWCS and the DEN Local Area Network.
- C. Related Sections:
 - 1. Section 272100 "Local Area Networks (LANs)".
 - 2. Section 260400 "Basic Electrical Requirements".
 - 3. Section 270526 "Grounding and Bonding for Telecommunications Systems".
 - 4. Section 270528 "Pathways for Communications Systems".
 - 5. Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling".

6. Section 271100 "Communications Equipment Room Fittings".
7. Section 271300 "Communications Backbone Cabling".
8. Section 271500 "Communications Horizontal Cabling".

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- D. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 SCOPE OF WORK

Edit to suit Project.

- A. MUFIDS System Expansion: The MUFIDS system expansion work defined under this project scope shall require provision of MUFIDS equipment, coordination with DEN and other trades, and installation tasks including, but not limited to:
 1. Coordinate with DEN IT, and the MUFIDS Design Team for equipment selections, installations, scheduling and related topics.
 2. Coordinate the detail design of mounting attachments and millwork fit with millwork trades, DEN IT, and the MUFIDS Design Team.
 3. Coordinate quantities, loads, outlet types and placement detail at MUFIDS equipment locations for communications (PWCS) and electrical power.

Note to Designer: DEN will normally purchase and pre-configure MUFIDS monitors and their associated OPS slot mounted computers. These will be made available to the Contractor for installation. The Contractor is responsible for all mounts, brackets and other hardware to successfully mount these monitors. Costs for the monitors and computers are normally encumbered to the project.

- B. Install MUFIDS equipment sets at display locations. Typical MUFIDS display types and locations planned for this project include:
 1. MUFIDS Video Display Banks: Arrival and Departure flight schedule information displays for the project as indicated on the drawings. Contents shall be displayed on multiple video flat screens, configured to operate as a single, continuous display using 46-inch LCD video screens.

Note to Designer: On projects that expand the terminal or concourses no action is required for display of emergency information on MUFIDS monitors as the fire alarm interface is existing. On a completely new facility a supplemental fire alarm interface may be required

- C. The MUFIDS system is interfaced to the Simplex Grinnell fire alarm system at room 45B08 at the terminal and at the center core public address room at each concourse. During an emergency one of eight fire alarm relay contacts closes at individual buildings or at all buildings. The MUFIDS system senses the contact closure and transmits the associated textual emergency message to all MUFIDS monitors in the selected building(s). When the emergency event is over the fire alarm contact opens and the MUFIDS displays return to normal operation.

Note to Designer: If video advertising is part of the project, DEN may elect to have the video advertising

company provide the emergency communications system interface to the MUFIDS system at the advertising company's expense.

- D. Video advertising display locations are equipped with both a Clear Channel advertising computer and a MUFIDS Direct Digital Control computer. A Lantronix Ethernet to serial server drives a DVI video switch to take the display away from the advertising computer and connect it to the MUFIDS computer. The advertising displays then display the emergency message for the duration of the event. When the event has passed the switch returns the display to the advertising computer.

1.4 REFERENCE STANDARDS

- A. Comply with the requirements of the reference standards and practices noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents. A listing of applicable reference standards is contained in Section 014225 "Referenced Standards".
 - 1. National Electrical Code.
 - 2. Conform to requirements of NFPA applicable sections.
 - 3. BICSI (Building Industry Consulting Service International, Inc.).

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product. Provide product cutsheets indicating each type of equipment, accessories and associated materials planned for installation.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Shop drawings of MUFIDS equipment showing layout, mounting hardware, accessories, and dimensions of all components and accessories. For displays intended for mounting inside millwork or casework designed and provided by others, the Contractor shall coordinate with those providers to ensure proper fit and functionality.

Retain "Wiring Diagrams" Subparagraph below if equipment includes wiring.

- 2. Wiring Diagrams: For power, signal, and control wiring, indicating component connection between equipment.

1.6 INFORMATIONAL SUBMITTALS

- A. Network interfaces including final and coordinated IP addresses coordinated with the DEN Technologies network staff.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- B. Qualification Data: For installer.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For multi-user flight informatin system (MUFIDS) to include in emergency, operation, and maintenance manuals.
 - 1. Include operating instructions, and maintenance and repair procedures. Procedures shall include shop manuals and schematic drawings to allow repair of equipment.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 - 1. Contractor shall maintain on site accurate as-built drawings indicating dimensioned locations of constructed raceway, box and device locations. Any modifications to work depicted on the Engineered shop drawings shall be noted. Documents shall be updated daily and shall at all times be available for DEN review.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1.9 QUALITY ASSURANCE

- A. Contractor shall be fully responsible for daily quality control of all system installation, coordination with trades, and coordination with DEN Maintenance and Engineering.
- B. Installer: A qualified company with personnel specializing in installation of electronic display equipment.
 - 1. Related Works and Project Coordination Requirements:

- a. Coordinate the Local Area Network transport requirements, VLAN requirements and implementation strategy with DEN technologies network staff.
 - b. As specified in Section 270500 "Basic Telecommunication Requirements" and Section 271000 "Premise Wiring Distribution System".
 - c. Coordinate the work of this Section with that of other Divisions as required to ensure that the entire Work of this project will be carried out in an orderly, complete and coordinated fashion.
2. Architectural Coordination:
- a. Coordinate the general installation of 46" video displays, displays mounting systems, Ethernet switch and power and communications cabling in environmental enclosures with architectural drawings. Develop shop drawings as required for approval by the Architect, DEN Project Manager and the Engineer.

1.10 DELIVERY, STORAGE AND HANDLING

- A. Inspect all products prior to installation. Any defects or damage shall be reported to DEN representative prior to transport of equipment to installation site.
- B. Deliver products to site under provisions of Division 1.
- C. Store and protect products under provisions of Division 1.

1.11 WARRANTY

- A. All installation shall be guaranteed against defects in workmanship for a period of 12 months following acceptance. Submit warranty per Division 1 requirements.
- B. Warranty service shall be provided by a trained specialist, experienced in installation of electronic equipment.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.12 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

Consultant shall coordinate with the DEN Project Manager to arrange a meeting with the DEN Technologies Passenger Services group during the design process to ensure that no changes have been made to standard equipment.

2.1 GENERAL

- A. All products shall be in new and undamaged condition, prior to acceptance by the Airport.
- B. Products shall be shipped, stored and installed in full compliance with the manufacturer's recommendations.

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.2 SOFTWARE

- A. The existing DEN MUFIDS system is based upon display software provided by SITA Com-Net™. This MUFIDS systems expansion shall utilize the existing product, configured to accommodate the additional displays being deployed as part of this project
- B. The Contractor shall carry in the price all work by SITA COM-Net to manipulate and configure the existing software and assign pages to the new display devices to meet the operational intent based on the number of displays being deployed including:
 - 1. Visual Paging.
 - 2. Display Windows in Hours.
 - 3. Display content.
 - 4. Advertising / other content.

2.3 46-INCH LCD VIDEO DISPLAYS

- A. The following video display types planned for this project shall be provisioned with 46-inch LCD Flat Screen units:
 - 1. MUFIDS Video Banks posting Arrival and Departure information.
- B. 46-inch LED backlit LCD video screens shall meet the following minimal specifications:
 - 1. Viewable image size: 46-inches.
 - 2. Pixel pitch: .53mm.
 - 3. 47 pixels per inch.
 - 4. Contrast Ratio: 3500:1.
 - 5. Brightness: 700 cd/m2 Maximum.
 - 6. Viewing angle: 178° vertical and horizontal.
 - 7. Response Time: 8ms.
 - 8. Refresh Rate: 60Hz.
 - 9. Aspect Ratio: 16: 9.
 - 10. 1Design Selection: DEN Standard NEC463 with NEC OPS-PCAFQ-PH plug-in Computer.

- C. 40-inch Podium Backwall LED backlit LCD video screens shall meet the following minimal specifications:
1. Viewable image size: 40-inches.
 2. Pixel pitch: .53mm.
 3. 47 pixels per inch.
 4. Contrast Ratio: 3500:1.
 5. Brightness: 700 cd/m2 Maximum.
 6. Viewing angle 178° vertical and horizontal.
 7. Response Time: 8ms.
 8. Refresh Rate: 60Hz.
 9. Aspect Ratio: 16 : 9.
 10. Design Selection: DEN Standard NEC403 with NEC OPS-PCAFQ-PH plug-in Computer.
- D. The Contractor shall coordinate with millwork, power and communication trades to assure proper fit and functionality of the display equipment, which includes, but is not limited to:
1. Proper structural mounting of video display.
 2. Proper power interface.
 3. Proper communication interface.
- E. Built In PC for NEC LCD Video Displays:
1. Single Board Computer (SBC) –NEC Compatible.
 2. 1.6 GHz Dual Core ATOM processor.
 3. RAM 1 GB DDR2.
 4. HDD 120GB, 2.5-inch.
 5. DVI-I Output.
- F. 46-inch video displays shall be provided with the following accessories:
1. Environmental Housing(s) if in an unconditioned space.
 2. VESA compliant flat screen display tilt mounting brackets, Single and dual screen mount attachments as indicated in the Project Drawings.
 3. Ceiling mount and structural support piping.
 4. CAT 6 Patch cables.
 5. Power cords.
- G. Design Selection:
1. NEC-463 with NEC OPS-PCAFQ-PH plug-in Computer.
- H. Designers are instructed to meet with the DEN Technologies Passenger Services group during the design process to ensure that no changes have been made to standard equipment.

2.4 MOUNTS AND ACCESSORIES

- A. Provide adjustable VESA 300 x 300mm pattern compliant mounts for all displays that meet the following criteria:
1. Orientation: Portrait.
 2. Extension: Up to 10.7".
 3. Stud Pattern: 16".
 4. Max Weight: 150 LBS.
 5. Plumb Adjustment: to 2.5 Deg.
 6. Design Selection: Chief Manufacturing LSMVPU, or approved equal.
- B. Displays and mounting brackets will be incorporated into an environmental enclosure specified by the Architect. Contractor shall be required to work with the DEN Project Manager to coordinate the placement of displays, mounts electronic equipment (Ethernet switch) and the routing of to coordinate cables in the enclosure.

PART 3 - EXECUTION

3.1 PRE-WORK MEETING

- A. The Contractor shall coordinate and arrange a pre-work meeting with the DEN Project Manager, and DEN Technical Maintenance one (1) week in advance of the beginning of any Work. The DEN Project Manager shall review the Contractor's construction, phasing, implementation and testing plans and schedule.
- B. Meeting Minutes: Meeting minutes shall be accurately recorded by the contractor and distributed within five (5) working days after the meeting.

3.2 GENERAL

- A. Installation shall be supervised and tested by a representative of the installing contractor.
- B. Displays and mounting brackets will be incorporated into an environmental enclosure specified by the Architect. Contractor shall be required to work with the DEN Project Manager and the Architect to coordinate the placement of displays, mounts, electronic equipment (Ethernet switches, etc.) and to coordinate the routing of cables in the enclosure.

3.3 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing and Reports:
1. The Contractor shall provide all personnel, equipment, instrumentation, and

- supplies necessary to perform all inspections, and testing.
2. Design Engineer and Airport representatives will witness all field tests.
 3. When installation is complete, the system shall be tested by the Contractor. A representative of the installing Contractor shall submit a written report of the findings to the DEN Project Manager.
 4. The MUFIDS contractor shall be required to develop a comprehensive test plan to be utilized in the testing and acceptance of the MUFIDS system. The plan is to be submitted to the Systems Manager and DEN IT for review and approval prior to testing. The Plan shall consist of a complete listing of all equipment. The Plan shall consist of a complete listing of all equipment, every device and feature, the date to be tested and witnessed by whom, the results, and the date retested (if failure occurred during any previous tests). The final test reports shall indicate that every device tested successfully.
 - a. Submit two (2) typed copies of the test reports in a neatly bound folder and a soft copy to the DEN Project Manager for approval.
 - b. Submit electronic copy of test reports in pdf format.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 1. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
 2. Complete installation and startup checks according to manufacturer's written instructions.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the multi-user flight information system (MUFIDS) system and equipment. Refer to Section 017900 "Demonstration and Training."

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 274219

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SECTION 274220 - COMMON USE PASSENGER PROCESSING SYSTEMS (CUPPS)

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. This Scope of Work provides installation of specialized IT equipment as an extension of the existing site wide Common Use Passenger Processing System (CUPPS) within the areas indicated in the Project Drawings.
- B. CUTE/CUPPS are industry descriptions for systems which allow an airport to support the use of facilities such as boarding gates and ticket counters, by multiple airline tenants at various times throughout the day. CUPPS will be an extension of the DEN Common Use System currently installed in select locations of the Terminal Building and Concourse A. DEN utilizes the Ultra CUSE Product as the site provider of Common Use, therefore the systems specified herein shall be a functional extension of the existing Ultra MUSE product installed at DEN.
- C. CUTE equipment types will be restricted to sole source manufacture and model selection, based upon compatibility with the site wide Ultra CUSE Common Use System. CUPPS equipment, software, equipment deployment and software configuration and system activation tasks will be provided and installed by the Contractor. Communication signaling for CUPPS equipment will be supported by the DEN Premise Wiring Communications System (PWCS) and the DEN Local Area Network.

D. Related Sections:

1. Section 272100 "Local Area Networks (LANs)".
2. Section 260400 "Basic Electrical Requirements".
3. Section 270526 "Grounding and Bonding for Telecommunications Systems".
4. Section 270528 "Pathways for Communications Systems".
5. Section 270544 "Sleeves and Sleeve Seals for Communications Pathways and Cabling".
6. Section 271100 "Communications Equipment Room Fittings".
7. Section 271300 "Communications Backbone Cabling".
8. Section 271500 "Communications Horizontal Cabling".

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- E. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by Alternates.

1.3 SCOPE OF WORK

Edit to suit Project.

- A. The CUPPS system expansion work defined under this project scope shall require provision of CUPPS equipment, coordination with DEN and other trades, and installation tasks including, but not limited to:
1. Coordinate with DEN IT, CUPPS Design Team and the selected CUPPS Contractor for equipment selections, installations, scheduling and related topics.
 2. Coordinate the detail design of check-in desk millwork inserts with millwork trades, DEN IT, CUPPS Design Team and the selected CUPPS Contractor.
 3. Coordinate outlet types and placement detail at CUPPS equipment locations for communications (PWCS) and electrical power.
- B. Furnish and install CUPPS equipment sets at each new check-in location. Typical CUPPS equipment sets for check-in desks shall include:
- a. CUPPS Agent Workstations: Typical for **[Insert number]** Agent Positions configured as shown on the drawings including:
 - 1) CUPPS Workstation complete with CPU, Display Keyboard with bar code /magnetic stripe reader.
 - 2) Boarding Pass Printer.
 - 3) Bag Tag Printer.
 - 4) VoIP Phone.
 - 5) Manifest Printer.
 2. Common Use Self Service Kiosks: Typical for **[Insert number]** Kiosk Positions. Coordinate millwork, placement of Kiosks and finishes with architectural work.

1.4 REFERENCED STANDARDS

- A. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents. A listing of applicable reference standards is contained in Section 270500 "Basic Telecommunications Requirements".
 - 1. National Electrical Code.
 - 2. Conform to requirements of NFPA applicable sections.
 - 3. BICSI (Building Industry Consulting Service International, Inc.).
 - 4. IATA RP 1797 and/or newest release.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product. Provide product cutsheets indicating each type of equipment, accessories and associated materials planned for installation.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Shop drawings of CUPPS equipment showing layout and dimensions of all components and accessories.
- C. Wiring diagrams indicating component connection between equipment.

1.6 INFORMATIONAL SUBMITTALS

- A. Network interfaces included final and coordinated IP addresses coordinated with the Systems Manager.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

- B. Qualification Data: For installer.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For common use passenger processing systems (CUPPS) to include in emergency, operation, and maintenance manuals.

1. Include operating instructions, and maintenance and repair procedures. Procedures shall include shop manuals and schematic drawings to allow repair of equipment.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".
 1. Contractor shall maintain on site accurate as-built drawings indicating dimensioned locations of constructed raceway, box and device locations. Any modifications to work depicted on the Engineered shop drawings shall be noted. Documents shall be updated daily and shall at all times be available for DEN review.

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1.9 RELATED WORKS AND PROJECT COORDINATION REQUIREMENTS

- A. Coordinate the Local Area Network transport requirements, VLAN requirements and implementation strategy with the Systems Manager as specified in Section 271333 "Communications Systems Interfaces (Legacy Systems)".
- B. As specified in Section 270500 "Basic Telecommunication Requirements" and Section 271000 "Premise Wiring Distribution System".
- C. Coordinate the work of this Section with that of other Divisions as required to ensure that the entire work of this project will be carried out in an orderly, complete and coordinated fashion.

1.10 MOCKUPS

- A. Mock-Up Equipment: The Contractor shall be required to provide a mock-up, in location determined by DEN Project Manager, of the equipment for a typical CUPPS Workstation position and the hardware associated with a kiosk position for millwork, placement and coordination purposes. Coordinate timely delivery of Mock-up products to meet mock-up team development schedule. Following use in Mock-up, turn equipment over to DEN (CUPPS/IT) for use as spares which is in addition to the quantity of equipment indicated in this Section above. Specific equipment to be

provided for Mock-up includes:

1. CUPPS Workstation as defined in Part 2 of this Section: Provide one (1) unit.
2. CUPPS Boarding Pass Printer as defined in Part 2 of this Section: Provide one (1) unit.
3. CUPPS Boarding Pass Reader as defined in Part 2 of this Section: Provide one (1) unit.
4. CUPPS Document Printer as defined in Part 2 of this Section: Provide one (1) unit.
5. CUPPS Keyboard as defined in Part 2 of this Section: One (1) unit.
6. CUPPS Kiosk Components: One (1) Unit.

1.11 QUALITY ASSURANCE

- A. Contractor shall be fully responsible for daily quality control of all system installation, coordination with trades, and coordination with DEN Maintenance and Engineering.
- B. Installer: Company with personnel specializing in installation of electronic equipment and specifically Common Use systems.
- C. As specified in Section 270500 "Basic Telecommunication Requirements".

1.12 DELIVERY, STORAGE AND HANDLING

- A. Inspect all products prior to installation. Any defects or damage shall be reported to DEN representative prior to transport of equipment to installation site.
- B. Deliver products to site under provisions of Division 1.
- C. Store and protect products under provisions of Division 1.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.13 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All equipment shall be new and undamaged by shipping or installation.

- B. CUPPS hardware shall be fully compatible with the DEN Common Use System equipment and software.

2.2 COMMON USE WORKSTATIONS (ATTENDANT CHECK-IN WORKSTATIONS):
Quantity [**Insert number**] and including accessory items in Articles and paragraphs below.

- A. Common Use Workstation shall be provided in PC format and be provisioned with a Serial Gear 8 port serial to port extender.
- B. Common Use PC Workstations shall be provisioned to meet the following minimal specifications:
 1. The DEN workstation product standard is manufactured by DELL OPTIPLEX 760.
 2. CPU: Intel Core 1333 MHz or newer processor.
 3. RAM: 1 GB or better.
 4. HDD: 80 GB or larger.
 5. CD/R.
 6. 19-Inch LCD Flat Screen Video Display with articulated arm mount.
 7. Patch cables as required to interface local data outlets.
 8. Software package and License: XP Pro
 9. Common Use System specialty software shall be provided by "Others".
 10. Workstation Design Selection: Dell Model Optiplex 760.
 11. Design Selection for 19-inch LCD display: NEC LCDSNXM.

2.3 COMMON USE BOARDING PASS PRINTERS

- A. Boarding Pass Printer: Printers shall meet or exceed the following minimal specifications:
 1. 1D/2D bar code compliant with IATA RP 722c, d and e.
 2. Graphics capable per AEA 99.
 3. Thermal transfer and direct printing.
 4. 200 dpi minimum resolution.
 5. Manufacturer: IER Model 400 with Ultra configuration.

2.4 COMMON USE BOARDING GATE READERS

- A. As Follows:
 1. Compliance: AEA2009.
 2. 1D Symbologies: Code 128, Code 2 of 5, IATA 2 of 5, Code 39.
 3. 2D Symbologies: IATA res 792, PDF417, Aztec, Datamatrix, QR Will Read from SmartPhone.
 4. Performance: Less than one second read time.
 5. Display: VFD 2 x 16 Characters.

6. Access Interfacing Solutions BGR120S.

2.5 COMMON USE DOCUMENT PRINTERS

A. Document Printers: The Printers shall meet or exceed the following requirements:

1. Production: 570 cpi or faster.
2. Resolution of: 420x216.
3. Memory: 128Kb or greater.
4. Paper stock: Continuous form.
5. Design Selection: Okidata Microline 420.

2.6 COMMON USE KEYBOARDS

A. Specialty Keyboards with Magnetic strip and Optical readers shall be provisioned with each Common Use Workstation. Keyboards shall be designed for commercial application and include specialized features including the following:

1. US Keyboard Layout -104 Keys.
2. Magnetic keyboard swipe supporting credit cards 1, 2 & 3 tracks. Compliant with ISO 7811/2-5.
3. Optical wand type reader compatible with Passports and ATB's. Conforming with ICAO 9303, IATA RP 1720a and 792 bar code formats.
4. Signal interface: USB, Serial and Ethernet.
5. Manufacturer: Desko BMOL 5000.

2.7 BAGGAGE TAG PRINTER

A. Bag Tag Printer: Printers shall meet or exceed the following requirements:

1. 1D/2D bar code compliant with IATA RP 1722 and 1740c with ability to process both Bar code and RFID tag stock.
2. 200 dpi resolution minimum (compliant with the 2D barcode PDF417).
3. Thermal direct printing.
4. Signal interface: Serial, USB, or Ethernet network.
5. Remotely monitored with project NMS.
6. Refer to Spares and Consumables Section of this document for additional requirements related to printers.
7. Design Selection: IER 560 or approved equal.

2.8 COMMON USE KIOSKS: Qty **[Insert number]** (Provide **[Insert number]** Kiosks with built in Bag Tag printers and **[Insert number]** without).

A. Common Use Self Service Kiosks shall be provided in quantities as noted on Project Drawings.

- B. Kiosks shall support passenger interface requirements for each airline designated as a DEN Common use participant.
- C. Kiosks shall be provisioned in the standalone unit form factor. Kiosk units shall be approximately 50" H x 20" D x 18" W. All kiosks shall meet the following minimal requirements:
 - 1. User Interface screen shall be a minimum 17-inch diagonal, touch screen with tactile/acoustic wave touch response.
 - 2. Full page passport reader with RF reader compatible with e-passports.
 - 3. Manual credit card reader.
 - 4. Modular 10/100BaseTX Network Interface Card providing system transactions and monitoring using Ethernet LAN, units shall be capable of modular network interface change to support future modem and wireless 802.11 interface.
 - 5. Omni-directional 1D/2D bar code reader, PDF 417, Datamatrix, Aztec and QR code products.
 - 6. IATA compliant boarding pass printer – direct thermal 300 dpi 2D bar code, Code 39,128 and PDF 417, minimum speed of 2" per second, auto cutter adjusted to coupon stock.
 - 7. On Board PC with Pentium processor and 2 GB Ram.
 - 8. Windows 7 Pro OS (or approved equal).
 - 9. Modular slot for Bag Tag printer. Built in printer shall meet the specifications built-in 2. 7 above and be suitable for mounting in the Kiosk. . Baggage tag printers shall be compliant with IATA CUSS using roll stock bar code.
 - 10. Integrated with the DEN for alerts on low stock, maintenance schedules and tamper.
- D. Each Kiosk shall be provisioned with consumable stock 3500 coupon roll of ATB size board pass stock.
- E. CUSS kiosks shall be networked to an on-site Core of redundant servers, software provided with software licenses, and have networked monitoring of each CUSS kiosk from Common Use NMS.
- F. Design Selection: IER 918 or approved equal

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

PART 3 - EXECUTION

3.1 PRE WORK MEETING

- A. The Contractor shall coordinate and arrange a pre work meeting with the Systems Manager, DEN Project Manager, and DEN Technical Maintenance one (1) week in advance of the beginning of any work. The Systems Manger shall review the Contractor's construction, phasing, implementation and testing plans and schedule.

- B. Meeting Minutes: Meeting Minutes shall be accurately recorded by the DEN Project Manager and distributed after the meeting.
- C. Manager and distributed within five (5) working days after the meeting.

3.2 COORDINATION MEETINGS

- A. Prior to ordering any equipment intended for the CUPPS scope of work, the Contractor shall participate in Coordination Meetings with the DEN Project Manager, DEN IT, the Systems Manager, Common Use staff and the Common Use Contractor. The Coordination meetings will be held for the purpose of reviewing each equipment type, model number and manufacture to assure compatibility with the DEN Common Use Program.
- B. The Contractor shall participate in meetings as required to coordinate with network, power and millwork trades to assure proper fit, functionality and ergonomics for Common Use workstations and associated peripherals planned for the project.

3.3 EXECUTION GENERAL

- A. Installation shall be supervised and tested by a representative of the installing contractor.

3.4 FIELD QUALITY CONTROL

Coordinate inspection and testing requirements with DEN Project Manager.

- A. Testing and Reports:
 - 1. The Contractor shall provide all personnel, equipment, instrumentation, and supplies necessary to perform all inspections, and testing.
 - 2. Design engineer and Airport representatives will witness all field tests.
 - 3. When installation is complete, the system shall be tested by the Contractor. A representative of the installing Contractor shall submit a written report of the findings to the DEN Project Manager.
 - 4. The Common Use Self Service contractor shall be required to develop a comprehensive test plan to be utilized in the testing and acceptance of the CUPPS system. The plan is to be submitted to the Systems Manager and DEN IT for review and approval prior to testing. The Plan shall consist of a complete listing of all equipment, every device and feature, the date to be tested and witnessed by whom. And the results, and the date retested (if failure occurred during any previous tests). The final test reports shall indicate that every device tested successfully.
 - 5. Submit two (2) typed copies of the test reports in a neatly bound folder and a soft copy to the Owner's Representative for approval.
 - 6. Submit electronic copy of test reports in pdf format.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to assist Contractor and perform startup service.
 - 1. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
 - 2. Complete installation and startup checks according to manufacturer's written instructions.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the common use passenger processing systems (CUPPS) and equipment. Refer to Section 017900 "Demonstration and Training."
 - 1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 274220

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SECTION 275114 - EMERGENCY COMMUNICATIONS SYSTEM, PUBLIC ADDRESS SYSTEM AND VIDEO INTERFACE - TENANT PROJECT REQUIREMENTS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Designer of Record (DOR)." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

DEN PROJECT MANAGER SHALL APPROVE DELETION OF ALL NOTES/COMMENTS FOLLOWING DOR FINAL DESIGN REVIEW.

PART 1 - GENERAL

For any projects installing audio head end equipment, including amplifiers, control units, etc. use Specification 275123. Do not use both this section and 275123 in the same project; they are redundant.

The engineer shall contact DEN Project Manager for the location of the nearest Denver International Airport Emergency Communication System (ECS) terminal cabinet or a junction box in the front of the tenant space with ECS speaker circuit(s) connections. The engineer shall designate the ECS terminal in the contract documents.

The engineer shall review the ECS loudspeaker layout with IED certified designer prior to issuing the drawings for bid and construction.

1.1 SUMMARY

- A. This specification is applicable to tenant and concession spaces that may or may not be equipped with a professionally installed background music or public address system. This type of space shall include tenant food service, retail establishments, airline tenant spaces, and other tenant leasehold areas used for other purposes. The tenant can provide their own music or PA system separate from the Denver International Airport Emergency Communication System (ECS) speakers and equipment. ECS speakers are required as part of the tenants project to allow ECS audio to be broadcast in the space.

1.2 SCOPE

- A. The ECS is utilized throughout public and private areas of the terminal and concourses for public emergency notification announcements. It is therefore required that all new

or renovated facilities within the terminal and concourses are equipped for emergency voice paging. This specification describes materials and methods that shall be utilized in all such extensions to the ECS.

- B. The ECS is also used for routine public and airline announcements utilizing the same equipment.
- C. Tenant audio systems cannot utilize ECS speakers. If tenant audio systems are installed, ECS audio must take priority and shunt all tenant audio during emergency messaging.
- D. ECS utilizes some tenant video displays for visual notification as defined within this specification. These video displays shall be capable of capture or shunt by the ECS.
- E. The work to be performed under this section shall include provision of one or more loudspeakers within the tenant or concessions space connected to the ECS. Each area within the tenant or concessions space shall be provided with at least one loudspeaker. Larger areas shall be equipped with multiple loudspeakers to provide uniform coverage and intelligibility throughout the space.
- F. DEN Life Safety Approved drawings and Denver Fire Department (DFD) permit is required for all work affecting audio and/or video ECS equipment.
- G. The contractor shall engage the services of a factory-certified audio designer certified by Innovative Electronic Designs (IED) (502-267-7436) for final design elements of the ECS tenant interface.

1.3 ACTION SUBMITTALS

- A. Shop drawings shall be legible and of scale suitable for review. They shall show materials, finishes and panel/control markings. Contractor shall provide the following shop drawing submittals:
 - 1. A complete list of equipment for installation.
 - 2. A complete set of detailed technical descriptions describing and illustrating all components and materials.
 - 3. A complete set of coordinated reflected ceiling plans with all ceiling devices shown including sprinklers, HVAC, lighting, fire alarm, speakers, etc.
 - 4. The audio designer shall indicate raceways and cabling to interconnect these loudspeaker(s) to the ECS at the designated ECS terminal cabinet location or J box location.
 - 5. System block diagrams including any muting/shunt system details.
 - 6. Equipment rack and console layouts.
 - 7. Details of cable installation, routing, support, and termination in: terminal boxes, junction boxes, and equipment racks.
 - 8. Wiring diagram, including:
 - a. The exact manner in which the Installer proposes to install the system.
 - b. All switches, equipment, control circuits, and equipment rack layouts.

- c. All equipment/apparatus items necessary for performance of the required functions.
 - d. Identification of all terminals, wire color-coding and control functions.
- B. Manufacturer equipment cut sheets of all equipment provided.
- C. All submitted documents shall be stamped by a licensed professional engineer registered in the state of Colorado.

1.4 CLOSEOUT SUBMITTALS

- A. Provide as-builts of tenant changes to the systems and building on the existing DEN Auto Cadd ECS as-built when available. If existing as-builts are not available to modify then Contractor shall modify documents for the project either in CADD or Building Information Modeling (BIM) model as required.
- B. Closeout Documents: Two weeks prior to final acceptance testing, the Installer shall provide two sets of record drawings and electronic copies of the following:
- 1. System block diagrams.
 - 2. System wiring diagrams.
 - 3. Test reports, as specified herein.
 - 4. Documentation, as specified herein.
 - 5. Written warranty, as specified herein.
 - 6. Drawings in Auto CADD shall have project specific layer(s) showing new work or modifications on its own layer(s) with the project name. The intent is to provide a clear record of the final installation, which will allow DEN to import the new layer(s) into their master ECS diagrams.

1.5 RELATED DOCUMENTS

- A. Drawings, general and special conditions, Division 1 – General Requirements and other applicable technical specifications apply to this Section.

1.6 RELATED SECTIONS

- A. Technical Specification Division 1 - General Requirements
- B. Division 26 - Electrical
- C. Division 27 - Communications
- D. Section 283100 – Intelligent Life Safety Fire Management System

THE DOR SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT WRITTEN PERMISSION FROM THE DEN PROJECT MANAGER.

1.7 REFERENCE STANDARDS

- A. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.
- B. National Fire Protection Association (NFPA):
- C. NFPA 70, National Electrical Code® edition as adopted by the State of Colorado.
- D. NFPA 72, National Fire Alarm and Signaling Code® (2016 Edition).
- E. 2015 International Building Code (IBC).
- F. 2015 International Fire Code (IFC).
- G. Currently adopted City and County of Denver Building and Fire Codes as amended.
- H. Underwriters Laboratories (UL):
 - 1. UL 6, Electrical Rigid Metal Conduit – Steel.
 - 2. UL 464, Standard for Audible Signal Appliances.
 - 3. UL 521, Standard for Heat Detectors for Fire Protective Signaling Systems.
 - 4. UL 797, Electrical Metallic Tubing – Steel.
 - 5. UL 1242, Standard for Electrical Intermediate Metal Conduit – Steel.
 - 6. UL 1480, Standard for Speakers for Fire Alarm, Emergency, and Commercial and Professional Use.
 - 7. UL 2572, Standard for Mass Notification Systems.
 - 8. Other UL Standards shall be applied to ensure that all materials are listed for their intended purpose.
- I. United States Access Board (USAB) – Americans with Disabilities Act (ADA) and the 2010 ADA Standards for Accessible Design.

1.8 QUALITY CONTROL

- A. Contractor shall be fully responsible for daily quality control of all system installation, coordination with trades, and coordination with DEN Airport Infrastructure Management (AIM).
- B. Installer for ECS system components shall have either an ECS Installer License or a Fire Alarm Installer License from the City and County of Denver Fire Department in addition to a manufacturer certification.
 - 1. For work within amplifier racks, an ECS installer license is required
- C. Pre-work conference shall be mandatory for all contractors and sub-contractors. Coordinate with DEN Project Manager.

- D. Contractor shall maintain on the site accurate as-built drawings indicating locations and details of installed equipment, constructed raceways, boxes, and devices. Any modifications to work depicted on the permitted shop drawings shall be noted. On-site drawings shall be updated daily.

1.9 SPARE PARTS

- A. Contractor shall at the time of system testing, maintain on-site spare stock adequate to replace any non-functional device.
- B. Required spare stock shall be determined by DEN Project Team prior to notice-to-proceed.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Loudspeakers, enclosures, line transformers, grilles and cabling utilized in this work shall be UL-Listed.
- B. All products utilized in the Tenant sound system shall be commercial grade.

Engineer shall verify that the product numbers listed below are manufacturer's current product.

2.2 SPEAKERS

- A. 6.5 inch Speaker – [**Atlas FAP62T with integrated backcan, grill and suspension system**] <insert product> or approved equal.
 - 1. Full Range Speaker, Flush mount with grill.
 - 2. Loudspeakers shall be 70 volt ceiling speaker with mounting hardware.
 - 3. Ninety (90) conical coverage with 88dB sensitivity, 63 to 16 kHz frequency response.
 - 4. Loudspeaker shall have selectable taps at 2, 4, 8, 16, and 32 watts.
- B. 4 inch Speaker – [**Atlas FAP42T or FAP42T-C with integrated backcan, grill and suspension system**] <insert product > or approved equal.
 - 1. Coaxial in-ceiling loudspeaker with 16-Watt 70V transformer
 - 2. One hundred thirty (130) degree conical coverage with 88dB sensitivity, 75Hz to 200kHz frequency response
 - 3. Loudspeakers shall have selectable taps at 1,2,4,8, and 16 watts.
- C. 4 inch Pendant speaker – [**JBL Control 64P/T with integrated backcan, grill, and suspension system**] <insert product> or approved equal.

1. Full range Paging speaker, pendant mount.
2. Loudspeakers shall be 70 volt.
3. 120 degree coverage angle, 65 to 15 kHz frequency response.
4. Loudspeaker shall have selectable taps at 3.7, 7.5, 15, and 30 Watts.

These loudspeakers below shall be utilized in the tenant spaces where ceilings are not provided.

D. Surface Mount, Full-range Paging Loudspeaker – **[Atlas SM52T (B, Black, or W, White)] <insert product>** or approved equal.

1. Loudspeaker shall be a full-range device with a frequency response of ± 3 dB, 80 Hz to 20 kHz and input sensitivity of 90 db at 1 meter with 1-watt input at 500 Hz to 2500 Hz. The coverage shall be nominal 100 degrees horizontal from 500 Hz to 2.5 kHz. The power rating shall be 100 W minimum, and a 70-volt line matching transformer with 7.5, 15 and 30 watt taps and a maximum insertion loss of 0.5 dB from 100 Hz to 15 kHz shall be provided. The loudspeaker shall be surface mounted and enclosed in a UL 94V-0 rated injection molded or metal enclosure with integral metal grille and mounting bracket to allow aiming. A cover plate for a 4- inch square electrical box shall be provided with grommets wire access hole.

E. Other Speaker – Provide other speaker types as required for project design.

2.3 LOUDSPEAKER CABLING

A. Trunk loudspeaker cable:

1. Manufacturer: Smartwire, #001260-11BR or Equal.
2. Size: #12 AWG, stranded.
3. Type: Unshielded twisted pair.
4. Insulation Color: Red (positive), black (negative).
5. Jacket Color: Dark green.
6. Cable shall be plenum rated.
7. All cable shall be installed in conduit.

B. Branch loudspeaker cable:

1. Manufacturer: West Penn, #25226B or Equal.
2. Size: #14 AWG, stranded.
3. Type: Unshielded twisted pair.
4. Insulation Color: Red (positive), black (negative).
5. Jacket Color: Dark green.
6. Cable shall be plenum rated.
7. All cable shall be installed in conduit.

2.4 RACEWAY

A. Refer to 260533 – “Raceways and Boxes for Electrical Systems” for additional

requirements.

B. Conduit

1. Type: EMT for all indoor installation locations.
2. Color: Green.
3. Minimum size: 3/4" trade size.

2.5 SYSTEM INTERFACES AND ELECTRONICS

Power shunt system shall provide system power sequencing and immediate shutdown for circuits feeding the audio and video systems. Power Shunt system shall be located and designed with the electrical panel for the tenant. In addition, audio mute function as described below shall also be provided.

A. Audio Mute/shunt requirements: Audio equipment shall be provided with shunt and mute equipment as follows:

1. Fire alarm control module: Provide fire alarm control module with control relay per Specification 283100 to shunt power to all tenant-provided audio systems.
2. Audio Mute: Provide Priority Paging Relay Controller, Atlas Sound AA-PPRC or approved Equal, with RDL TX-70A isolation transformer, to mute owner-furnished audio upon ECS activation.

B. Video capture/shunt requirements:

1. For dynamic video displays larger than 60" (diagonal), provide power shunt equipment as follows:
 - a. Fire alarm control module: Provide fire alarm control module with control relay per Specification 283100 to shunt power.
2. For static video displays (i.e. menu boards, POS devices, etc.), and dynamic video displays smaller than 60" (diagonal), except MUFIDS, shunting is not required.
3. For FIDS/BIDS/GIDS within tenant spaces, provide ECS capture equipment as defined in 274219 "Multi-User Flight Information Display Systems (MUFIDS)".

2.6 CONNECTORS AND TERMINATIONS

A. Connectors utilized to interconnect loudspeakers to cabling shall be nylon insulated butt crimp devices with a protective shell to contain exposed conductors. The crimping tool used with these connectors shall be specifically designed for use with the type of connector being utilized.

B. Wiring terminations to terminal blocks and loudspeaker screw terminal terminations shall be made using the correctly sized insulated spade lug connection.

1. Spade Lugs: Thomas and Betts or approved equal.

Retain paragraph below for concession tenants only.

- C. Tenant ECS terminal box shall provide speaker connection points and be a minimum 12" x 12" x 6". Provide Amp flex terminal strips or other approved method of connection that is field serviceable for testing and troubleshooting in the terminal box for speaker connections.

2.7 MISCELLANEOUS

A. Cable Labels:

- 1. Self-adhesive, pre-printed labels with black text on white background, as produced by Brady BMP21 or equal.

B. Loudspeaker Labels:

- 1. Self-adhesive, pre-printed 1" x 0.5" labels with red text on white background, printed with the following text: "FIRE ALARM DO NOT DISCONNECT"

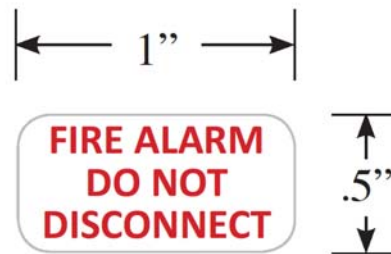


Figure 1 - Sample Loudspeaker Label

PART 3 - EXECUTION

3.1 GENERAL

- A. Pre-Work Meeting: The Contractor shall coordinate and arrange a pre-work meeting with the DEN Project Manager and DEN Life Safety one week in advance of the beginning of any work. The Contractor shall assure attendance of trades installing the ECS including any electrical, telecommunications, and audio- and video-related trades involved. The Contractor shall present the Contractor's construction, demolition, phasing, implementation, and testing plans and schedule. Meeting notes shall be accurately recorded by the DEN Project Manager and distributed within three (3) working days.
- B. All work shall be provided complete, and the voice paging systems shall be fully operational as shown and described herein. DEN Life Safety will witness all final connections to existing circuits.

- C. Modifications and additions to the existing ECS: Contractors must give DEN Life Safety 5 working days notice before making any connections, deletions, or modifications to the existing ECS. DEN Life Safety Shutdown Request form must be used for this purpose.
- D. Electrical Related Work:
 - 1. Furnish and install all electrical conduit, wiring, and outlets for electrical power to ECS equipment.
 - 2. Furnish and install raceway, conduit, and junction boxes for audio signal and control wiring. Junction box covers for this system shall be painted green and labeled with circuit ID.
 - 3. Furnish and install loudspeaker junction boxes and enclosures.

3.2 PREPARATION

- A. Prior to any demolition, all ECS speakers and circuits in construction area must be protected in accordance with DEN Life Safety. This work requires a mandatory shutdown request.

3.3 INSTALLATION

- A. A Fire Alarm Permit is required for any work on the ECS system. No Exceptions.
- B. Exposed components such as grilles may be painted for aesthetic purposes prior to assembly with the loudspeaker.
- C. Emergency paging audibility and intelligibility shall conform to requirements of the currently adopted version of NFPA 72:
- D. Pre-tone: 15dBA above ambient noise level.
- E. Identification:
 - 1. All speaker cables shall be labelled with circuit ID using an approved Cable Label at all connections, junction boxes, and splices.
- F. Secure equipment firmly in place. Make fastenings and supports adequate to support their loads with a safety factor of three.
- G. Exercise care in wiring, to avoid damage to the cables and to the equipment. Make all joints and connections with rosin-core solder or with mechanical connectors approved for NEC Class 1 power-limited wiring.
- H. Phasing shall be observed on all loudspeaker wiring interconnections. For example, in junction boxes, all positive conductors shall be joined together and all negative conductors shall be joined together. At loudspeakers, the negative conductor shall be connected to the transformer common terminal or lead with the positive conductor

used for the remaining terminal or appropriate transformer tap lead.

- I. All unused transformer tap leads shall be separated and capped to prevent shorting to each other or to ground.
- J. DEN Life Safety will witness all final connections to existing circuits.

3.4 TESTING AND CERTIFICATION

- A. Refer to Appendix A - "ECS Pre-Inspection Checklist" for installation sequencing.
- B. When the tenant sound system and all interfaces to the ECS are complete, the contractor shall schedule a functional test of the system with DEN Life Safety. This notification shall occur a minimum of 5 days prior to the desired time of the test. DEN Life Safety will establish a time of day (or night) for the test that is least disruptive to normal airport and tenant operations.
- C. Demonstration Test: Upon completion of installation, and at a time established by DEN Life Safety, demonstrate the operation of each major component of the system and the completed installation. Assist as required in the following acceptance tests:
 - 1. Reference Appendix A for checklist items required for the Demonstration Test.
 - 2. Prior to connection to the ECS, DEN Life Safety will test the loudspeaker system for impedance, shorts, and grounds. The contractor shall perform a basic short and ground test of the completed wiring system in advance of this test. Any anomalies noted in either test shall be corrected by the contractor before the loudspeaker(s) will be connected to the ECS.
 - 3. Upon completion of the ECS installation, the contractor shall arrange with DEN Life Safety to review programming and conduct a test of the emergency paging within the tenant or concession area. This test may be scheduled during a period of low airport activity at night at the discretion of DEN Life Safety.
 - 4. This work requires a mandatory shutdown request.
 - 5. Listening Tests: These tests shall include speech intelligibility survey and subjective aural evaluations by observers at various positions under various operating conditions, using live speech and/or recorded speech.
 - 6. If the need for adjustment or modification becomes evident during demonstration and testing, accomplish adjustments or alterations until the installation operates fully in accordance with the requirements of this specification.
- D. DFD Acceptance Test:
 - 1. Reference Appendix A for checklist items required for the DFD Acceptance Test.
 - 2. Upon satisfactory completion of the demonstration test, DEN Life Safety will schedule DFD Acceptance Test. This notification shall occur a minimum of 5 days prior to the desired time of the test. This test may be scheduled during a period of low airport activity at night at the discretion of DEN Life Safety.
 - 3. This work requires a mandatory shutdown request.
- E. All work shall be provided complete, and the ECS shall be fully operational as shown

and described herein.

3.5 CONSTRUCTION WASTE MANAGEMENT

- A. Construction Waste Management: Construction Waste shall be managed in accordance with provisions of Section 017419 – “Construction Waste Management”. Documentation shall be submitted to satisfy the requirements of that section.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this section. The cost of the work described in this section shall be included in the applicable unit price item, work order of lump sum bid item.

END OF SECTION 275114

APPENDIX A: ECS Pre-Inspection Checklist

#	Yes	No	TO BE COMPLETED PRIOR TO DEMONSTRATION TEST	Initials
1			A shutdown request is in place and approved prior to working on any part of the Fire Alarm/ECS.	
2			The Approved construction drawings, shop drawings, and permit card are on site prior to inspection.	
3			The "Tie-in" points for the ECS speaker circuits are clearly shown on the shop drawings.	
4			All ECS conduits are green per specifications.	
5			All ECS conductors match the Wire Schedule provided on ECS shop drawings.	
6			Speaker cables are labeled with speaker circuit ID at all terminations and junction boxes.	
7			Where an end of line branch monitor is used, the device(s) and their enclosures must be marked ECS EOL.	
8			Audio Contractor and Installing Contractor both have licensed representatives present during Demonstration Test.	
#	Yes	No	TO BE COMPLETED PRIOR TO FIRE ALARM TIE-IN	Initials
9			A ground fault test has been completed in the presence of a DEN Life Safety representative.	
10			An impedance test has been completed in the presence of a DEN Life Safety representative.	
11			All deficiencies identified in the Demonstration Test have been corrected and system was successfully tested in the presence of DEN Life Safety.	
12			Audio Contractor and Installing Contractor both have representatives present during fire alarm tie-in. Representatives must possess a current CCD Fire Alarm Installer's license or CCD Mass Notification license.	
#	Yes	No	AT FIRE ALARM INSPECTION	Initials
13			Stamped & Signed set of ECS plans, Permit card, & payment for DFD on hand at the time of the final test.	
14			All required testing materials are available for the test, including but not limited to: Ladders, extension cords, impedance meter, multimeter, sound pressure level meter.	
15			All appropriate parties are present & access to the area being inspected has been arranged. These include Owner Rep; Licensed contractor holding a current CCD Fire Alarm Installers or CCD Mass Notification Installers license.	
16			All required Spare Parts delivered to DEN Life Safety.	
17			ECS Supplementary Record of Completion is on-site, completed and signed. This form may be obtained from DEN Life Safety.	

Project Name: _____

Revised July 2016

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SECTION 275119 - SOUND MASKING SYSTEMS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

Edit to suit Project.

1. Electronic noise generators.
2. Amplifiers.
3. Wiring.
4. Masking speaker assemblies.
5. Controls.
6. Component mounting racks.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- B. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. Covered Spaces: Spaces above which masking speakers are installed.

1.4 SYSTEM DESCRIPTION

Revise this article to indicate extent of system coverage required. Coordinate with Drawings to indicate extent of system or individual zones to be covered. Revise number of channels and modify number of zones to suit Project. See Evaluations.

- A. Zones: [**Single**] [**Multiple**]-zone coverage.

Retain one of first two paragraphs below to specify number of channels. See Evaluations.

- B. Channels: Single channel of masking sound to each zone.
- C. Channels: Separate channel of masking sound to each of [**two**] [**three**] groups of speakers in each zone.
- D. Signal Levels: Individually adjustable for each of 14 one-third octave bands centered at 200 through 4000 Hz, for sound-masking noise channels.

Options in first paragraph below specify system performance for typical office occupancies. Revise to suit Project.

- E. Sound-Power Level Produced by System: Match [**NC 40**] <Insert value> contour between [**400 and 2000 Hz**] <Insert value>, with smooth roll-off above and below those frequencies.
1. Initial Level: [**40 dB**] <Insert value>, A-weighted.
 2. Final Adjusted Level: [**40 to 50 dB**] <Insert value>, A-weighted. Determine final level for each space individually by measurement as specified in Part 3.
 3. Measurements: Made under calibration conditions.
- F. Maximum Local Variance of Sound-Power Level: [**6 dB**] <Insert value> for the 500-Hz octave band and [**3 dB**] <Insert value> for the 1000-, 2000-, and 4000-Hz octave bands for 75 percent of the locations in covered spaces.
- G. Maximum Average Range of Sound-Power-Level Deviation: [**2 dB**] <Insert value> in the 250-, 2000-, and 4000-Hz octave bands and [**1.5 dB**] <Insert value> for the 500- and 1000-Hz octave bands for all locations.
- H. Directional Effect: People in covered spaces under calibration conditions cannot determine source of masking sound.
- I. Uniformity with Respect to Time: One-minute time-averaged sound-pressure level of any octave band of masking sound from [**250 to 8000 Hz**] <Insert value> remains constant in any space to within a standard deviation of [**2 dB**] <Insert value> when measured over a 30-minute period.
- J. Sound Quality: No audible hum or noise from this system in covered spaces when noise generators are off and power amplifiers are on with input volume controls set at [**50**] <Insert number> percent.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT

PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include nationally recognized testing laboratory listing data.
 - 1. Include data substantiating that materials comply with requirements.
- B. Shop Drawings:
 - 1. Dimensioned plans and elevations showing minimum clearances and installed features and devices for system components. Include the following:
 - a. Show types and locations of masking speakers and their wiring connections, channel assignments, and axis orientations.
 - b. Show ducts, beams, and other significant sound-reflecting and -absorbing elements in ceiling space and show locations of partitions below ceiling.
 - c. Include a diagram showing interconnection of major system components for each zone and channel and indicating grounding connections.

Retain subparagraph below if equipment includes wiring.

- 2. Wiring Diagrams: For power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article. Edit to suit Project.

- A. Qualification Data: For qualified [**Installer**] [**manufacturer**] [**and**] [**testing agency**].

Retain first paragraph below for product certificates from manufacturers.

- B. Product Certificates: For sound-masking equipment and components, signed by product manufacturer.

Retain first paragraph below if Contractor is responsible for field quality-control testing and inspecting.

- C. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sound-masking equipment and components to include in emergency, operation, and maintenance manuals.

Verify requirements for as-built plans with DEN Project Manager.

- B. As-Built Plans: Submit complete as-built plans of all Work, including interface with

other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Sound-Masking Speaker Assemblies: **[One (1)] <Insert number>** for each 10 of each type used, but no fewer than one.
 - 2. Fuses: **[One (1)] <Insert number>** for each type used, but no fewer than one.

1.9 QUALITY ASSURANCE

- A. Installer Qualifications: An experienced installer trained and approved by manufacturer of sound-masking equipment.

Retain first paragraph below if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

- B. Testing Agency Qualifications: An independent agency with the experience and capability to conduct testing of sound-masking systems according to ASTM E 1130. Required experience includes having tested a minimum of five different systems within the last five years, each system similar in size and complexity to Project system.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with NFPA 70.
- E. Comply with UL 813 unless a more stringent standard is specified in Part 2.

1.10 COORDINATION

- A. Coordinate quantity and arrangement of speaker assemblies with ceiling space configuration and with components occupying ceiling space, including structural members, pipes, air-distribution components, raceways, cable trays, recessed lighting fixtures, and other items.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. American Sound Masking, LLC.
 2. Atlas Sound LP.
 3. Dynasound, Inc.
 4. GE Security, Sound and Communications.
 5. Lencore.
 6. LynTec, Inc.
 7. Moeller, K. R. Associates Ltd.
 8. Proudfoot Company, Inc. (The).
 9. Sound Advance.
 10. <Insert manufacturer>
 11. or approved equal.

2.2 GENERAL REQUIREMENTS FOR SOUND-MASKING EQUIPMENT

- A. Components: Modular plug-in, heavy-duty, industrial-grade integrated circuit devices.
- B. AC Supply Voltage Tolerance: 105 to 130 V with no degradation of system performance.
- C. Protection from Power Line Surges: Integral surge protection devices listed in UL 1449; with the following features:
1. Suppression Level: 300 V.
 2. Maximum Response Time: 5 nanoseconds.
 3. Circuit: Multistage, using inductors and silicon-avalanche zener diodes or equivalent.
 4. Indicator Lamp: Neon or light-emitting diode located on control panel and arranged to extinguish on failure of protection.
 5. Fuses: Externally accessible.
- D. Component Housings: Suitable for mounting in standard 19-inch (480-mm) relay racks, with connections at rear and controls either on rear panel or protected by a

screw-fastened security cover.

2.3 NOISE GENERATOR AND FILTER UNITS

- A. Digital Masking Generator Spectra: Pink, white, and superwhite.
- B. Pink Noise Generator: Output octave bands from 30 to 4000 Hz.
- C. Filters for One-Third Octave Bands: Adjustable from 10 dB of boost to 10 dB of cut at each center frequency.
- D. Mixer Inputs: Two high level and one microphone level.
- E. High-Pass Filter: Approximate range of cutoff adjustment is 37 to 400 Hz.
- F. Low-Pass Filter: Adjustable roll-off frequency 100 Hz to 10 kHz.
- G. High-Cut Filter: Approximate range of cutoff adjustment is 180 to 9000 Hz with slope varying to 12 dB per octave.
- H. Auxiliary Inputs: Able to accept two, high-level, auxiliary signals such as music and telephone paging as well as general paging.
- I. Mounting: Shelf or rack **3-1/2 inches** (90 mm) high.

2.4 PROGRAMMABLE AUDIO-LEVEL CONTROL UNIT

This article specifies an optional feature providing automatic adjustment of masking sound to suit predictably recurring changes in occupancy patterns.

- A. Automatic Sound-Power-Level Changes: Six system channel changes, four times per day, and capable of different time settings for each day of week.
- B. Level Changes: Programmable from front panel of unit, and automatically incremented over a period long enough for sound-level variations to be imperceptible to occupants of covered spaces.
- C. Muting: Control unit shall be programmed to permit muting for emergency paging.
- D. Built-in zone-level control shall drive other amplifiers and provide minimum [7] **<Insert number>**-position level control.
- E. Program Memory: Nonvolatile for at least one year without power. When re-energized after a power outage, control starts at zero level and automatically advances system sound level at same rate used for programmed level changes.

2.5 POWER AMPLIFIERS

- A. Power Amplifiers: Comply with CEA-426, and have the following minimum features:
1. Mounting: Rack mounted.
 2. Output Regulation: Less than 2 dB from zero to full load.
 3. Total Harmonic Distortion: Less than 3 percent, at rated power output from 50 to 12,000 Hz.
 4. Signal-to-Noise Ratio: 60 dB or greater, at rated output.
 5. Frequency Response: Within plus or minus 2 dB from 50 to 12,000 Hz.
 6. Input: From internal masking or mixer board, or from an exterior source such as an automatic level control or other mixer.

2.6 MASKING SPEAKER ASSEMBLIES

- A. Speakers: Cone type, with the following minimum features:
1. Minimum Axial Sensitivity: 45 dB.
 2. Frequency Response: Within plus or minus 3 dB from 50 to 15,000 Hz.
 3. Size: 8 inches (200 mm) with 1-inch (25-mm) voice coil and minimum 5-oz. (142-g) ceramic magnet unless otherwise indicated.
 4. Dispersion Angle: 100 degrees.
 5. Rated Output Level: 10 W.
- B. Configuration: Dual 8-inch (200-mm) and dual 5-inch (125-mm) units mounted on metal baffles and arranged for optimum, multidirectional, angular sound distribution. Arrange units for suspension from the building structure above the ceiling.
- C. Matching Transformers: Full-power rated with 4 standard taps, and a maximum insertion loss of 0.5 dB.
- D. Assemblies installed in air-handling spaces shall comply with NFPA 70 requirements for rate of heat-release and rate of smoke-release characteristics. Tests for these requirements shall be according to UL 2043.

2.7 WIRE

- A. Speaker Wire: UTP cable complying with manufacturer's requirements; listed and labeled for environmental air plenums where cable is indicated in cable trays and is not indicated to be in raceway. Comply with requirements in Section 271500 "Communications Horizontal Cabling." All cables must be installed in an approved raceway or cable tray.

2.8 COMPONENT MOUNTING RACKS

- A. Configuration: Comply with CEA-310-E. Factory-fabricated units designed for interchangeable mounting, forced or convection air cooling, wiring connection, and enclosure of standard 19-inch (482-mm) relay rack modules.

Coordinate first paragraph below with Drawings.

- B. Mounting Provisions: Equipped for freestanding floor mounting.
- C. Cabinet: Factory-finished steel with component mounting rails and prewired plug strips for component power connections. Full front and rear doors with continuous hinges, handles, and cylindrical keyed locks.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Speaker Assemblies: Suspend with chains from building structure above ceilings so bottom of assembly is 6 to 8 inches (150 to 200 mm) above upper plane of finished ceiling material. Use eyebolts on speaker assemblies for attachment. Suspend independently of supports for components of other building systems.

Retain first paragraph below if piping is required to withstand seismic design loads.

- B. Install seismic restraints on speakers. Comply with requirements for seismic-restraint devices specified in Section 260548 "Vibration and Seismic Controls for Electrical Systems."
- C. Speaker Connections: For two- or three-channel systems, connect speaker assemblies alternatively so masking sound is redundant throughout zones of coverage.

Retain one of first two paragraphs below and coordinate with Drawings. Delete both paragraphs if wiring methods for system are indicated on Drawings.

- D. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters and unless otherwise indicated.

Retain one or both of first two subparagraphs below to make exceptions to the wiring method specified above.

- 1. Where cables are installed within consoles, cabinets, desks, and counters, the maximum cable length outside raceway is 6 feet (2 m).
- 2. Conceal raceways and wiring except in unfinished spaces.
- E. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.

Retain first subparagraph below if retaining option for unenclosed wiring method.

- 1. Install plenum cable in environmental air spaces, including cable trays.
- 2. Comply with requirements specified in Section 260536 "Cable Trays for Electrical Systems" and Section 271500 "Communications Horizontal Cabling" for cable trays

3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceway and Boxes for Electrical Systems."
4. Comply with requirements in Section 271500 "Communications Horizontal Cabling."

F. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

Retain first paragraph below for cable wiring method.

G. Exposed Cable: Install parallel to building lines, follow surface contours, and support as recommended by manufacturer.

Coordinate first paragraph below with Drawings.

H. Grounding: As recommended by manufacturers unless more stringent requirements are indicated. Ground equipment and conductors to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments with a maximum of 5-ohm to ground at main equipment location. Measure, record, and report ground resistance.

I. Impedance Matching: For system components, including connecting cable, provide end-to-end level and impedance-matched signal paths. Use matching networks and balancing devices at connections where necessary to avoid mismatches.

J. Splices, Taps, and Terminations: Make splices, taps, and terminations on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.

3.2 IDENTIFICATION

A. Use color-coded conductors and apply wire and cable marking tape to designate wires and cables so media are identified in coordination with system wiring diagrams. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

B. Label speaker assemblies as to channel, zone, and address.

3.3 FIELD QUALITY CONTROL

Retain first paragraph below to identify who shall perform tests and inspections. If retaining second option, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

Coordinate inspection and testing requirements with DEN Project Manager.

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

B. Perform tests and inspections.

Retain subparagraph below to require a factory-authorized service representative to assist Contractor with inspections, tests, and adjustments.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist Contractor in testing.

Retain first paragraph below to describe tests and inspections to be performed.

C. Tests and Inspections:

1. Operational Test: Start system to confirm proper operation. Remove malfunctioning units, replace with new units, and retest. Make initial sound-spectrum and -level adjustments for each zone.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Inspection: Verify that units and controls are properly labeled and interconnecting wires and terminals are identified.
4. Pretesting: Tune, align, and adjust system and pretest components, wiring, and functions to verify they comply with specified material, installation, and performance requirements. Correct deficiencies and retest until satisfactory performance and conditions are achieved.
5. Masking Sound-Power-Level Adjustments: Adjust independently for each space to minimum level between 40 and 50 dB that will provide speech privacy between adjacent workstations while complying with other system requirements.

D. Final Acceptance Testing: Provide a minimum of 10 days' notice of acceptance test performance schedule. Schedule tests after pretesting has been successfully completed.

1. Tests and Calibration Conditions: Spaces shall be completely furnished but unoccupied; lights and HVAC systems shall be on; HVAC system testing and balancing shall be completed; and electronic ballasts, lighting relay panels, and low voltage transformers shall be in place.
2. Test Conditions: Complying with ASTM E 1130 and calculated according to ANSI S3.5.
3. Instrumentation: Use a professional-quality, sound-level meter with octave-band filters and documentation of recent calibration against recognized standards.
4. Record test observations, readings, and corrective actions.
5. System Tests: Include the following for each system zone:
 - a. Speaker Circuit Impedance Test: Measure impedance at 1000 Hz with amplifier disconnected, using a professional impedance meter or bridge. Locate and correct faults denoted by abnormal readings.
 - b. Ambient Sound-Level Tests: With system off, measure ambient sound level in one-third octave bands. Also measure ambient sound level as a single, wide-band, A-weighted reading.
 - c. Amplifier Noise Test: Check for performance specified in "System Description" Article with masking noise generator off and amplifiers on.

- d. System Noise Test: With masking noise signal on and amplifiers adjusted at a working level 10 dB above ambient sound level, check for hum, buzz, rattle, or other operating deficiencies.
 - e. Spatial Uniformity Test: Measure sound level at locations no greater than **15 feet** (4.6 m) o.c. throughout covered spaces to determine compliance with specified performance level.
 - f. Frequency Response Adjustment and Test: Adjust one-third octave frequency bands and other unit filters to provide response. Adjust to meet requirement of space speech intelligibility and quality of background sound. Comply with ANSI S3.2, CEA 426, and ASTM E 1110.
6. Adjust level of masking sound for each space so one-third octave band centered at 500 Hz has final selected sound-power level for that space. Measure deviation from listed values in one-third octave bands from 100 to 1000 Hz. Measured values must not deviate from those listed by more than 4 dB for open plan areas and 8 dB for enclosed offices. The total of individual band deviations in eight bands must not exceed 16 dB for open plan areas and 30 dB for enclosed offices.
 7. Walk-through Test: People in covered spaces cannot discern speaker locations.
 8. Temporal Stability Test: Check for uniformity of time by measuring sound level in each of 14 octave bands at one-minute intervals over a 30-minute test period. Deviations must not exceed limits specified in "System Description" Article.
 9. Where required, space shall meet the Health Insurance Portability and Accountability Act for privacy and the Gramm-Leach Bliley Act to protect consumer personal and financial information in open office layouts.
- E. Retest: Correct deficiencies identified by tests and observations and retest until meeting specified requirements.
- F. Recording Control Settings and System Adjustments: Record final control settings and programming, and final tap setting of speaker matching transformers. Record final sound-level measurements and observations.
- ### 3.4 ADJUSTING
- A. Occupancy Adjustments: When requested within [**twelve (12)**] <Insert number> months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two (2)**] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.
- ### 3.5 DEMONSTRATION
- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain services.
1. Schedule training with Owner, through DEN Project Manager, with at least (7) seven days advance notice.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 275119

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SECTION 275123 - EMERGENCY COMMUNICATIONS SYSTEM

THIS SECTION INCLUDES GENERAL REQUIREMENTS FOR THE VOICE PAGING SYSTEM.

NOTE: THIS SECTION COVERS WORK TO BE PERFORMED AT DENVER INTERNATIONAL AIRPORT. THE DESIGN CONSULTANT IS RESPONSIBLE FOR PROVIDING A COMPLETE SPECIFICATION AND CORRELATIVE SPECIFICATIONS AND DRAWINGS, ETC. THE CONSULTANT SHALL ADD TO OR CORRECT INFORMATION CONTAINED HEREIN TO ASSURE THEY AUTHOR A COMPLETE AND CONSTRUCTIBLE SPECIFICATION. CONSULTANT MAY MODIFY TESTING INFORMATION CONTAINED HEREIN, SUBJECT TO REVIEW AND APPROVAL BY DEN.

Revise this Section by deleting and inserting text to meet Project-specific requirements. Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. Section Includes: Microprocessor-switched intercommunications and program systems with the following components:
 - 1. Announcement Control System.
 - 2. Software.
 - 3. Server.
 - 4. Workstation.
 - 5. Visual Display Devices.
 - 6. Monitoring and Testing Systems.
 - 7. Ambient Noise Sensing System.
 - 8. Flight Announcement System.
 - 9. Master Emergency Communication Microphone stations.
 - 10. Microphone stations.

11. Amplifiers.
12. Loudspeakers.
13. Conductors and cables.
14. Raceways.

B. Related Sections:

1. Sections of Division 01 "General Requirements".
2. Sections of Division 26 "Electrical".
3. Sections of Division 27 "Communications".
4. Sections of Division 28 "Electronic Safety and Security".

- C. This section covers the voice paging system, and associated equipment for use in all projects. The Contractor shall provide all skilled labor, material, and equipment for the complete installation of the voice paging system as shown on the drawings and specified herein. The extent of work shall be as shown on drawings, including locations, elevations and details of construction.

Retain paragraph below if Alternates are specified in Division 01 Section 012300 "Alternates" for work in this Section. Coordinate requirements for Alternates with DEN Project Manager.

- D. Alternates: Refer to Division 01 Section 012300 "Alternates" for description of Work in this Section affected by alternates.

1.3 REFERENCE STANDARDS

- A. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents.
- B. A listing of the applicable reference standards is contained in Section 014225 "Reference Standards".
- C. In addition to all applicable local and state codes, the work shall be in accordance with the latest revisions of all applicable standards and specifications, including the following:
1. NFPA: National Fire Protection Association.
 2. NAB: National Association of Broadcasters.
 3. UL: Underwriters Laboratories.
 4. EIA: Electrical Industries Association.
 5. NEC: National Electrical Code.

1.4 PERMITS

Verify that permit and code information below is current.

- A. Any work performed on the DEN PA System shall be permitted as a 3A Permit to the CCD consistent with Appendix K of the 2011 Denver Amendments to the 2009

International Fire Code.

ENGINEER SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS

- A. Provide Submittals in accordance with requirements of Division 01.
- B. Product Data: For each type of product indicated.
 - 1. Technical data on each component.
 - 2. Materials list and backbox schedule (including unique backboxes).
 - 3. Include data substantiating that materials comply with requirements.
- C. Shop Drawings: For emergency communications system. Include plans, elevations, sections, details, spreadsheets and attachments to other work.
 - 1. Shop drawings shall be stamped by an RCCD as part of the submittal.
 - 2. Shop drawing submittals shall be done on the existing DEN as-builts and clouded to show the scope of work. Shop drawings in Auto CADD shall have project specific layer(s) showing new work or modifications on its own layer(s) with the project name.
 - 3. Shop drawings shall be of scale suitable for use for fabrication. They shall show materials, finishes and panel/control markings. Contractor shall make the following shop drawing submittals:
 - a. A complete list of equipment for the systems, including that required for items that are to be fabricated by the Contractor.
 - b. A complete set of detailed technical descriptions describing and illustrating all components and materials.
 - c. A complete set of shop drawings of items that are to be fabricated by the Contractor and/or which the Contractor intends to fabricate or has fabricated, including but not limited to, the custom panels and receptacle plates.
 - d. System block diagrams with provisions for entry of future test results.
 - e. Equipment rack and console layouts.
 - f. Details of cable management and termination in terminal boxes junction boxes and equipment racks.
 - g. Wiring diagrams showing the exact manner in which the Contractor proposes to install the system. Show all switches, modifications to equipment, control circuits, and equipment rack layouts. Show all equipment/apparatus items that are required for performance of the required functions. Include the following:
 - 1) Single-line diagram showing interconnection of components.
 - 2) Cabling diagram showing cable routing.
 - h. Drawings identifying all terminals, wiring color-coding and control functions.

4. Detail equipment assemblies and indicate dimensions, weights, required clearances, method of field assembly, components, and location and size of each field connection. They shall show materials, finishes and panel/control markings.

Retain first subparagraph below for systems with built-in equipment.

5. Include scaled drawings for master microphone station located in fire operation control centers as well as other locations as required that detail built-in equipment.
6. Microphone Station Schedule including the following information:
 - a. Station number.
 - b. Location.
 - c. Station type.
 - d. Station mounting.
 - e. Handset type.
 - f. IP or Analog.
 - g. Identity of associated parent station.
7. Equipment design considerations for future expansion, when indicated.
8. Description of system operation.
9. A complete list of equipment for the systems, including that required for items that are to be fabricated by the Contractor.
10. Equipment rack and console layouts.
11. Zone programming table with microphone station programming for each location.
12. Details of cable management and termination in terminal boxes, junction boxes, and equipment racks.

- D. The data submitted by the Contractor shall be sufficiently detailed to enable the Owner's Representative to determine whether or not the equipment, materials and installation that the Contractor proposes to furnish comply with the requirements of this specification, and whether or not the Contractor's organization is qualified by experience, and by capability of personnel, to execute the work described herein.

1.6 INFORMATIONAL SUBMITTALS

- A. Spreadsheet of all IP devices, their functionality, model number and location with placeholders for Owner to provide IP address, Masking, port assignment, switch name and default gateway assignments. Also include POE power requirements and the equipment room that the supporting network switch is located

Coordinate first paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- B. Qualification Data:
 1. Qualifications shall be provided for installer as required in Qualifications paragraph 1.8.A.
- C. Field Quality-Control Reports. Submit quality reports throughout project as decided in Pre-Construction Meeting. Include communication room conditions, speaker testing

information, infrastructure connectivity quality and power outage coordination to prevent power issues from damaging installed equipment.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For intercommunications and program systems to include in operation and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

Retain subparagraph below for microprocessor-switched equipment.

1. A record of Owner's equipment-programming option decisions.
2. Factory-prepared operation and service manual for each system.
3. Contractor shall provide technical information for all electronic apparatus, including but not limited to schematic diagrams and parts lists, manufacturer's installation instructions, operating instructions and technical specifications.
4. Contractor submittal shall include all system spreadsheets, as-built drawings and, shop drawings prepared and used by the Contractor, as well as those that were not required to be submitted for approval. This shall include, but not be limited to, wiring diagrams, schedules for identification of building wiring and installation details useful to a maintenance technician.
5. Instruction Manuals:
 - a. Provide five (5) hard copies and one (1) electronic copy of an Instruction Manual containing the following:
 - 1) Table of Contents.
 - 2) Instructions for operating the system in all modes of operation and for fulfilling all functional requirements.
 - 3) List of settings and adjustments for semi-fixed controls.
 - 4) Manufacturer's sheets of specifications, operating instructions and service information arranged alphabetically by manufacturer and then by model number.
 - 5) Complete detailed wiring diagrams and one-line diagrams for the "as-built" system in reproducible format.
 - 6) Recommended preventive and remedial maintenance.
 - 7) Complete parts list.
6. Tenant User Manuals:
 - a. Provide ten (10) hard copies and one (1) electronic copy of Tenant User Manual. They shall include the following information:
 - 1) Basic description of equipment and its functions.
7. As-Built Documents: Two (2) weeks prior to final acceptance testing, the Contractor shall provide two (2) sets of "as-built" prints and one (1) electronic copy of the following:
 - a. System block diagrams.

- b. Equipment rack and console layouts.
 - c. System wiring diagrams.
 - d. Test reports, as specified herein.
 - e. Written warranty, as specified herein.
 - f. Asbuilt drawings in Auto CADD shall have project specific layer(s) showing new work or modifications on its own layer(s) with the project name. The intent is to provide a clear asbuilt of what is new, review the information and then allow DEN to import the new layer(s) into their master ECS asbuilts.
8. Project Record:
- a. Provide As-Built drawings.
 - b. Provide four (4) cd's, or format as requested by DEN Project Manager with electronic files of project information to DEN.
 - c. Provide one-half sized set to keep in the equipment room, three (3) full-size sets and four (4) cd's, or format as requested by DEN Project Manager with electronic files to DEN.
9. Field Documentation:
- a. Provide system drawings for each new communication room for simple troubleshooting of system during break in period.
 - b. Provide laminated information sheets of new zone or message information for new operating positions at the gates. Include simple microphone station use directions.

1.8 QUALITY ASSURANCE

A. Qualifications:

1. Manufacturers' Qualifications: Paging control system, microphone stations, amplifiers, ambient noise system equipment, monitoring hardware: Innovative Electronic Designs, Inc. (IED).
2. Contractor's Qualifications: The ECS shall be installed by a Contractor who has been regularly engaged in the installation of electronic equipment for at least five (5) years and certified to install IED Voice Paging Systems. The Contractor shall be experienced in all aspects of this work and shall be required to demonstrate direct experience on recent systems of similar type and size.
3. A resume of qualification shall be submitted with the Contractor's bid indicating the following:
 - a. A list of recently completed projects of similar type and size with contact names and telephone numbers for each.
 - b. A technical resume of experience for the Contractor's Engineer and on-site installation foreman who will be assigned to this project.
 - c. Similar documentation will be required of any subcontractor who will assist the Contractor in performance of this work. All proposed subcontractors must demonstrate equal or superior experience or technical qualifications to the Special Systems Contractor in order to contract for any part of the

installation or testing of the system.

4. Contractor shall be an authorized installer and dealer of the specified equipment with a service facility within 100 miles of the project site.
5. Contractor shall submit proof that the primary system programmer to be used in the programming of the systems has attended a programming school hosted by the manufacturer of the computerized systems to be provided under this section within the past two years. Attendance shall have been within one (1) year prior to the date of project notice to proceed.

If an independent testing agency is required, see Division 01 Section "Quality Requirements" for general testing and inspecting agency qualification requirements.

Retain first paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Division 01 Section "Quality Requirements," which also includes the definition for "NRTL" (nationally recognized testing laboratory).

6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
7. Comply with NFPA 70.
8. Microprocessors, transistors, capacitors, resistors, integrated circuits, printed circuit boards and other components shall not be operated to exceed their rated values. Design system for 24-HR continuous operation.

Coordinate warranty requirements with DEN Project Manager.

B. Warranty:

1. Provide a written two (2) year warranty, signed by the Contractor, due on the date of the final acceptance.
2. Include the following provisions:
 - a. Warrant all equipment and the installation to be free of faulty workmanship.
 - b. Warrant all components, including solid state devices, to be free of defects for a period of two (2) years from the date of final acceptance.
 - c. Paint and exterior finishes, fuses and lamps are excluded from the above warranty, except when damage or failure results from defective materials or workmanship covered by the warranty.

1.9 COORDINATION

- A. Coordinate layout and installation of ceiling-mounted speaker and ambient noise sensor microphones with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
- B. Coordinate installation with existing DEN Fiber Optics network(s), and all other existing DEN systems. Notify DEN Project Manager promptly of any conflicts that are identified.

Extra stock materials may not be allowed on publicly funded projects.

Coordinate extra stock submittal requirements with DEN Project Manager.

1.10 EXTRA STOCK

- A. Contractor shall supply spare parts to the Owner in the amount of 10% of the equipment installed under this contract or one of each item, whichever is greater.
- B. All spare stock shall be delivered in the manufacturer's standard shipment packaging and turned over to the DEN Project Manager, and each item shall be clearly identified as to the package contents and what project or area the item was used. Speaker types used that are not listed shall be provided with a unique identifier. Include the following:
 - 1. Storage cabinets.
 - 2. Controller Plug-in Cards (each type).
 - 3. Microphone Stations (of each type, Podium, Jetway, Main).
 - 4. Microphone Handsets.
 - 5. Type S1 Loudspeaker.
 - 6. Type S2 Loudspeaker.
 - 7. Type S3 Loudspeaker.
 - 8. Type S4 Loudspeaker.
 - 9. Type S5 Loudspeaker High Frequency Horn Driver Diaphragm Replacement Kits.
 - 10. Type S5 Loudspeaker 10-inch Midrange Cone Drivers.
 - 11. Type S6 Loudspeaker.
 - 12. Type S7 Loudspeaker.
 - 13. Type S8 Loudspeaker.
 - 14. Type S9 Loudspeaker.
 - 15. Type S10 Loudspeaker.
 - 16. Type S11 Loudspeaker.
 - 17. Other type of loudspeakers.
 - 18. Amplifier Cards (of each type used).
 - 19. Fuses (of each type/size used in system).
 - 20. Connectors (of each type used in system).

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

1.11 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All materials, equipment and apparatus provided shall be new and of the latest design or model offered for sale by the manufacturer.
- B. Acceptability for use in the systems shall be determined by the DEN Project Manager. Such items shall be installed only after receipt of written approval of the DEN Project Manager.

2.2 ENVIRONMENTAL CONDITIONS

- A. The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:
 - 1. Location: (Indoors/Outdoors).
 - 2. Altitude: 5,500 feet (1677 m) above sea level.
 - 3. Ambient Temperature Range: Minus 30 deg F (minus 35 deg C) to 120 deg F (49 deg C).

2.3 SYSTEM DESCRIPTION

- A. Components provided under this Contract shall be compatible with and connected to the existing Innovative Electronic Designs, Inc. (IED, Inc.) IED 500 Mainframe located in the center core of each concourse, Concourse B RJ facility, South Terminal, and Room 45B08 in the Terminal.
- B. Remote amplification rooms shall be configured to match existing rooms.
- C. The Emergency Communications System (ECS) provides paging and background music to all public areas of the airport facilities with the exception of the existing AGTS platforms that the IED system interfaces through the existing train announcement system. A line level output and dry contact closure cause tenant sound system announcements to mute and allow an emergency message to be sent. Voice paging must be provided to all non-public support areas and parking areas. The system is used for general announcements and emergency announcements throughout Concourses A, B, and C, Terminal, AGTS Tunnel, Office Tower and Central Plant.
- D. The emergency announcements functions of the system provide audio evacuation messaging and announcements for the airport. All changes to the system shall be coordinated with the airport and Denver Fire Department before the work begins. A pre-construction meeting shall be required to coordinate outages, schedules, hours of work, backup plans, system faults and system sets and all other aspects of the work. All ECS projects require Fire Alarm Permits as per article 1.4.
- E. The system provides ambient noise sensors and monitoring which allow automatic level control of individual loudspeaker zones located in public areas.

- F. The monitor/test system is capable of monitoring and/or testing all audio or DC signal, speaker level outputs, or system wiring to insure integrity and reliable operation. All line-level zone inputs and outputs, equalizer inputs and outputs, and amplifier inputs and outputs must be monitored for correct operation.
- G. The ECS shall be integrated with and supplement the facility Fire Alarm System (FAS). The interface with the FAS will enable the use of the ECS's power amplifiers, and loudspeakers in public areas. The FAS provides the messages via FAS contact closures that enable the ECS to broadcast incident-specific messages into pre-designated audio zones.
- H. The output of each amplifier must go through a terminal cabinet. This network allows loudspeaker loads to be disconnected from the amplifier outputs for manual measurement of load impedances by maintenance personnel. This shall serve as a demarcation point for trades to test their portion of the work independent of each other.
- I. All loudspeakers operate on a 70 Volt distributed system. The loudspeakers shall be grouped in modular zones allowing maximum flexibility for paging area assignment. Loudspeaker types shall match DEN current standards to the greatest extent possible allowing existing service stock to be utilized.
- J. All Podium microphone stations must be manufactured by IED, Inc., and equipped with microphone, twelve-button control input, alphanumeric display or LCD display, and accept up to three optional slave microphone handset stations. Airline Ticketing counters and Baggage Claim Office microphone stations must be equipped with a single microphone handset, twelve-button control input and alphanumeric or LCD display. Jetway microphones shall be either a single handset microphone station with limited four-button control and status indicators or, a sidekick microphone handset station that is connected to the Podium microphone station. Match existing configurations for operator continuity between areas.
- K. All microphone stations, ambient noise sensors, and loudspeakers shall be hardwired to the local P.A. Rooms. Local P.A. Rooms within a building are interconnected via copper and fiber-optic cable to the building ECS Control Room. Spare copper and fiber-optic cable for new installations may not exist. Contractor to verify the existence of available cable and cable raceways/conduit. Verify cable requirements with the understanding that fiber optic cabling used for the system is a hardened, redundant cable infrastructure designated as the part of the fire alarm infrastructure .
- L. Network Equipment and Design (Directions to Designers) Designers shall meet with DEN Technologies network engineers to determine specific network equipment, architecture and attachment points that are specific to the Project. The DEN network engineers shall provide a specific bill of material for the ECS network expansion including manufacturer, model number and description for each device. The DEN network engineers shall also work with the designer to create a diagram showing fiber interconnections between new network devices and attachment points to the existing ECS network. The architecture of the ECS equipment shall be shown on the contract drawings including uplinks to specific ports in the existing ECS network. The network bill of material shall be included in the Part 2 Products section of this Section. First year Cisco SmartNet coverage shall be included for all devices not covered under

Cisco's limited lifetime warranty. No substitutions shall be allowed unless approved by DEN Technologies. Designer shall instruct Contractor to deliver Switches and other network equipment to DEN Technologies with signed receipt. DEN Technologies shall configure this equipment, label equipment with switch names and place equipment back in original factory boxes. City asset tags shall be applied to equipment where applicable. Once configuration work is complete, the Contractor shall pick up the equipment and provide a signed receipt to DEN Technologies network staff. The Contractor shall then install the equipment in the relevant room(s) and interconnect the equipment as indicated in the architecture diagram in the contract drawings.

- M. DEN Network Engineer will inspect the installed equipment and activate ports to join the new network equipment to the production ECS network. Once this occurs the DEN Technologies network staff will operate and maintain the new devices as an integral part of the production ECS network.
- N. Terminal cabinets are and shall be used for breakout of speaker wiring home to the equipment racks.
- O. Tenant ECS requirements: Refer to Emergency Voice Paging System Tenant Revision 275114. It is mandatory for at least one loudspeaker be located in every room and corridor with uniform coverage required in larger spaces.
- P. Visual Information System (VIS) shall be provided as required. VIS shall provide visual features of the system to be utilized for Visual paging, way finding, advertising, Emergency visual communications, Flight Information System, Train Information Display System, baggage information display systems and gate information display systems.
- Q. Flight Announcement System (FAS) shall be provided as required. System shall interface to Owner provided AIDX feed for data to populate the Flight Announcement System with information to automatically or manually announce flight messages at gate areas. System shall support Visual paging and graphics that are synchronized with the announcement in multiple languages as identified in these specifications.

2.4 SYSTEM OPERATION

- A. The following functional capabilities are required for the DEN ECS:
 - 1. The system is capable of automatic or manual audible testing of microphone inputs, IED headend audio outputs, ambient noise sensor frame outputs, equalizer outputs amplifiers and loudspeaker systems.
 - 2. In all Public Areas, the system has the capability of sensing ambient noise sound levels and adjusting loudspeaker zone signal levels up or down accordingly to maintain good speech intelligibility.
 - 3. All inputs and outputs shall be monitored for correct operation. Audio levels of each logical system parameter shall be monitored including but not limited to Microphone Stations, DSP, Amplifiers, Speaker lines with impedance and ground faults, and ambient noise system. Other data information of equipment and power monitoring shall be included in monitoring when available. All detected

faults shall be displayed on the ECS standard and remote CPU's.

2.5 ANNOUNCEMENT CONTROL SYSTEM

- A. The ACS shall provide system setup, control and messaging for the PA system and integrate with the existing systems at DEN in order to provide a fully functioning and monitored system.
- B. ACS shall be capable of managing 240 microphone stations and 65,536 zone outputs per unit.
- C. ACS shall provide 8 x 8 message system expandable to 64 x 64 of pre-recorded messages via the use of additional message controller(s).
- D. ACS shall provide up to 180 simultaneous announcements and messages over a single LAN or VLAN.
- E. ACS shall provide the following:
 - 1. Fully redundant architecture over standard LAN.
 - 2. System backup and restoration configuration files.
 - 3. Built-in wizards for initial setup.
 - 4. Integrated visual paging support.
 - 5. Seamless integration to legacy 510/520ACS.
 - 6. Event messaging allowing multiple actions or events to be triggered.
 - 7. Multi-Language support for different language packages or second language requirements as defined in the specification.
- F. Manufacturer:
 - 1. IED 1100 Or 1200 GlobalCom with vACS1000 Software. Include IED Lifeline Backup GlobalCom for each primary Globalcom.
 - 2. **<Insert manufacturer>**
 - 3. or approved equal.

2.6 DIGITAL AUDIO BRIDGE (DAB)

- A. The DAB shall provide Cobranet audio to two separate networks. The DAB shall include:
 - 1. Redundant connections for both networks.
 - 2. 8 channels of bidirectional Cobranet audio.
 - 3. Cobranet expansion beyond layer 2 network.
- B. Manufacturer:
 - 1. IED 100DAB.
 - 2. **<Insert manufacturer>**
 - 3. Or approved equal

2.7 AMBIENT NOISE SENSING SYSTEM

A. Ambient Noise Sensor Collector shall be provided for noise sensor termination from the field devices. Collector shall be used with Titan 9160 amplifier system exclusively. Collector shall:

1. Be PoE device or connect to local 48Vdc power supply.
2. Connect 32 ambient noise sensors on each frame.
3. 1 RU and rack mountable.

B. Manufacturer:

1. IED T9032NS with IED 540S-2 Sensor on 2-Gang Plate.
2. **<Insert manufacturer>**
3. or approved equal.

2.8 AUTOMATIC TEST AND MONITOR SYSTEM (New System)

A. The Automatic Test and Monitor System shall provide for self-diagnostics that operate in real time under software control. This self-testing shall include testing of logic, audio operation, power supplies and power amplifiers. This test shall be automatic and utilize only one system as the interface for the test. Results shall be logged on the PC and a fault list generated that can be printed for the Owner Maintenance staff.

B. System shall report results of actual audio signals being routed through the entire system as well as speaker impedance load changes, speaker ground faults and End of Line speaker faults.

C. System faults shall be reported through software with clearly labeled information and through external interfaces to other systems, via RSS feeds, contact closures or network messages.

D. System shall collect information from internal IED test and monitoring devices in hardware and report faults or settings.

E. System shall allow circuit testing and reset of corrected fault.

F. Manufacturer:

1. 610 Monitor/Test Software for the system server.
2. 596SGFI Dual Channel sensors for speaker lines.
3. 596EOL Speaker end-of-line sensor as required by Designer.
4. **<Insert manufacturer>**
5. or approved equal.

2.9 MICROPHONE PAGING STATIONS (New Installations)

A. General:

1. Microphone stations shall originate announcements into zone groups as determined by the DEN Project Manager. Any microphone page station shall be capable of being programmed into any zone group. Microphone stations shall be capable, when so programmed, of making emergency zone group announcements, terminal zone group announcements, local zone group announcements, and multi-local group announcements. When so programmed, they shall also be capable of performing any or all of the control functions for pre-recorded and assembled messages. These control functions shall include initiating a playback sequence, interrupting a playback sequence, recording a message, monitoring a message, or playing back a message to its own multi local group, or to a terminal zone group instead of to the zone map assigned to that message. The microphone stations shall include a microphone; either handheld, handset or gooseneck-mounted type. Each microphone station shall have buttons for zone group selection to activate that microphone station for announcements into pre-programmed zones. Green and Red LED's shall indicate ready or busy respectively. Any 5 second pause after the green LED has illuminated shall terminate the announcement. Each station shall include its own microphone preamplifier, test oscillator, compressor, and balanced output line amplifier for driving long lines without appreciable high frequency loss. The ACS microprocessor, under software control shall continuously interrogate all active microphone and telephone page stations for requests.
 2. Specifications – Total System, Direct Microphone Station input to Zone Output:
 - a. Frequency Response: 0.5dB 20Hz - 20kHz.
 - b. Total Harmonic Distortion (THD): < .05% @ +24dBm 20Hz - 20kHz.
 - c. Noise Referred to Input: -125dBv 20Hz - 20kHz.
 - d. Signal-to-Noise (limited by input amp): > 80dB.
 - e. Gain, Adjustable at each paging station: 65dB Maximum.
 - f. Maximum Output Level: +24.0dBm.
 - g. Normal Output Level: +2.0dBm.
 - h. High-pass filter in mic station defeated.
- B. Full function Communication Stations: Stations shall have a 12-button keypad for data entry, (8) soft function keys and a color graphical LCD. The station shall be a network appliance with control and CobraNet audio communicating on the audio network. Connection to the system shall be 100BaseT with power provided by a PoE switch port or PoE mid span power. Microphones shall be provided as handheld or gooseneck as required. Each microphone shall utilize a magnetic mount and include a line amplifier in the microphone shell to eliminate microphone signal levels beyond the microphones. Each station shall support the connection of up to three 528SK Sidekick, or 500FMC-H remote stations. Stations shall be provided in vertical, horizontal, surface, flush, or desktop as noted on the drawings and based on the mounting situation required.
1. Acceptable Products:
 - a. Horizontal Communications Station:
 - 1) IED 528HFM-H.
 - 2) <Insert manufacturer>
 - 3) or approved equal.

- b. Vertical Communications Station:
 - 1) IED 528VFM-H.
 - 2) **<Insert manufacturer>**
 - 3) or approved equal.

- C. Microphone Communication Station Enclosures: For station mounting locations requiring desktop, angled vertical, or angled horizontal, provide factory enclosures to match the finish of the station. Enclosures shall be non-metallic and include rubber feet.
 1. Acceptable Products:
 - a. IED 528VBB or 528HBB.
 - b. **<Inset manufacturer>**
 - c. or approved equal.

- D. Master Emergency Communications Systems Microphone Station: Microphone station shall be complete with integral 17- inch touchscreen monitor computer workstation and graphics user interface per DEN Standards. MECSMS shall provide:
 1. Standard Microphone station as required.
 2. Software GUI developed for project.
 3. "A" panel software application for microphone zone selection and message playback.
 4. Message selection and de-selection.
 5. Live page capabilities.
 6. Match Existing Units.
 7. Acceptable Products:
 - a. IED 528 series with touchscreen workstation IED 591D.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

- E. Expansion Microphone Communication Station: Expansion stations shall act as an intelligent slave station to a full function station. Expansion stations shall include (4) soft function keys that can be programmed for operations independent of the master station to which it is connected. This shall allow flight announcements and other cued messages to be controlled from the expansion location. Microphones shall be provided as handheld and include a line amplifier in the microphone shell to eliminate microphone signal levels beyond the microphone. The station shall mount in a standard 2-gang wall box and connect to the full function station with Cat5e cable and RJ45 modular connectors.
 1. Acceptable Products:
 - a. Expansion Communications Station IED 528SK.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

- F. Rack Communications Station: Rack Communication Stations shall have a 12-button keypad for data entry, eight (8) soft function keys and a color graphical LCD. The station shall be a network appliance with control and CobraNet audio communicating on the audio network. Connection to the system shall be 100BaseT with power provided by a PoE switch port or PoE mid span power. Microphones shall be handheld and utilize a magnetic mount. It shall include a line amplifier in the microphone shell to eliminate microphone signal levels beyond the microphones. The station shall include a flush speaker for monitoring selected audio. The speaker shall be powered by an 8-watt power amplifier and include a panel volume control. The station shall use no more than four (4) standard rack units.

1. Acceptable Products:
 - a. IED 528SRM-H Rack Communications Station.
 - b. <Insert manufacturer>
 - c. or approved equal.

2.10 EXTERNAL SYSTEM INTERFACE

- A. An external interface shall be provided to allow interfacing contact inputs or outputs into the ACS system from the Fire Alarm System, Voice Evacuation System, or other systems. Each interface shall provide 64 input closures and output closures or voltage ports in groups of 8.
- B. Acceptable Products:
1. IED 508BI/O Interface Station (Existing System Modification).
 2. or IED T9032LVIO, T9064LVIO, PoE required.
 3. or IED T9040NLR.
 4. <Insert manufacturer>
 5. or approved equal (model and quantity as required).

2.11 POWER AMPLIFIERS

- A. Integrated Digital Power Amplifier System (IDPAS): The Integrated Power Amplifier System shall provide DSP processing and power amplification for up to (16) zones in a single modular mainframe.
1. Digital Audio Network Interface: The network interface shall receive (32) dynamic assigned audio channels from the ACS via the Ethernet Network. Control for the IDPAS and monitoring shall be included on the network. The NIC shall provide dual outputs to support a redundant network.
 2. Zone Manager: The IDPAS shall provide zone management for (16) channels as directed by the ACS. Channel management shall be structured to utilize the minimum channels necessary on the network to support paging, messaging and background music activity for any combination of zones.
 3. DSP Processing: The IDPAS shall include digital signal processing for (16) channels of audio. Each channel shall include (9) bands of parametric

- equalization, time delay, ambient analysis control, (7) monitoring points, and (7) testing points. Complete setup and control software shall be integrated within the Enterprise Software and available on the network for configuring, controlling, monitoring, and testing the DSP for each channel.
4. Ambient Analysis and Control: The Ambient Analysis System shall adjust signal levels in response to either ambient noise levels or computer commands. The system shall operate in real time and shall not be a "sample and hold" system. The system shall include an automatic calibration sequence. All setup, configuration and monitoring controls shall be software based with the ability for multiple sensors averaged to control a single channel(s) or for a single sensor to control multiple channels. The sensors shall utilize control signaling and levels that allow co-locating with the speaker cable for cable routing efficiency. Three (3) modes of operation shall be possible:
 - a. Automatic: Changes attenuation levels in response to noise levels reported by remote sensors.
 - b. Slaved: Changes attenuation levels based on remote sensors of an automatic channel.
 - c. Fixed: Fixed attenuation as set by the computer and user.
 5. Power Amplifier Cards: Each IDPAS mainframe shall be designed to accept (9) amplifier cards. Each card shall be removable and replaceable without disabling or interfering with the operation of the DSP or other power amplifier cards. The amplifier cards shall be available as dual 200-watt cards or single 400-watt cards, and shall be of a high efficiency design to maintain a minimum of 78% efficiency at 100% output. The mainframe shall support simultaneous use of (8) amplifier cards (16 channels) plus the hot spare card. Provide appropriate card models as required.
 6. Automatic Backup Amplifier Switching: The 9th power amplifier slot shall be reserved for automatic backup amplifier switching. A matching amplifier card shall be installed as a hot spare amplifier in the event of failure of one of the primary amplifiers. The system shall detect a failure of an amplifier card and shall electronically replace that amplifier without loss of service. Switching shall result in no loss or change of source or destination routing. Detection and switching shall take place in less than 2 seconds. A failure shall be reported immediately to the fault logging system.
 7. Internal Monitoring: Each IDPAS shall include an internal audio monitoring buss with software selected switching. This monitor shall allow selection of a monitor point from the control software to allow visual and audio monitoring of the channel network input, channel direct input, ambient channel output, EQ output, amplifier input, amplifier output, and speaker load monitor for each of the (16) channels. This feature shall operate simultaneously and independent of the automatic testing.
 8. Automatic Testing: The automatic testing system shall locally test and process audio test signals through the IDPAS. These tests may be done manually on demand for any single test point as well as globally in the mainframe on a completely automated basis during the day. The test points duplicate those of the monitoring points above with a testing resolution of 0.5 dB.
 9. Local Inputs: The IDPAS shall include (16) analog inputs for local zone program sources or BGM. One channel shall be configurable as a backup emergency

input usable in the event of a network failure.

a. Acceptable Products:

- 1) Integrated Amplifier Mainframe: IED T9160L, or approved equal.
- 2) Dual 200 Watt 70-Volt Amplifier Card: IED T6472L, or approved equal.
- 3) 400 Watt 70-Volt Amplifier Card: IED T6471L, or approved equal.
- 4) **<Insert manufacturer>**
- 5) or approved equal.

2.12 END OF BRANCH SUPERVISION

A. The end of branch supervision module shall enhance the speaker line supervision functions of the system. The module shall be capable of monitoring multiple end of branch locations on a single circuit. Module shall include:

1. Supervision of 70 and 100 volt speaker lines without the need for a return wire.
2. Unique ID number for identification in the system monitoring software.
3. Proof that cable is intact to the end of the circuit.

B. Manufacturer:

1. IED T597EOB, IED T596EOL (for end of Line).
2. **<Insert manufacturer>**
3. Or approved equal.

2.13 UNINTERRUPTABLE POWER SUPPLY (UPS)

A. Provide UPS in accordance with Section 263353 "Static Uninterruptible Power Supply".

B. A UPS shall be supplied for critical components of the PA system including the ACS to insure uninterrupted service and control of the system.

C. UPS shall be rack mounted device with four (4) hours of operation of full load and monitor LAN connection for supervision of unit.

1. Manufacturer:

Verify requirements specified in Section noted in paragraph below.

- a. See Section 263353 "Static Uninterruptible Power Supply" for latest standard.

2.14 VISUAL DISPLAY DEVICES

A. General: Provide server, Visual system software, updates to Enterprise Software,

initial content, hardware and all components as required for a fully operating visual information system based on requirements in specification and on contract drawings.

- B. System Server: Server shall provide information to visual displays through the network. Server shall include all software and interfaces as required to access AIDX database and operate Visual Systems. Server shall include:
1. Window 2008 Server software 32 bit.
 2. Intel Quad Core processor 2.93Mhz.
 3. Minimum 4GB- expandable to16GB memory.
 4. Raid 5 with 1TB 7.2K RPM Sata drives.
 5. Acceptable Products:
 - a. Dell R710 or latest.
 - b. **<Insert manufacturer>**
 - c. or approved equal.
- C. Visual Display Device (VDD) Type 1: The VDD shall be a 40- inch LCD flat screen display and meet the following minimum specifications:
1. Size: 40- inch Diagonal.
 2. Resolution: WXGA.
 3. Pixels: 1,366 x 768.
 4. Pixel Pitch: 0.648 mm.
 5. Number of colors: 16.7 Million.
 6. Contrast Ratio: 2,000:1.
 7. Brightness (cd/m2): 700.
 8. Response Time (ms at 25 degrees C): 8.
 9. Viewing Angle: 89 degrees.
 10. Acceptable Products:
 - a. Samsung M40C 40-inch LCD Display.
 - b. **<Insert manufacturer>**
 - c. or approved equal.
- D. Visual Display Device Mount: Provide a display mount for each VDD. The mount shall provide a secure and solid installation to minimize the chance of tampering. The mount shall allow positioning and tilting to optimize the viewing angle at each installation location. The mount shall provide for easy removal of the display by authorized personnel and provide for integral installation of the DDC if applicable.
- E. Acceptable Products:
1. Chief Manufacturing MCS Series Ceiling Mount, or approved equal.
 2. Chief Manufacturing MTR Series Ceiling Mount, or approved equal.
 3. Chief Manufacturing MAC-251 Flat Panel CPU Mount, or approved equal.
- F. Visual Display Device Controller (DDC): The DDC shall be a PC based controller equipped to control one or two (as designated on the drawings).

- G. Visual Display Devices. Provide the most recent configuration as recommended by the system manufacturer meeting the following minimum specifications:
1. Intel Pentium D Processor 925 (3.00GHz, 2X2M, 800MHz FSB).
 2. File System: NTFS File System for all Operating Systems.
 3. Memory: 2.0GB DDR2 Non-ECC SDRAM, 667MHz, (2DIMM).
 4. Video Card: 256MB ATI Radeon X1300PRO, Dual Monitor, DVI to dual VGA.
 5. Boot Hard Drives: 80GB SATA 3.0Gb/s and 8MB DataBurst Cache.
 6. Operating System: Genuine Windows(tm) XP Professional, SP2, x32.
 7. Removable Media Storage Devices: 24X Slimline CDRW/DVD Combo.
 8. Acceptable Products:
 - a. Dell OptiPlex Small Form Factor PC.
 - b. <Insert manufacturer>
 - c. or approved equal.

2.15 LOUDSPEAKERS

- A. General: Loudspeaker design shall be provided to meet the requirements of the 2010 Edition of NFPA72 - 18.4.10. Match Existing speakers in areas if Project includes additions or remodels.
- B. Type S1, Full-Range Paging Loudspeaker, Flush Mount with grille:
1. Loudspeaker Type S1 shall be a 6.5- inch diameter coaxial device UL 2043 with a minimum input sensitivity of 88 dB measured at 1 meter with 1 watt input from 500 Hz to 2.5 kHz, frequency response shall be ± 7 dB, 63 Hz to 20 kHz and the coverage angle shall be a nominal 90 degrees conical from 500 Hz to 2.5 kHz. The loudspeakers shall be rated for 32 W minimum and shall include a 70 V line matching transformer, with 0.5 dB maximum insertion loss over the frequency range of 100 Hz to 15 kHz and selectable level taps at 2, 4, 8, 16 and 32 watts, which shall be wired in parallel with the voice coil. Type S1 loudspeakers shall be suitable for mounting in suspended tile or drywall and shall be an integrated flush mounted loudspeaker enclosure, 8.5- inches minimum depth x 12.5- inches wide.
 2. These loudspeakers shall be utilized in public areas with suspended tile or drywall ceiling height of 15 ft. or less.
 3. Manufacturer:
 - a. Atlas FAP62T with integrated back can, grill and suspension system.
 - b. <Insert manufacturer>
 - c. or approved equal.
- C. Type S2, Full-range Paging Loudspeaker, Flush Mount behind perforated metal ceiling:
1. Loudspeaker Type S2 shall be a 4- inch diameter coaxial device with a minimum input sensitivity of 88 dB measured at 1 meter with 1 watt input from 500 Hz to 2.5 kHz, frequency response shall be ± 7 dB, 75 Hz to 20 kHz and the coverage angle shall be a nominal 90 degrees conical from 500 Hz to 2.5 kHz. The

loudspeakers shall be rated for 16 W minimum and shall include a 70 V line matching transformer, with 0.5 dB maximum insertion loss over the frequency range of 100 Hz to 15 kHz and selectable level taps at 1, 2, 4, 8 and 16 watts, which shall be wired in parallel with the voice coil. A mounting ring shall be provided to secure the loudspeaker to the enclosure. Standard grilles will not be used behind perforated metal. All other specified requirements apply as stated.

2. These loudspeakers shall be utilized in public areas with perforated metal ceiling at a height of 15 ft. or less.
3. Manufacturer:
 - a. Atlas FAp42T and support.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

D. Type S3, Two-way Curbside Paging Horn:

1. Loudspeaker Type S3 shall be a two-way device with a compression driver and folded high frequency horn, coupled through a crossover network to a horn-loaded woofer. The frequency response shall be ± 5 dB, 190 Hz to 18 kHz with low frequency cut-off at 200 Hz. The input sensitivity shall be 111 dB at 1 meter with 1 watt pink noise input from 400 Hz to 5 kHz. The loudspeaker shall be rated for 30 W with 250 Hz to 5 kHz pink noise signal with a 6 dB crest factor for a period of eight hours. The low-frequency horn shall be constructed of reinforced fiberglass and the high frequency horn of die-cast aluminum finished in white. The horn shall produce a 63 degree horizontal by 85 degree vertical coverage pattern at 2 kHz. The loudspeaker shall be provided with a 70 Volt line matching transformer with 3.75, 7.5, 15 and 30 watt taps and bracket to allow aiming. The loudspeaker shall be suitable for mounting to a 4- inch octagonal electrical box.
2. These loudspeakers shall be utilized on Terminal levels 4, 5 and 6 curbsides.
3. Manufacturer:
 - a. Penton MSH30T.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

E. Type S4, 12- inch Coaxial Loudspeaker:

1. Loudspeaker Type S4 shall be a high quality two-way loudspeaker system, consisting of a constant directivity horn, coaxially mounted in front of a cone transducer. The overall frequency response shall be ± 3 dB, 100 Hz to 15 kHz and the loudspeaker shall be rated for 150 W continuous pink noise. The low frequency transducer shall be 12- inches in diameter with an input sensitivity of 99 dB at 1 meter with 1 watt averaged from 500 Hz to 2.5 kHz. The high frequency driver/horn shall have a symmetrical coverage pattern of 90 degrees between 1 kHz and 10 kHz and a sensitivity of 110 dB at 1 meter with 1 watt input averaged from 2 kHz to 10 kHz. Type S4 assemblies shall be provided with a passive crossover with a crossover frequency of 1.5 kHz. A 70 Volt line matching transformer, with 0.5 dB maximum insertion loss over the frequency range of 100 Hz to 15 kHz and 7.5, 15, 30 and 60 watt taps, shall be wired in

parallel with the voice coil. The assembly shall be suitable for mounting in a (3) cubic foot square enclosure provided under another contract. A square 22 gauge steel grille shall be provided which can be mounted to enclosures in the Terminal airline ticketing areas or in the Concourse ceilings.

2. These loudspeakers shall be flush mounted above the airline ticket counters in the Terminal and flush mounted in the Mezzanine level ceiling structure down the center of the Concourses at a height of approximately 32 ft.
3. Manufacturer:
 - a. Atlas 12CX with Q4812 Back box and mounting hardware.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

F. Type S5, Ceiling Loudspeaker

1. Loudspeaker Type 5 shall be a two-way coaxial loudspeaker with a constant directivity horn mounted in a backcan with supports and grill assembly. Unit shall be flush mounted in ceiling and supported with a safety cable to structure above besides normal means and methods. Speaker shall be 92dB 1W/1M with a frequency response of 60Hz 0- 15kHz +/- 5 dB. Speaker shall have a an internal 70/100 volt transformer with taps of 7.5, 15, 30 and 60 watts including an 8 ohm setting.
2. These speakers shall be installed in new high ceiling areas in lieu of the 12- inch speakers in the center of the concourses.
3. Manufacturer:
 - a. Atlas FAP8CXT with mounting hardware.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

G. Type S6, Paging Horn:

1. Loudspeaker Type S6 shall be a high power paging horn consisting of a compression driver and an aluminum re-entrant horn flare with a symmetrical dispersion angle of 100 degrees. The frequency response shall be ± 10 dB, 300 Hz to 6,500 Hz at the minimum, with a sensitivity of 107 dB at 1 meter with 1 watt 1 kHz input. Type S6 units shall have a power rating of 30 W and shall be supplied with a transformer with 4, , 7.7, 15 and 30 watt taps. An adjustable mounting bracket shall be provided which is suitable for mounting to a 4- inch octagonal electrical box and allows aiming of the device.
2. These loudspeakers shall be used in the Terminal Parking Garage, the AGTS Tunnel, Central Plant, mechanical rooms and other high noise environments.
3. Manufacturer:
 - a. Atlas AP30T with APXB-N Base.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

H. Type S7, Paging Horn with Dual Horn Flares:

1. Loudspeaker Type S7 shall be a high power paging horn consisting of a single compression driver, coupler and two aluminum re-entrant horn flares with a symmetrical dispersion angle of 100 degrees. The frequency response shall be ± 10 dB, 250 Hz to 12,500 Hz with a sensitivity of 101 dB at 1 meter with 1 watt input swept from 500 Hz to 2.5 kHz. The loudspeakers shall have a minimum power rating of 30 W and shall be provided with a 70 Volt line matching transformer wired in parallel with the voice coil with 4, 7.5, 15 and 30 watt taps. An adjustable mounting bracket shall be provided that is suitable for mounting to a 4-inch octagonal electrical box and allows aiming of the device.
 2. These loudspeakers shall be used in the AGTS Tunnel and in the Central Plant.
 3. Manufacturer:
 - a. Atlas APT-34AT with APXB-N Base.
 - b. **<Insert manufacturer>**
 - c. or approved equal.
- I. Type S8, 4-inch Paging Loudspeaker, Flush Mount:
1. Loudspeaker Type S8 shall be a 4- inch general paging loudspeaker with a frequency response of ± 1.5 dB, 100 Hz to 10 kHz, an input sensitivity of 94 dB at 1 meter with 1 watt input swept from 500 Hz to 2.5 kHz. The loudspeaker shall be rated for 15 W minimum and shall be supplied with a 70 Volt line matching transformer with 0.5, 1, 2 and 4 watt taps. The insertion loss of the 70 Volt transformer shall be 1 dB maximum over the frequency range of 100 Hz to 12 kHz. The loudspeakers shall be suitable for recess mounting in a standard 4-inch recessed mounted loudspeaker round enclosures provided under another contract. A white, 22 gauge steel loudspeaker grille shall be provided.
 2. These loudspeakers shall be flush mounted in suspended tile and drywall ceilings in non-public areas of the Airport buildings.
 3. Manufacturer:
 - a. Atlas FC104T72 with Backcan, support mounting hardware and baffle.
 - b. **<Insert manufacturer>**
 - c. or approved equal.
- J. Type S9, 4-inch Paging Loudspeaker, Surface Mount:
1. Loudspeaker Type S8 shall be a 4-inch general paging loudspeaker with a frequency response of ± 1.5 dB, 100 Hz to 10 kHz, an input sensitivity of 94 dB at 1 meter with 1 watt input swept from 500 Hz to 2.5 kHz. The loudspeaker shall be rated for 15 W minimum and shall be supplied with a 70 Volt line matching transformer with 0.5, 1, 2 and 4 watt taps. The insertion loss of the 70 Volt transformer shall be 1 dB maximum over the frequency range of 100 Hz to 12 kHz. The loudspeakers shall be suitable for recess mounting in a standard 4-inch recessed mounted loudspeaker round enclosures provided under another contract. A white, 22 gauge steel loudspeaker grille shall be provided.
 2. These loudspeakers shall be surface mounted in non-public areas of the Airport buildings that do not have ceilings.
 3. Manufacturer:

- a. Atlas FC104T72 with Aluminum Housing 410-4 and support mounting hardware.
- b. **<Insert manufacturer>**
- c. or approved equal.

K. Type S10, Full-range Paging Loudspeaker, Surface Mount:

1. Loudspeaker Type S10 shall be a full-range device with a frequency response of ± 3 dB, 80 Hz to 20 kHz and input sensitivity of 90 db at 1 meter with 1 watt input at 500 Hz to 2500 Hz. The coverage shall be nominal 100 degrees horizontal from 500 Hz to 2.5 kHz. The power rating shall be 100 W minimum, and a 70 volt line matching transformer with 7.5, 15 and 30 watt taps and a maximum insertion loss of 0.5 dB from 100 Hz to 15 kHz shall be provided. The loudspeaker shall be surface mounted and enclosed in a UL 94V-0 rated injection molded or metal enclosure with integral metal grille and mounting bracket to allow aiming. A cover plate for a 4- inch square electrical box shall be provided with grommets wire access hole.
2. These loudspeakers shall be utilized in the public areas of the Concourses, and shall be surface mounted on the sides of crossover bridges and walkways where the ceiling heights exceed 20 ft.
3. Manufacturer:
 - a. Atlas SM52TB.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

L. Type S11, Full-range Paging Loudspeaker, Pendant Hung:

1. Loudspeaker Type S11 shall be a white 8- inch diameter coaxial device with a minimum input sensitivity of 90 dB minimum measured at 1 meter with 1 watt input from 500 Hz to 2.5 kHz, frequency response shall be ± 5 dB, 60 Hz to 20 kHz and the coverage angle shall be a nominal 100 degrees conical from 500 Hz to 2.5 kHz. The loudspeakers shall be rated for 60 W minimum, and a 70 Volt line matching transformer with 0.5 dB maximum insertion loss over the frequency range of 100 Hz to 15 kHz and selectable level taps at 1.9, 3.8, 7.5, 15, 30 and 60 watts shall be wired in parallel with the voice coil. Type S11 loudspeakers shall be suitable for mounting in a 8- inch suspended round pendant enclosure. Suspension hangers shall be provided to lower loudspeaker within 15 ft. of the floor.
2. These loudspeakers shall be mounted to down pipe suspended from structure above with safety cable concealed in the down pipe in the ceiling of public areas of the Concourses where ceiling heights exceed 15 ft.
3. Manufacturer:
 - a. Atlas PM8FA-W.
 - b. **<Insert manufacturer>**
 - c. or approved equal.

Edit the following paragraph to suit Project.

- M. Type <Insert> Loudspeaker <as required for the design>.

2.16 OTHER DEVICES

A. Equipment Racks:

1. Vertical floor equipment racks shall be located in P.A. Rooms and shall be constructed of heavy gauge steel frame with removable sides and rear door. Racks shall be equipped with 11 gage CRS adjustable mounting rails plated, drilled and tapped 10-32 thread on E.I.A. standard hole spacing, and shall accept standard 19" rack-mountable equipment. Cabinet depth shall be 25-1/2" and provide 77-1/8" rack space mounting. Racks shall allow opening on sides and bottom to facilitate wiring of components, shall have a rear door equipped with a cylinder lock and shall have louvered top and side panels. Base shall be tapped to accept leg levelers, and the frame shall be finished in textured black. The top and side panels, rear door, and all trim shall be finished as directed by the DEN Project Manager.
2. Except as otherwise specified or shown, ECS equipment shall be installed in equipment racks. Include racks for facilities for which racks are not shown on the drawings, and provide an adequate number of sections, at all locations, for installation of the equipment which the Contractor will provide.

B. Sound System Terminal Cabinets:

1. Wall mounted terminal cabinets shall be provided in each P.A. Room and ECS Control Room to allow breakout of wiring from conduit to the equipment racks. The terminal cabinets shall be 36"H by 24"W by 9"D and constructed of 14 gauge CRS throughout. Rear section shall be of one-piece construction with all welded seams. Cabinet finish shall be as selected by DEN Project Manager from standards available. Cabinet shall include AMP Flexiblocks with track and end stops for cable termination and connection points.
2. Manufacturer:
 - a. Hoffman T series cabinet.
 - b. <Insert manufacturer>
 - c. or approved equal.

C. Wiring and Conductors:

1. Microphone and Line Level Cable:
 - a. Microphone, line level, and ambient sensor cable, when installed in conduit, shall be NEC Type CM cable consisting of ASTM stranded tinned copper, 22 AWG, 100% aluminum polyester foil shielded twisted pair with tinned copper drain wire and 75 degree Centigrade rated polypropylene insulation. The cable shall have a nominal O.D. of 0.135" with a green outer jacket, nominal capacitance of 34 pF/ft. between conductors and nominal capacitance of 67 pF/ft. between one conductor and other conductors connected to shield.

- b. Where cable is installed in cable trays, it shall be NEC Type PLTC stranded tinned copper, 22 AWG, 100% aluminum polyester foil shielded twisted pair with tinned copper drain wire. The insulation shall be PVC with nylon and rated for 105 degrees Centigrade. The cable shall have a nominal O.D. of 0.201" with a green outer jacket, a nominal capacitance of 50 pF/ft. conductor to conductor and a nominal capacitance of 90 pF/ft. between one conductor and the others connected to the shield.
 - c. Manufacturer of all cable:
 - 1) Belden.
 - 2) Liberty.
 - 3) **<Insert manufacturer>**
 - 4) or approved equal.
 2. Trunk loudspeaker cable, when installed in conduit, shall be 12 AWG stranded Green/White twisted pair.
 - a. Branch loudspeaker cable shall be 12 AWG stranded green/white twisted pair to the first loudspeaker in the home run. No overall jacket is required.
 - b. Cable thereafter shall be sized to provide no more than 0.5 dB loss but shall be no smaller than 14 AWG. Color code and jacket requirements shall be the same as used on trunk cable.
 - c. Where installed in cable tray, loudspeaker cable shall be plenum rated.
 - d. Manufacturer:
 - 1) 12 AWG Cable – Tappan PLN1202TC GN.
 - 2) 14 AWG Cable – Tappan PLN1402TC.
 - 3) **<Insert manufacturer>**
 - 4) or approved equal.
 3. Control cable shall be installed in conduit and shall be low capacitance 22 AWG stranded four twisted pair with 100% aluminum polyester overall shield and drain wire. The nominal O.D. shall be 0.325" with a green outer jacket, nominal conductor D.C.R. shall be 24 ohm/1000 ft., the nominal capacitance shall be 15.5 pF/ft. between conductors and the nominal capacitance shall be 27.5 pF/ft. between one conductor and other conductors connected to shield.
 4. The installation may involve localized conditions in which metallic-conductor cable systems will transition from conduit to tray installation, and vice versa, for limited lengths of run. If a cable is transitioning from a room via tray into conduit for the remaining distance of the run, the wiring should be the type rated for use in conduit. If the majority of the cable run is in conduit, use cable rated for such use. If the majority of the cable run is in cable tray, use cable rated for use in tray.
 5. Speaker Test Panels: Provide speaker circuit test panels matching existing. Panel shall house IED speaker load modules, disconnect switch and banana jack test points. Match existing panels including engraving. Provide one panel for every 8 amplifier channels.

2.17 RACEWAYS

Retain one of first three paragraphs below. Coordinate selection with "Wiring Methods" Article and with Section 260533 "Raceways and Boxes for Electrical Systems." Retain first paragraph to allow Contractor to choose any material specified in Section 260533 "Raceways and Boxes for Electrical Systems."

- A. Intercommunication and Program System Raceways and Boxes: Comply with requirements in Section 260533 "Raceway and Boxes for Electrical Systems."
- B. All cabling shall be housed in conduit raceway
- C. Provide a complete raceway system for the ECS. Emergency signal infrastructure from Master Microphone stations or network connections for amplifier frames shall not be allowed in cable trays. They must be provided in conduit. Raceways shall be installed utilizing the most efficient route.
- D. Outlet boxes shall be not less than 2- inches (50 mm) wide, 3- inches (75 mm) high, and 2-1/2- inches (64 mm) deep.

Retain paragraph below to prohibit use of flexible metal conduit.

- E. Flexible metal conduit is allowed where other conduit will not suffice.

PART 3 - EXECUTION

3.1 GENERAL

- A. All work shall be provided complete, and the ECS shall be fully operational as shown and described herein.
- B. Modifications and additions to the existing ECS:
 - 1. Work Meeting: The Contractor shall coordinate and arrange a pre-work meeting with the DEN Project Manager and DEN Technical Maintenance one week in advance of the beginning of any work. The Contractor shall assure attendance of trades installing the ECS including any electrical, telecommunications, and audio-related trades involved. The Contractor shall present the contractor's construction, demolition, phasing, implementation, and testing plans and schedule. Meeting notes shall be accurately recorded by the DEN Project Manager and distributed within three (3) working days.
 - 2. All Work shall be provided complete, and the voice paging systems shall be fully operational as shown and described herein. DEN Technical Maintenance will make all final connections to existing circuits.
 - 3. Modifications and additions to the existing ECS: Contractors must give DEN AIM five (5) working days notice before making any connections, deletions, or modifications to the existing sound system. DEN System Shutdown Request form must be used for this purpose.

C. Electrical Related Work:

1. Furnish and install all electrical conduit, wiring and outlets for electrical power to paging and announcement control equipment.
2. Furnish and install raceway, conduit, junction boxes and for audio signal and control wiring.
3. Furnish and install loudspeaker junction boxes and enclosures.
4. Furnish and install ground conductor from building earth ground to each group of equipment racks in accordance with requirements of Section 260526 "Grounding and Bonding for Electrical Systems". The insulated ground conductor shall be installed in conduit and sized for a DC resistance of 0.1 ohm or less to ground. For example, a 15 ft. run would be 8 AWG or larger.

D. Power or ECS System Outages:

1. Power or ECS System Outages: Any power or ECS System outages necessary to install or test systems and/or equipment shall be coordinated with Denver International Airport Project Manager. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

3.2 DELIVERY, STORAGE AND HANDLING

- A. Deliver products to site and store and protect under provisions of Division 01.
- B. Store products in secure locations as approved and directed by DEN Project Manager.

3.3 FABRICATION

- A. Designation/Engraving: All equipment controls, receptacles and all indicators shall have, unless otherwise noted, permanently engraved or silk screened, fully descriptive identification labels. The resolution of silk screened labels shall not be less than 90,000 dots/sq. in.
- B. Terminals and Terminations:
 1. Cables shall not be spliced or otherwise interrupted from termination to termination. All cables shall have visible heat-shrink identifying markers on each end in compliance with DEN labeling standards.
 2. Wiring in terminal cabinets shall be tied and clamped neatly to backboards or cable forms.
 3. Terminal blocks shall be fully insulated, rated for the wire size to be terminated, suitable for mounting inside an electrical enclosure and, unless otherwise specified, be one of the following types:
 - a. Terminal strips with interposing barriers between screw terminals.
 - b. Terminal strips with gas-tight screw type clamp connectors.
 4. Each terminal strip shall have a legibly marked permanent identification strip.

C. Structural Assemblies:

1. Loudspeaker mounting frames and brackets shall be fabricated and assembled in shop to the greatest extent possible. Fabricate items of structural steel in accordance with AISC Specifications and as indicated on final shop drawings.
2. Provide high-strength threaded fasteners for bolted connections and comply with AWS code for procedures, appearance and quality of welds and for methods used in correcting welding work.
3. Provide holes required for securing other components or assemblies to structural steel framing and for passage of other components through steel framing members as shown on final shop drawings. Cut, drill or punch holes perpendicular to metal surfaces. Do not flame cut holes or enlarge holes by burning.
4. In fabricating mounting brackets and other steel components requiring bends, the radii of the bends shall not be less than three times the thickness of the steel being bent.

3.4 REDUNDANCY

- A. The PA System shall be a fully redundant system with the minimum basic requirements of the following:
1. Redundant Globalcom equipment shall be implemented into the system for full redundancy. Locate redundant Lifeline Globalcom as shown on contract documents.
 2. Utilize redundant Cobranet connections on amplifier frames.
- B. System shall be connected via a physically separated fiber optic premise wiring system designed for the Fire Alarm System. Redundancy shall include redundant core and intermediate switches with redundant connections to the edge switch as shown on contract drawings.
- C. IP Microphone stations shall connect to each regional Announcement Control System (ACS) over Owner provided network. The remainder of the ECS equipment Ethernet connectivity shall be provided by a stand-alone Ethernet network consisting of access layer switches, pairs of regional distribution switches and core switches. Connectivity of access layer to distribution switches shall be done using diversely routed fire alarm system single mode fiber provided by Owner. Inter-Building connectivity shall use DEN Premise Wiring and Distribution System Fiber Strands.
- D. Cabling required for network infrastructure shall be provided by the Owners Premise Wiring Contractor Services (PWCS). PWCS shall be provided with the drawings and shall then provide pricing to be included in the Project for the network cabling and connectivity.

3.5 INTERFACES

- A. Several interfaces to other system shall be required for both physical hardware and

software. These systems include, but are not limited to Fire Alarm System, AIDX Database, Tenant PA systems and DEN Networks. Specific requirements for each shall be as follows:

1. Fire Alarm System Interfaces shall be connected to ACS and Globalcom locations throughout the airport. Provide interfaces through dry contacts to allow required functionality to occur including tenant areas. System sequence of operation shall be defined by Section 283100 "Intelligent Life Safety Fire Management System" and Section 283112 and the fire alarm documentation. Critical faults from the ECS shall be faulted to the fire alarm system through the interface.
2. Airport Information Data Exchange (AIDX) Database shall provide information for the Flight Announcement System. System shall be interfaced at IED Server locations.
3. DEN Networks: DEN networks work and interfaces shall be coordinated at the Pre-construction meeting. DEN network representatives shall be available during any scheduled work with regard to interfaces or LAN, VLAN modifications of the PA system.

3.6 WIRING METHODS

Retain one of first two paragraphs below and coordinate with Drawings. Delete both if wiring methods for system are indicated on Drawings. Coordinate selection with "Raceways" Article.

- A. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters, and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Conceal raceway and cables except in unfinished spaces.

Retain first subparagraph below if retaining option in paragraph above.

1. Install plenum cable in environmental air spaces, including plenum ceilings.
 2. Comply with requirements for raceways and boxes specified in Division 26 Section "Raceway and Boxes for Electrical Systems."
- B. Wiring within Enclosures: Bundle, lace, and train cables to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

3.7 INSTALLATION OF RACEWAYS

- A. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for installation of conduits and wireways.
- B. Install manufactured conduit sweeps and long-radius elbows whenever possible.

3.8 INSTALLATION OF CABLES

A. Comply with NECA 1.

B. General Requirements:

1. Terminate conductors; no cable shall contain unterminated elements. Make terminations only at outlets and terminals.
2. Splices, Taps, and Terminations: Arrange on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures. Cables may not be spliced.
3. Secure and support cables at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
4. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.
5. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
6. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used.

C. Open-Cable Installation:

1. Install cabling with horizontal and vertical cable guides in telecommunication spaces with terminating hardware and interconnection equipment.
2. Suspend speaker cable not in a wireway or pathway a minimum of 8 inches (200 mm) above ceiling by cable supports not more than [60 inches (1524 mm)] **<Insert dimension>** apart.
3. Cable shall not be run through structural members or be in contact with pipes, ducts, or other potentially damaging items.

D. Separation of Wires: Separate speaker-microphone, line-level, speaker-level, and power wiring runs. Install in separate raceways or, where exposed or in same enclosure, separate conductors at least 12 inches (300 mm) apart for speaker microphones and adjacent parallel power and telephone wiring. Separate other intercommunication equipment conductors as recommended by equipment manufacturer.

3.9 INSTALLATION

A. Identification of Conductors and Cables: Color-code conductors and apply wire and cable marking tape to designate wires and cables so they identify media in coordination with system wiring diagrams. Clearly, logically and permanently mark switches, connectors, jacks, relays, and receptacles.

B. Weatherproof Equipment: For units that are mounted outdoors, in damp locations, or where exposed to weather, install consistent with requirements of weatherproof rating.

- C. Speaker-Line Matching Transformer Connections: Make initial connections using tap settings indicated on Drawings.
- D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- E. Mount equipment firmly in place, including loudspeakers, amplifiers and cables in accordance with manufacturer's instructions. Make fastenings and supports adequate to support their loads with a safety factor of three. Appliances shall be mounted independently of their attachments to the circuit conductors.
- F. Appliances subject to mechanical damage shall be suitably protected. If guards, covers, or lenses are employed, they shall be listed for use with the appliance.
- G. Secure equipment firmly in place, including loudspeakers, amplifiers and cables. Make fastenings and supports adequate to support their loads with a safety factor of three
- H. Clearly, logically and permanently mark switches, connectors, jacks, relays, receptacles, cables and cable terminations.
- I. The Contractor shall take precautions to prevent electromagnetic and electrostatic hum. Install the equipment to provide safe operation. Provide ventilation as required to maintain equipment within the manufacturer's specified temperature limits.
- J. Provide all cables necessary for interconnection of permanently mounted equipment. Use terminations required to achieve full function of equipment as specified herein.
- K. Exercise care in wiring, to avoid damage to the cables and to the equipment. Make all joints and connections with rosin-core solder or with mechanical connectors approved for Class I wiring. Execute all wiring in strict adherence to standard broadcast procedures.
- L. Run lines in separate metallic conduits or install cable tray dividers for microphone level circuits (up to -20 dBm), line level circuits (up to +30 dBm), loudspeaker circuits (above +30 dBm) and power circuits. Ground power conduits with heavy wire to the power system ground. Use only cables which are insulated from the conduit and from each other for the entire conduit length. Connect conduits mechanically and electrically to the sound system ground point. Do not splice lines in conduit.
- M. The Installer shall coordinate all sound equipment panel and control locations with the DEN Project Manager prior to installation.
- N. Speaker circuits shall be run in continuous line to provide circuit supervision utilizing End of Line Module.
- O. Speaker circuits, speakers, and control equipment shall be installed to meet the pathway survivability requirements of NFPA 72, Chapter 24. Specifically, Level 1 Pathway Survivability shall be provided.

3.10 GROUNDING

- A. Ground cable shields and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.
- B. Signal Ground Terminal: Locate at main equipment cabinet. Isolate from power system and equipment grounding.

Retain paragraph below for special applications only.

- C. Install grounding electrodes as specified in Section 260526 "Grounding and Bonding for Electrical Systems."

3.11 SYSTEM PROGRAMMING

Retain this article for microprocessor-switched systems.

- A. Programming: Fully brief Owner on available programming options. Record Owner's decisions and set up initial system program. Provide all programming required for a fully functioning system and associated interfaces. Prepare a written record of decisions, implementation methodology, and final results.

3.12 FIELD QUALITY CONTROL

Retain first paragraph below to describe tests and inspections to be performed.

- A. Electrical/Electronic Tests and Inspections: At the job site, the Contractor shall perform tests not conducted and certified by the manufacturer and, be prepared to repeat any or all tests as may be directed by the DEN Project Manager during the period of final inspection and checkout. Furthermore, the Contractor shall be prepared to perform work required to modify the performance of the system in accordance with this specification. Test all electrical circuits before plugging ECS equipment into the circuit.
 - 1. Schedule tests with DEN Project Manager with at least seven (7) days' advance notice of test performance. Do not proceed with testing without written approval from DEN Project Manager.
 - 2. General Inspection and Adjustment: Make all measurements, and subsequently deliver documentation, to demonstrate that all individual components, not previously measured and certified by the manufacturer, are performing in accordance with each manufacturer's published specifications. Specifically, examine frequency response, total harmonic distortion and signal-to-noise ratio. Replace any components found to be defective.
 - 3. Operational Test: Test microphone stations at each area that the microphone station is installed. Verify proper routing and volume levels and that system is free of noise and distortion. Test each available message path from each station on system.
 - 4. Redundancy Test: Test redundancy and back up amplifier switching for all redundant components including a power loss scenario. Determine that system components are configured for automatic boot up recovery as part of redundancy

- and that the appropriate files are correctly backed up for system configurations.
5. Distortion Test: If distorted signal is present, measure distortion at normal gain settings and rated power. Feed signals at frequencies of 150, 200, 400, 1000, and 2500 Hz into selected amplifiers. For each frequency, measure distortion in the system outputs. Maximum acceptable distortion at any frequency is 5 percent total harmonics. Replace defective equipment
 6. Acoustic Coverage Test: Feed pink noise into system. Use sound-level RTA meter with octave-band filters to measure level at three locations in each paging zone. Equalize and delay loudspeakers with Pink Noise and sufficient analyzer to maximize audio quality and intelligibility in every instance. Consultant shall spot check these loudspeaker systems with the Contractor in the field during test out. Maximum permissible variation in level is plus or minus 3 dB; in levels between adjacent zones, plus or minus 5 dB. Set equalization for maximum flat response of loudspeaker system. Use filters to cut, if possible, rather than boost frequencies. If 6dB of boost or cut is required, verify position of test microphone, speaker polarity issues or reflections that may be skewing the test. Slight repositioning of the test Microphone may be required

Retain first subparagraph below if paging is specified.

7. Power Output Test: If loudspeaker performance is not producing the required and calculated level in a zone, measure electrical power output of each paging amplifier at normal gain settings of 150, 1000, and 2500 Hz. Maximum variation in power output at these frequencies is plus or minus 3 dB. Replace defective equipment or verify speakers are tapped and performing correctly.
8. Signal Ground Test: Measure and report ground resistance at system signal ground. Comply with testing requirements in Section 260526 "Grounding and Bonding for Electrical Systems."
9. Loudspeaker Line Impedance: Measure the impedance and the resistance of each loudspeaker line leaving the sound equipment racks with the line disconnected from its normal driving source. Maintain values within $\pm 10\%$ of the value calculated for that circuit based upon the parallel impedances of the loudspeakers connected plus the resistance of the loudspeakers. Measure loudspeaker impedance at multiple frequencies according to the speaker type. Measure for ground faults on each leg of the speaker system. Correct any faults found for both impedance and ground faults. .
10. Hum and Noise Level: If hum or noise is present, measure the hum and noise levels of the overall system. Adjust gain controls for optimum signal-to-noise ratio. The adjustment shall also be such that full amplifier output would be achieved with 0 dBm input. Terminate inputs with shielded resistors of 600 ohms, and disconnect the loudspeaker lines, terminating the power amplifier outputs with power resistors for these measurements. The load resistors shall match the rated load impedance and output power of the amplifiers.
11. Power Output and Signal Level Adjustments: Adjust gain controls as for the hum and noise level test. Set variable equalizers for flat response. Apply 1,000 Hz sinewave signal at the input tested, at a level required to produce a full amplifier output. Use a distortion analyzer to measure the output level and total harmonic distortion of the amplification equipment. Make all measurements with loads actually incurred in system operation. Power amplifier loads shall be resistors equal to the nominal impedance of the output terminals used in the system.
12. Gain Control Settings: Establish tentative normal settings for all gain controls. All

- gain controls on rack-mounted equipment shall be adjusted for optimum signal-to-noise ratio and signal balance. Settings may require further adjustment by the Contractor as a result of testing by the DEN Project Manager. Programmed settings shall be recorded in hardcopy format.
13. Provide System Set with no faults. System shall run fault free from the Contractors work for a minimum of 30 days with no issues for final closeout of work.
 14. Freedom from Switching Transient Noise: Operate all control switches and relays, while listening for clicks and pops in the system outputs. Eliminate any found.
 15. Listening Tests: These tests shall include speech intelligibility surveys and subjective aural evaluations by observers at various positions under various operating conditions, using live speech and/or recorded music material.
 16. Equipment Tests: Any measurements of frequency response, distortion, noise or other characteristics and any operational tests deemed necessary may be performed on any item or group of items to determine conformity with these requirements. Measurements of system performance shall be made using a calibrated ANSI S1.4, Type 1 sound level meter set for "slow" meter damping and flat response. The microphone shall be positioned 5 feet above the floor within the area served by the system. All interior finishes and furnishings shall be in place, and the system gain shall be set to provide octave band levels at least 10 dB above background noise levels in any octave band at the measuring locations.
 17. Identification: Verify that units and controls are properly labeled and interconnecting wires and terminals are identified. Prepare a list of final tap settings of paging speaker-line matching transformers.

See Division 01 Section "Quality Requirements" for retesting and reinspecting requirements and Division 01 Section "Execution" for requirements for correcting the Work.

- B. The ECS shall be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.
- D. Report: Upon completion of the above tests and any necessary adjustments, submit two (2) copies of a written report presenting test results, including numerical values where necessary, for review by the DEN Project Manager prior to acceptance testing, final tuning and demonstration. With this report, submit written certification that the installation conforms to the requirements stated herein, is complete in all respects, and is ready for inspection, testing and final tuning.

3.13 STARTUP SERVICE

- A. Engage an IED factory-authorized service representative to assist Contractor and perform startup service and initial system programming and final commissioning.
 1. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements.
 2. Complete installation and startup checks according to manufacturer's written

instructions.

3.14 ADJUSTING

Delete this article if Owner contracts separately for this service. Consider including a provision for submitting a continuing maintenance agreement proposal.

- A. On-Site Assistance: Engage a factory-authorized service representative to provide on-site assistance in adjusting sound levels, resetting transformer taps, and adjusting controls to meet occupancy conditions.
- B. Occupancy Adjustments: When requested within [twelve (12)] <Insert number> months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two (2)] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.

3.15 MAINTENANCE SERVICE

- A. Replace defective materials and repair faulty workmanship within 48 hours of discovery during the period of the warranty.

3.16 DEMONSTRATION

- A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain the intercommunications and program systems.
 - 1. Train Owner's maintenance personnel on programming equipment for starting up and shutting down, troubleshooting, servicing, and maintaining the system and equipment.
 - 2. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.
- B. Upon approval of the test report by the DEN Project Manager, and at a time established by the DEN Project Manager, demonstrate the operation of each major component of the system and the completed installation. After demonstration, assist as required in the following acceptance tests:
 - 1. Listening Tests: These tests shall include speech intelligibility survey and subjective aural evaluations by observers at various positions under various operating conditions, using live speech and/or recorded music material.
 - 2. Equipment Tests: Any measurements of frequency response, distortion, noise or other characteristics and any operational tests deemed necessary may be performed on any item or group of items to determine conformity with these requirements.
 - 3. If the need for adjustment or modification becomes evident during demonstration and testing, accomplish adjustments or alterations until the installation operates fully in accordance with the requirement of this specification.

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 275123

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SECTION 275313 - DEN STANDARDS FOR TIME SYNCHRONIZATION

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

ALL ENGINEER NOTES SHALL BE DELETED FROM THE FILE OR MARKED AS HIDDEN.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

Edit to suit Project.

- A. DEN was constructed with a Simplex Time Recorder master clock systems. Over the years slave clocks have subsequently been removed, largely due to the prevalence of time displayed on flight information monitors and passenger cell phones. Once the last of the slave clocks is removed the master clock will be retired.
- B. DEN operates two Stratum One GPS time servers. One server is located in the data center on Concourse A. The other server is located at the Airport Office Building (AOB). These servers synchronize time with the US GPS constellation.
- C. DEN systems connecting to the DEN enterprise network, Emergency Communications System network or Security Access Control Network may obtain time synchronization by periodically forwarding a Network Time Protocol (NTP) request to the default gateway on their respective subnets. The networks have been configured to relay this information to the NTP servers
- D. Systems and Computers that are not network connected may also receive time synchronization directly from the time servers. The primary and secondary time servers at DEN are equipped to provide an IRIG-B output. IRIG-B is a 1000 hertz modulated tone that can be extended to various locations on the airport over copper telephone pairs. IRIG-B interface cards are available from a number of manufacturers for various bus configurations and operating systems.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

- A. GPS: Global Positioning System.
- B. IRIG-B: Inter-Range Instrument Group Protocol B.
- C. NIST: The National Institute of Science and Technology.
- D. NTP: Network Time Protocol.
- E. PC: Personal computer.
- F. UTC: Universal Time Coordinated. The precisely measured time at zero degrees longitude; a worldwide standard for time synchronization.

1.4 PERFORMANCE REQUIREMENTS

- A. Devices utilizing the airport time reference system with either Network time protocol or IRIG-B shall display time synchronization of one second or less with the time servers.

ENGINEER/ARCHITECT SHALL NOT REDUCE THE REQUIREMENTS BELOW WITHOUT PERMISSION FROM THE DEN PROJECT MANAGER.

1.5 ACTION SUBMITTALS (NOT APPLICABLE.)

1.6 INFORMATIONAL SUBMITTALS (NOT APPLICABLE.)

1.7 CLOSEOUT SUBMITTALS (NOT APPLICABLE.)

1.8 QUALITY ASSURANCE

- A. Comply with NFPA 70.

Retain article below if required for Project. Coordinate requirements with DEN Project Manager.

B. CONSTRUCTION WASTE MANAGEMENT

- 1. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 - PRODUCTS

2.1 IRG-B PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Symmetricom.
 - 2. Spectracom.
 - 3. Brandywine Communications.
 - 4. **<Insert manufacturer>**
 - 5. or approved equal.

PART 3 - EXECUTION (NOT APPLICABLE)

PART 4 - MEASUREMENT

4.1 METHOD OF MEASUREMENT

- A. No separate measurement shall be made for work under this Section.

PART 5 - PAYMENT

5.1 PAYMENT

- A. No separate payment will be made for work under this Section. The cost of the work described in this Section shall be included in the Lump Sum Contract price.

END OF SECTION 275313