APPENDIX 11

Great Hall Infrastructure Capacities Report

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Great Hall Infrastructure Capacities

Airport Infrastructure Management



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Printed in the United States of America



Version History

Version	Description	Date Created	Author
1.0	Initial Report	10/26/2015	M. Santos
2.0	Included capacities as per Sebesta for TP's, included infrastructure definition w/source and POU, – format and distribute to KPMG	1/25/2017	M. Santos
3.0	Capacity and infrastructure definition edits by Glavin and Walinchus	3/7/2017	M. Santos

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1 Executive Summary

The following is a brief summary of the utility systems, by discipline, as they currently exist and support the Jeppesen Terminal Facility. This condition assessment provides our best estimation of current capacity.

Mechanical:

Central Utility Plant (CUP) – Chilled Water. The current chilled water plant capacity is 13,300 tons excluding the capacity of one chiller reserved for N+1 redundancy. The current demand load based on actual demand data, plus projected nominal load for the hotel and CUP chiller addition is projected to be about 8,807 tons. This leaves about 4,493 tons of cooling to support future re-development and additions. The airport has programmed in multiple expansion options, with a total connected load of around the current installed capacity. CUP Chiller Plant is being upgraded to a firm capacity of 15,000 tons and will be complete by Q1 2020

Central Utility Plant (CUP) – Heating Hot Water. The current hot water plant firm capacity is -101,000 MBH excluding the capacity of one boiler reserved for N+1 redundancy. The current demand load based on actual demand data, plus projected load for the hotel and train station is projected to be about 91,672 MBH. The airport has programmed in multiple expansion options, with a total connected load in excess of the current installed capacity. The terminal redevelopment will need to be coordinated with other airport projects. The Boiler #2 project will be complete in Q2 2017 and expand the firm capacity to 141,000 MBH

Air and Hydronic Distribution Systems: The main terminal hydronic distribution system for HHW and CHW appear adequately sized to support the terminal re-development. The secondary pumping skids appear to be the limiting factor and based on outdoor ventilation rates and / or number of tenants, greater capacity may be required and will need to be analyzed. The air handling unit supply fan capacity and return / relief fan capacity is adequate for the Great Hall Program. Depending on the outdoor air requirements, the air handling coils may need to be resized and subsequently replaced. This will need to be analyzed as part of the redevelopment effort.

Building Automation System (BAS): A LonWorks backbone with routers was installed in 2012 with connection to a new head-end controls Honeywell EBI. Routers are strategically located in all mechanical rooms and selected locations throughout the facility. HVAC equipment and unitary controls must be replaced with new BAC-NETdevices / technology as devices fail due to the obsolescence of the LonWorks system.





Electrical: For normal and emergency power and distribution, there is capacity in the system to nearly double the load (see details in Section 5)

Plumbing: The size and distribution of the sanitary drains appear to be able to support redevelopment and expansion plans. The kitchen sanitary and grease traps are adequately sized for their current use, but if redevelopment plans include additional kitchens, this system will need to be analyzed. The domestic water incoming service is undersized and will need to be addressed as part of any redevelopment plans (see details in Section 6). Natural gas will need to be reviewed on a case by case basis.





The facility is laid out by area and the following report will reference these areas. See the key plan below for layout.







Figure 1: DEN Keyplan (circa 2014)

2 Central Utility Plant – Chilled Water Details

The chilled water portion of the Central Utility Plant (CUP) consists of four chillers, associated primary chilled water and condenser water pumps, and a ten cell cooling tower. A waterside economizer consisting of plate and frame heat exchangers and related controls provides chilled water without mechanical cooling when ambient conditions permits the cooling tower to provide condenser water at a suitable temperature. Current available CUP chilled water capacity is summarized in Table 2-1 below.

TAG	TONS	GPM	LWT (°F)	EWT (°F)
C-1	4150	6225	40.0	56.0
C-2	4150	6225	40.0	56.0
C-3	4150	6225	40.0	56.0
C-4A	2500	3750	40.0	56.0
C-4B	2500	3750	40.0	56.0
SUBTOTAL	17450	26175	40.0	56.0
TOTAL N+1	13300	19950	40.0	56.0

TABLE 2-1 CUP Chilled Water Capacity

The Great Hall Redevelopment Program scope includes adding an increased but undetermined amount of square footage of restaurant tenant space and reconfiguring and/or moving ticketing and security areas on the Terminal's fifth and sixth levels. Since this project is in its early development stage, an accurate prediction of the square footage space use change is not available. Current CUP project planning includes retrofitting water cooled centrifugal chiller tags C-1 to C-3 from R-22 to R-134a refrigerant due to future availability constraints of R-22 refrigerant.





The current actual CUP chilled water load is 8,807 tons (=8000 actual + 37 CUP Chiller Addition + 770 Hotel). Comparing the current CUP chilled water N+1 capacity versus the current documented load, an additional 4,493 tons (=13300 - 8807) of capacity appears to be available to support the Great Hall Redevelopment Program.

3 Central Utility Plant – Heating Hot Water Details

The heating hot water portion of the Central Utility Plant (CUP) consists of six dual fuel (natural gas / jet fuel oil) boilers located in boiler bays one to four, and associated primary heating hot water pumps. The six boilers consist of a smaller start-up/warm-up boiler and five larger primary boilers. Boiler 6 is located outdoors, at the southeast end of the CUP. The primary heating hot water supply temperature setpoint is 230°F, presumably to provide greater transport heating density, and primary heating hot water is blended to the secondary heating hot water supply setpoint of 190°F at the buildings served by the CUP. Current available CUP heating hot water capacity is summarized in Table 3.1-7 below.

TAG	MBH	GPM	LWT (°F)	EWT (°F)
B-1	17000	450	190.0	160.0
B-2a	20000	1750	230.0	160.0
B-2b	20000	1750	230.0	160.0
B-2c	20000	1750	230.0	160.0
B-6	56000	1750	230.0	160.0
B-3	25000	1750	230.0	160.0
B-4	25000	1750	230.0	160.0
TOTAL	183000			

TABLE 3.1-7 CUP Heating Hot Water Capacity

Notes:

- 1. Boiler tag B-1 is a warm-up boiler. Capacity is not included in hot water capacity.
- 2. Boiler 2 (failed in 2015) is being replaced with (3) new 20MBH units (2a, 2b and 2c) in FY17.
- 3. Boilers 3 and 4 have been de-rated to 40% of MBH due to mechanical issues and will be replaced as part of an upcoming CUP CIP project.





4. Boiler 6 is located outdoors on the southeast side of the CUP

CUP heating hot water demand analysis at the time of the Central Plant Master study reached a conclusion that CUP had not seen a heating hot water peak load demand in excess of approximately 85,000 MBH. A recent hot water peak load of 60,000 MBH was recorded during a FY13 -14°F outdoor air temperature occurrence.

The current CUP heating hot water capacity of 188,200 MBH is adequate to serve the Great Hall Redevelopment Program.

The Great Hall Redevelopment Program scope includes adding an increased but undetermined amount of square footage of restaurant tenant space and reconfiguring and/or moving ticketing and security areas on the Terminal's fifth and sixth levels. Since this project is in its early development stage, an accurate prediction of the square footage space use change is not available.

4 Main Terminal HVAC: Air & Hydronic Distribution Systems

The Main Terminal chilled water (CHW) and heating hot water (HHW) is provided by the CUP via a primary - distributed secondary variable speed variable volume pumping system. The Terminal's secondary system originates in the utility tunnel housing the extended CUP primary piping and the building secondary CHW & HHW piping connection are downstream of the system de-coupler which gives the primary and secondary pumping loops hydraulic independence. It should be noted this is not a true de-coupler. These systems cannot run independently and the de-coupler must always remain in a positive flow scenario to maintain Cup performance. An 18 inch CHW and a 12 inch HHW piping taps are routed to a mechanical room housing both secondary CHW (7000 GPM N+1 capacity) and HHW (2600 GPM N+1 capacity) pumping skids. The CHW & HHW is distributed from the pumping skids to eight primary mechanical fan rooms serving the Terminal.

Similar CHW & HHW pumping skids serve the North Terminal Support and Airport Office buildings adjacent to the Terminal building. The Great Hall Program development area also includes a small area on the north end of level six served by these pumping skids.

Eight mechanical fan rooms located on level four provide both hydronic and air distribution to levels four, five and six of the Terminal. The Great Hall Program development area includes interior level five office, tenant and great hall areas (baggage claim and most perimeter areas excluded) and exterior and interior level six perimeter, ticketing, and great hall areas.

The CHW and HHW hydronic piping in each of the eight Fan Rooms is distributed to the various custom and central station air handing units, heating and ventilating units, 100% outdoor air make-up units in the room and additional risers are piped to the parallel fan powered variable air volume terminals with HHW reheat coils and other small terminal equipment such as fan coil





units, cabinet heaters, unit heaters, and air curtains. Dedicated CHW and HHW risers for tenant use are distributed vertically through vertical shafts, also.

Hydronic DSM Facility Design tenant standards indicate the Airport will provide a maximum of 20 GPM of chilled water (CHW) and/or heating hot water (HHW), regardless of tenant size. Table 4-1 below indicates the current CHW & HHW infrastructure in the eight Fan Rooms and the dedicated tenant hydronic loops serving the Great Hall Program development area.

FAN RM	AREA	CHW SVC (IN)	CHW GPM	CHW FUTURE GPM	TENANT CHW (IN)	HHW SVC (IN)	HHW GPM	TENANT HHW (IN)
1	14C	6	400	250	3	6	250	3
2	14A	8	775	375	3	6	400	2 1/2
3	8C	8	775	375	3	6	400	2 1/2
4	8A	6	250	450	3	6	250	3
5	8B	6	400	250	3	6	250	3
6	11B	8	775	375	3	6	400	2 1/2
7	11D	8	775	375	3	6	400	2 1/2
8	14D	6	450	250	3	6	250	3
SUM			4600	2700			2600	

TABLE 4-1 CHW & HHW Infrastructure - Fan Rooms & Tenant

Notes:

- 1. CHW GPM is the design intent Fan Room allocation per Fentress & Bradburn Associates Main Terminal Record Drawings dated January 1995.
- 2. CHW Future GPM is the future design intent Fan Room allocation per Fentress & Bradburn Associates Main Terminal Record Drawings dated January 1995.
- 3. HHW GPM is the design intent Fan Room allocation per Fentress & Bradburn Associates Main Terminal Record Drawings dated January 1995.





Table 4-1 above indicates either six or eight inch CHW & HHW piping services were distributed to each Fan Rooms from the associated CHW & HHW pumping skids with tenant loops of either three or two & one-half inch size derived from Fan Room Services.

A review of the floor plans indicated a tenant loop riser was provided in each vertical shaft (total of 11 for all keyed plan areas 8A to 8D, 11A to 11D, and 14A to 14D - except 14C) with terminations on both level 5 and level 6.

The air handling units in Fan Rooms one through eight serving the Great Hall Program development area are large, custom type, variable air volume central station air handling units. Medium pressure supply air ductwork is distributed from the air handling unit through vertical shafts and serve Automated Guideway Transit System (AGTS) platforms and elevator lobbies on level four, and all areas of the Terminal on level five and six. Plenum return air is routed through the same vertical shafts and is either exhausted at the top of the shaft via utility type return / relief fans for building pressurization control or returned the air handling units in the Fan Rooms. Outdoor air is provided to the Fan Room via dedicated vertical shafts. Both return and outdoor air is ducted from theses shafts to the Fan Room air handling units.

Air Distribution DSM 4 Chapter 13 Facility Design tenant standards indicate the Airport will provide a maximum of 1.00 CFM/Ft² of tenant space of cooled and heated air distribution for airline, office and retail type tenants and 1.25 CFM/Ft² for seating areas of restaurant, bar, and food court type tenants, regardless tenant of size. For clarity, it is noted the DSM 4 CHW & HHW 20 GPM/Tenant allowance is for the tenant's use and is not available for increasing hydronic flow at the air handling unit coils. It is anticipated exterior envelope thermal loads will be handled separately and will not be included in the tenant air distribution services. Table 4-2 below indicates the current air handling unit (AHU) infrastructure in the eight Fan Rooms serving the Great Hall Program development area.

TAG	FAN ROOM	AREA	AREA SERVED	CFM SA	CFM OA	% OA
AHU-1	1	14C	3,4,5	46000	13000	28
AHU-2	1	14C	1, 2	43000	12500	29
AHU-6	2	14A	3,4,5	40000	11000	28
AHU-7	2	14A	3,4,6	47000	15000	32





TAG	FAN ROOM	AREA	AREA SERVED	CFM SA	CFM OA	% OA
AHU-8	2	14A	1, 2	86000	25000	29
AHU-11	3	8C	3,4,5	48000	15000	31
AHU-12	3	8C	3,4,5,6	39500	11000	28
AHU-13	3	8C	1, 2	86000	25000	29
AHU-16	4	8A	3,4,5	45500	13000	29
AHU-17	4	8A	1, 2	43000	12500	29
AHU-20	5	8B	3,4,5	45500	13000	29
AHU-21	5	8B	1, 2	43000	12500	29
AHU-24	5	11B	3,4,5	48000	15000	31
AHU-25	6	11B	3,4,6	39500	11000	28
AHU-26	6	11B	1, 2	86000	25000	29
AHU-29	7	11D	3,4,5	40000	11000	28
AHU-30	7	11D	3,4,6	47000	15000	32
AHU-31	7	11D	1, 2	86000	25000	29
AHU-34	8	14D	3,4,5	46000	13000	28
AHU-35	8	14D	1, 2	43000	12500	29

TABLE 4-2 AHU Infrastructure - Main Terminal Fan Rooms

Key - Area Served:

- 1. Great Hall Level 5
- 2. Great Hall Level 6
- 3. Ticketing, Perimeter & Tenant Level 6
- 4. Bag Claim, Perimeter & Tenant Level 5
- 5. Elevator Lobby Level 4





6. AGTS Level 4

Per Table 4-2 above, the open two-story Great Hall area is served by air handling unit tags AHU-2, -8, -13, -17, -21, 26, -31, & -35. It is anticipated these AHU will continue to serve the same open area (i.e., Level 5 & 6) open area as the air distribution is integral to the smoke exhaust system and is located on the interior areas without provisions for ductwork revisions.

Areas such as toilet rooms and support rooms requiring general type exhaust per the Building Code are exhausted at the top of the vertical shafts shaft via utility type exhaust fans. The general exhaust is routed through the same shafts serving supply air, return/relief air, and hydronic piping.

The piping sizes from the pumping skids to the Fan Rooms appear generously sized and will provide additional Fan Room capacity, if larger pumping skids are provided.

The Terminal's hydronic tenant infrastructure appears well suited for tenant expansion if excessive additional demand is not required by an increased amount of tenant spaces generated under the Great Hall Program.

If during design, it is determined the current AHU outdoor air volume percentage must be increased, the air handling unit coils may require replacement due to increase unit thermal capacity. It is recommended to perform a ventilation outdoor air calculation for a multi-floor / multi-space area served by an air handling unit with the expected increased restaurant tenant area to evaluate this possibility and any impact on AHU coil capacity. The original construction submittal data is available to evaluate existing coil performance.

It appears air handling unit supply fan capacity and return/relief fan capacity is adequate for the Great Hall Program. Likewise, general exhaust fan capacity appears adequate if it is not anticipated to revise either toilet rooms or support spaces requirements.

5 Electrical and Power Distribution

The existing terminal building is provided with multiple electrical services from Xcel Energy's 25kV primary power distribution network. Xcel's power distribution network at DEN is supplied from two 230-25kV, 100MVA substations, with one located north of the airport site and one located south of the airport site. These substations are commonly referred to as "Barr Lake" and "Sky Ranch," respectively.

The Xcel electrical services to the terminal building consist of pad-mounted transformers rated at 2500kVA transformers with 480/277V secondary voltage. These transformers feed service switchboards that are each rated at 480/277V, 3ph, 4W, 3000 Amp. The service transformers are located on level 3, and the service switchboards are located in electrical rooms on level 2 of the main terminal. Each service switchboard is double-ended, with dual redundant feeds from two utility transformers served by two different sources. The switchboards will automatically switch from one source to the other on a loss of one of the sources.





The terminal building is broken up into three sections known as modules. Module 8 is the northernmost module. Module 11 is located in the center. Module 14 is the southernmost module. Each of these modules are subdivided into four areas: A, B, C, and D. Each of the three modules has eight utility transformers: Four grouped on the east and four grouped on the west side of the terminal. On each side, two transformers are fed from Barr Lake and two are fed from Sky Ranch. Two transformers (one from each source) serve terminal normal loads, and two transformers (one from each source) serve emergency and parking garage loads.

Each transformer serves two double ended switchboards. The double ended switchboards have one source marked as preferred and the other marked as alternate, with automated switching logic to transfer to the alternate source in the event of a power loss. Under normal conditions, each transformer serves one preferred switchboard and one alternate switchboard, distributing load evenly across all utility transformers under normal operating conditions. Because of this configuration, each switchboard's demand load must be limited such that the combined load of the preferred and alternate switchboards paired on a transformer does not exceed the 2500kVA transformer capacity. The electrical demand on each switchboard should be limited to a maximum of 1250 kVA (1187.5kW at 0.95 pF) or 1500A to avoid exceeding the available capacity of the Xcel transformers.

Table E1 shows the electrical service peak electrical demand values for FY16, which is the latest information available. These service switchboards have a bus rating of 3000 amps which at 480V is equal to 2500kVA/2375kW (at 0.95 power factor). The Denver International Airport Electrical Design Standards Manual states that the design target is a power factor of 0.95 and calls for power factor correction on motors 15hp or larger to correct to this 0.95 value. The largest transformer from Xcel Energy is a 2500kVA transformer.

The largest combined load on a service transformer pair is the 8A/8C switchboards, fed from transformers T21 and T24, at approximately 1100kW of total demand. In the event that either T21 or T24 lost power, the existing loads in 8A and 8C would load the remaining transformer to approximately 46.3% of transformer capacity. Even in the worst-case loading scenario, demand loads can be increased to approximately double the current amount prior to reaching the capacity of the existing transformers.





Table E1 - Electrical Services							
Service Switchboard	Served by Transformer	Area Served	Load Type	Peak Demand Load (kW)			
2-8ASG1	T21/T24	8A	Normal	446			
2-8CSG1	T21/T24	8C	Normal	654			
2-8BSG1	T25/T28	8B	Normal	505			
2-8DSG1	T25/T28	8D	Normal	506			
2-11ASG1	T21/T24	11A	Normal	362			
2-11CSG1	T21/T24	11C	Normal	547			
2-11BSG1	T25/T211	11B	Normal	373			
2-11DSG1	T25/T211	11D	Normal	521			
2-14ASG1	T21/T24	14A	Normal	369			
2-14CSG1	T21/T24	14C	Normal	382			
2-14BSG1	T25/T214	14B	Normal	590			
2-14DSG1	T25/T214	14D	Normal	541			

Distribution

Each quadrant A, B, C, and D of areas 8, 11, and 14 on levels 5 and 6 have a distribution panel that serve both house and tenant loads in that quadrant. The distribution panels on level 5 are 480/277V, 3ph, 4W, 400A. These panels are Westinghouse Pow R Line C, PRL 4 Panelboards with 16 spaces for breakers rated 200A/3P or less. The distribution panels on level 6 are 480/277V, 3ph, 4W, 600A. These panels are Westinghouse Pow R Line C, PRL 4 Panelboards with 14 spaces for breakers rated 200A/3P or less. A panelboard for 480/277V house loads and a transformer with a panelboard for 208/120V house loads are served from each of these area distribution panels. All tenants in the Area are served from this 480/277V distribution panel. All tenants receive a single 480V feeder sized for their individual needs. The tenant is responsible for installing their own 480/277V panelboard, transformer, and 208/120V panelboard per their





individual needs. The tenant transformers are allowed to be mounted above the ceilings in accordance with the NEC. No circuits are allowed to cross between modules.

Distribution panels have breakers for the existing tenants and at least 2 spaces for future breakers. Circuit breakers for tenants are sized based on the needs of the tenant, so there are a variety of breaker sizes in use. Additional distribution panels in each division of level 5 and level 6 could be beneficial in more than just adding capacity and should be considered. Additional distribution panels would allow the segregation of house loads and tenant loads which are consistent with concourse distribution practices. Safe work practices call for de-energizing a panel when working within the panel. By segregating house loads and tenant loads, the distribution panel that serves tenants could be de-energized to add or change a tenant circuit breaker without a power interruption to house loads which could include TSA electrical loads.

Table E2 shows the level 5 and level 6 distribution panel peak electrical peak demand values for FY13, which is the latest information available. The level 5 panels have a capacity of 400A. The Denver International Airport Electrical Design Standards Manual calls for a spare capacity of 25%, this would yield a design maximum capacity of 249.3kVA/236.8kW (at 0.95 power factor). The level 6 panels have a capacity of 600A. The Denver International Airport Design Manual 5 calls for a spare capacity of 25%, this would yield a design maximum capacity of 374.0kVA/355.3kW (at 0.95 power factor). The data shows that the maximum level 5 panel load is 100kW which yields a spare capacity of 136.8kW. The data shows that the maximum level 6 panel load 1s 170kW which yields a spare capacity of 185.3kW. Both level 5 and level 6 tenant and house loads could double without concern for exceeding capacity.

Table E2 - Electrical Distribution Panels						
Service Switchboard	Level	Area Served	Peak Demand Load (kW)			
5-8AD1	5	8A	50			
5-8BD1	5	8B	100			
5-8CD1	5	8C	70			
5-8DD1	5	8D	65			
5-11AD1	5	11A	60			
5-11BD1	5	11B	70			
5-11CD1	5	11C	90			





Table E2 - Electrical Distribution Panels						
5-11DD1	5	11D	80			
5-14AD1	5	14A	100			
5-14BD1	5	14B	70			
5-14CD1	5	14C	90			
5-14DD1	5	14D	50			
6-8AD1	6	8A	50			
6-8BD1	6	8B	10			
6-8CD1	6	8C	60			
6-8DD1	6	8D	70			
6-11AD1	6	11A	45			
6-11BD1	6	11B	150			
6-11CD1	6	11C	170			
6-11DD1	6	11D	170			
6-14AD1	6	14A	80			
6-14BD1	6	14B	Not Available			
6-14CD1	6	14C	60			
6-14DD1	6	14D	50			

Distribution panels have breakers for the existing tenants and at least 2 spaces for future breakers. Circuit breakers for tenants are sized based on the needs of the tenant, so there are a variety of breaker sizes in use.





6 Plumbing, Domestic Water, Sanitary Sewer and Grease Traps

The current terminal is served by a single 4 inch domestic water line to a pair of domestic water booster pumps. The 4 inch service comes in on level four in area b. The incoming water pressure has decreased from 70 – 80 psi at the time of original construction to a current pressure of about 65 psi as documented by Denver Water. The water booster pumps are sized to deliver about 500 gpm at 230 FT of head. The domestic water pump skid serves both the main terminal and north terminal areas.

The sanitary sewer system and grease traps are laid out symmetrically along the north south axis. The sanitary lines collect in the terminal and exit the building lines in periodic locations. The drain lines tie into exterior sanitary sewer main line running north – south parallel to the terminal on the east and west side.

There are also kitchen sanitary sewer lines which collects kitchen waste sanitary sewer and discharges it to a grease trap. There is a 1,500 gallon grease trap on the west and east side near area 11c and 11d respectively. The grease trap is located adjacent to the parking garage at about grid line w15 & e15. The outlet from the grease traps combine with the adjacent 6 inch sanitary lines into an 8 inch main that discharges into the North / South mains. The original installation of the 4" main in the terminal rises up in a pipe chase by N12.5 W4 & E4 up to the ceiling of the 5th floor, where it runs north to grid line N16 and capped for tenant tie-in.

In the airport original design, there was a kitchen sanitary serving area exiting area 5 (a,b,c & d) which was to serve the main kitchen which was never constructed. The 4" kitchen sanitary line was to exits area 5a to the west to a 1,500 gallon grease trap. It was noted that this was probably never installed, and if it was it was immediately abandoned. A condition assessment should be conducted if this is to be used.

See following sketch (Figure 2) for size location of the sanitary and kitchen drain lines.









The overall capacity of the sanitary sewer is adequate for the current configuration. Based on the current fixture counts, the drain lines are lightly loaded (less than 30%). The distribution and capacity of the existing sanitary sewer system mains appear well suited to support a redevelopment of the main terminal.





The current kitchen sewer distribution piping and grease traps are more closely designed per the current uses. If re-development plans include additional kitchen / restaurant spaces, the kitchen sewer system should be closely reviewed. Additional capacity including point of use grease traps, additional grease traps and piping or replacing existing systems with large pipe and grease traps should be considered.

7 Natural Gas

Natural gas is supplied to the airport systems from natural gas meters north of area 8b. The main Xcel service is between 70-120 PSI. Each tenant is responsible for their own meter and pressure reducing valve (PRV) that deliver anywhere from 14" to 5 psig.

The tenants are responsible for metering and bringing in the natural gas for their own use. Natural gas for the airport systems are tied in as needed. For planning purposes, we recommend a new natural gas service for any new equipment requiring natural gas or existing equipment that uses natural gas that is upsized

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