APPENDIX 7-B-2

DRAFT FORMAL DBC ADMINISTRATIVE MODIFICATIONS

(See attached.)

April 24, 2017

City and County of Denver
Development Services
201 W. Colfax Ave. Dept 203
Denver, Colorado 80202-5330

RE – Administrative Modification
Denver International Airport
Terminal Redevelopment Project
Building Classification

To Whom It May Concern,

This Administrative Modification request is submitted by Denver International Airport (DEN), with consultation from Jensen Hughes, for the Terminal Redevelopment Project Team to obtain concurrence of the overall building classification for the Jeppesen Terminal. The classification addressed herein will be utilized as the foundation for the proposed Terminal Redevelopment project. Applicable codes for this project are the 2015 International Building and Fire Codes (IBC & IFC) and the 2016 Denver Amendments (IBCA & IFCA).

The Terminal's primary function is an airport transportation center. As such, IBCA Appendix S, Construction of Airport Buildings and Structures, is applicable and will be utilized to address the special requirements unique to airport buildings. Other potential classifications of Covered Malls and High-rise buildings are addressed below. The attached preliminary Master Plan for the Terminal Building is attached to this document to provide additional information regarding the building and applicable code requirements.

1. Covered Mall

IBC Section 402.1, Applicability, states that the provisions of the Covered Mall Section apply to buildings or structures defined as covered or open mall buildings that do not exceed three levels. This section of code is therefore not applicable to the Terminal building, which is six stories in height. Additionally, while Level 5 of the Great Hall will contain a mixture of retail, eating and drinking establishments like a mall, occupants will not be in the Terminal building solely for shopping. The Terminal also contains a number of unique attributes such as TSA security that would not be present in a mall. Further, while many of the covered mail requirements were included in the original Chapter 59, then Appendix N, and now Appendix S, the airport Terminal building was never classified as a covered mall.

This Administrative Modification specifies that the Terminal building is not a covered mall building and the project will not be required to incorporate the applicable requirements from IBC Section 402.1 and associated sections from the IBCA and IFCA for a covered mall classification.

2. High-rise Classification

The 1988 UBC and the 2015 IBC define a high-rise as a building with occupied floors located 75 feet or more above the lowest level of fire department vehicle access. The original FPLS report (included as an attachment to the attached Master Plan) considered Level 5 of the Terminal to be the lowest level of fire department vehicle access. With Level 6 located only 20 ft above Level 5, the Building was not classified as a high-rise. Currently, Level 6 has been established as the primary level of fire department response for events in the Great Hall area with Level 5 being the secondary level of response.

In 2014-2015, the new Hotel and Transit Center (HTC) was constructed as an addition to the Terminal. HTC was classified as a high-rise building as its highest occupied floor level was located approximately 160 ft above the lowest level of fire department access. Because HTC was built as an addition to the Terminal complex, the Terminal is now considered an unseparated part of an overall building that includes a high-rise. Also, the addition of the T-1 Roadway between the Terminal and HTC provided a means for fire department vehicle access at Level 1 of the Terminal. Level 6 is located approximately 85 ft above the T-1 Roadway.

Despite the new features introduced with the addition of the HTC, the fire department response procedure for the Terminal remains the same. Primary fire department vehicle response points are on Level 6, where the Fire Command Centers (FCC’s) are located, and Level 5, where the Fire Department Connections (FDC’s) are located. The fire alarm system also provides separate response for the HTC and the Terminal building addressing these buildings.

Per Section 403.1 of the IBC Code Commentary, 75 ft is considered the effective reach of a 100 ft fire department aerial apparatus, assuming that the vehicle cannot park directly next to the building due to curbs, parked cars, etc. When an occupied floor level is more than 75 ft above the vehicle’s elevation, it is assumed that the occupied level is beyond the reach of the fire department and as a result, the fire may need to be fought internally. In the case of the Terminal building, the fire department is able to access all Levels of the Terminal without the need for ladder access.

Based on the original classification, the current fire department response, and the implementation of many of the same criteria in IBCA Appendix S, this Administrative Modification specifies that the Terminal building will not be classified as a high-rise building. Section 5.3 of the attached Master Plan provides details regarding requirements that will be implemented for the Terminal.

3. Great Hall Sprinkler Protection

The Great Hall tent is not provided with sprinkler protection. This Administrative Modification specifies that the project will not modify this condition. Further discussions regarding localized tenant sprinkler protection and fuel loading restrictions will be discussed in further detail as the project progresses.

4. Egress Approach

This Administrative Modification specifies that an ASET/RSET analysis will be performed (Available Safe Egress Time versus Required Safe Egress Time) to justify extended exit access travel distances from the Level 4 train platforms and the Great Hall.

ASET is the amount of time that elapses between fire ignition and the development of untenable conditions. The RSET is the amount of time from the time of ignition for all occupants to exit the building or space. Egress design will be considered acceptable if the ASET is greater than the RSET.

5. Exit Discharge

Exterior Terminal exit doors discharge to the upper open roadway and to the lower covered roadway. As documented in the *DIA Terminal Fire Protection Alternatives* letter dated October 11th, 1990 (Memorandum of Understanding #90122800), once occupants have exited the Terminal onto the Public Way (i.e. the curbside) their exit path is accomplished. The project will not modify this existing exit discharge condition; however, Jensen Hughes and DEN will assist in providing Denver Fire Department with detailed emergency response procedural information.

Please contact us if you have questions or comments. Thank you for your time and attention to this matter.

Sincerely,

PENDING
PENDING President of Airport Operations
Denver International Airport

Prepared by,

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Associate Director; Sr. Fire Protection Engineer
Jensen Hughes

Reviewed by,

Scott A. Craig, PE
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Attachments: Denver International Airport Terminal Building Master Plan, dated 04/24/2017

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DENVER INTERNATIONAL AIRPORT

TERMINAL BUILDING MASTER PLAN

-PRELIMINARY REPORT-

Prepared For

Denver International Airport

24 April 2017

Prepared by: Julie Brown, PE

Reviewed by: Scott Craig, PE

Project #: 1DLB00021.048.000

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KEY ISSUES

In order to proceed with the Terminal Redevelopment Project, the design team requests concurrence from the City and County of Denver Building and Fire Departments on the following key items:

- KEY ISSUE 1 – *Great Hall kiosks in circulation areas. Refer to Report Section 5.2.1.*
- KEY ISSUE 2 – *Building high-rise classification. Refer to Report Section 5.3.*
- KEY ISSUE 3 – *Great Hall sprinkler protection. Refer to Report Section 6.1*.
- KEY ISSUE 4 – *Fire sprinkler system water supply redundancy. Refer to Report Section 6.3.*
- KEY ISSUE 5 – *Great Hall exit access travel distance. Refer to Report Section 7.3*.
- KEY ISSUE 6 – *Terminal building exit discharge. Refer to Report Section 7.4.*

1. INTRODUCTION

This Master Plan document is being prepared as requested by Denver International Airport and the City and County of Denver Building and Fire Departments. This Master Plan is intended to serve as a means of recording the design intent for Terminal Building (referred to herein as the Building) compliance with building and fire safety code requirements. The document includes a discussion of applicable existing Memorandums of Understanding and Administrative Modifications that have been registered with the City and County of Denver to document performance-based solutions to deviations from prescriptive building and fire codes.

This Master Plan is intended to be a living document that will be maintained as the Building is modified and renovated. The focus of this current submission is to detail design intent for the planned Terminal Redevelopment project to reach concurrence on critical compliance issues.

Note that this report does not encompass the Airport Office Building.

2. APPLICABLE CODES

2.1. Authorities Having Jurisdiction

The following is a list of Authorities that have review, comment, and/or approval responsibility for the Building.

2.1.1. Primary Approval and Permitting Authority

- Denver Building Department (approval and permitting responsibility)
- Denver Department of Fire (approval and permitting responsibility)

2.1.2. Design Criteria

- Denver International Airport Design Standards and Guidelines

2.1.3. Limited Design Feature Authority

- Federal Aviation Administration
- Department of Homeland Security
- Occupational Safety and Health Administration
- United States Access Board

2.2. Code of Record

The following codes and standards applied at the time of Building construction:

- Uniform Building Code (UBC), 1988 Edition
- Denver Amendments to the 1988 UBC (UBCA), 1991 Edition

2.3. Current Applicable Codes and Standards

The following codes and standards shall apply to Building Alterations as defined by the International Existing Building Code Sections 202 and 403:

- International Building Code (IBC), 2015 Edition
- Denver Amendments to the 2015 IBC (IBCA), 2016 Edition
- International Existing Building Code (IEBC), 2015 Edition
- Denver Amendments to the 2015 IEBC (DEBC), 2016 Edition
- International Fire Code (IFC), 2015 Edition
- Denver Amendments to the 2015 IFC (IFCA), 2016 Edition
- NFPA 13 *Standard for Installation of Sprinkler Systems,* 2016 Edition
- NFPA 72 *National Fire Alarm and Signaling Code,* 2016 Edition
- NFPA 130 *Standard for Fixed Guideway Transit and Passenger Rail Systems,* 2014 Edition
- NFPA 415 *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways,* 2013 Edition.

2.4. Code Compliance Approach

The DEN Terminal building is a unique structure that, at the time of construction, utilized a number of performance-based design strategies as opposed to meeting prescriptive code requirements. All future projects will make every attempt to meet the new construction requirements of the IBC. Where the design is not able to meet prescriptive requirements, the project will maintain the design performance intent of the existing building.

2.4.1. Code Compliance Approach for the 2017 Terminal Redevelopment Project

The IEBC requirements are applied based upon the extent/type of project work being performed in an existing building. Categories of work include Repair, Alteration, Change of Occupancy, Addition, and Relocation.

Repair: Not Applicable. The primary purpose of the project is not for maintenance or correction of damage.

Addition: Small areas of roof levels near the intersection of the Terminal to the current Security Bridge are being converted into building area resulting in a small increase to the area of the building. These spaces will be addressed as Additions based on IEBC

Relocation: Not Applicable. The project will not relocate the building.

Change of Occupancy: Not Applicable. A change of occupancy is described by IEBC Section 202 as follows:

> "A change in the use of the building or a portion of a building. A change of occupancy shall include any change of occupancy classification, any change from one group to another group within an occupancy classification or any change in use within a group for a specific occupancy classification."

Levels 5 and 6 of the Terminal building are currently used for airline ticketing, retail, food/drink consumption, baggage claim, and Transportation Administration Security (TSA) screening. Incidental areas include offices and mechanical/electrical support space. The Terminal Redevelopment project plans to reconfigure the layout of Levels 5 and 6, however use of the spaces will continue to be airline ticketing, retail, food/drink consumption, baggage claim, TSA screening, and incidental support spaces.

Alteration: The Terminal Redevelopment project is defined as an Alteration, as described by IEBC Section 202 as any construction or renovation to a structure other than a repair or addition. IEBC Chapter 5 classifies Alterations as Level 1, 2, or 3. This project is considered a Level 2 Alteration as it will reconfigure the Level 5 and 6 spaces, but the alterations will not exceed 50% of the building area.

Per IEBC Section 403, Alterations are required to comply with the requirements of the IBC for new construction and the building shall be no less conforming to the provisions of the IBC than the building was prior to the alteration.

3. OCCUPANCY CLASSIFICATION

According to the "Preliminary Fire Protection and Life Safety Plan for Phase I of the Landside Terminal Denver International Airport" report prepared by Rolf Jensen & Associates, Inc. and dated 27 September 1990 (Memorandum of Understanding #900927, referred to hereafter as the Original FPLS Report), the Terminal building's primary occupancy classification was B-2, with Level 5 restaurants classified as A-3. At that time, the code of record was the 1988 Uniform Building Code (UBC) and the 1991 Denver Amendments to the 1988 UBC were under development.

The UBC did not specifically classify transit centers of any kind. Rather, the Group B-2 classification encompassed a number of different use groups including drinking and dining establishments with occupant loads less than 50 as well as wholesale and retail stores. In 1991 when the Denver Amendments to the 1988 UBC were released, Chapter 59 *Construction of Airport Buildings and Structures* defined hold rooms, passenger circulation space, offices, retail, and drinking and dining establishments with occupant loads less than 50 as occupancy Group B-2.

The current code of record for all new construction associated with the 2017 Terminal Redevelopment project is the 2015 International Building Code (IBC) with the 2016 Denver Amendments (IBCA). IBC Section 303.3 defines restaurants, dining facilities and bars as Assembly Group A-2. IBC Section 303.4 defines waiting areas in transportation terminals as Assembly Group A-3. The primary occupancy for 2017 Terminal Redevelopment project will therefore be defined as Assembly. Table 1 below indicates the appropriate occupancy classification based on IBC Chapter 3 for the various uses on Levels 5 and 6 of the Building.

Table 1 – Building Area Use and Occupancy

Use	Occupancy Classification
Restaurant	A-2
Bar	A-2
Commercial Kitchen	A-2
Ticketing	A-3
Security Check Point & Queuing	A-3
Baggage Claim	A-3
Offices	B
Mechanical/Electrical Spaces	F-1
Retail Stores	M
Storage	S-1

The building has multiple occupancies and is a mixed-use facility. Section 508 of the 2015 IBC identifies two approaches for addressing mixed-use conditions: non-separated and separated. IBC Section 508.1 allows buildings to be designed using a non-separated approach, a separated approach, or a combined approach.

The design for the 2017 Terminal Redevelopment project will utilize the non-separated occupancy approach based on IBC Section 508.3 for all occupancies on Levels 5 and 6. Non-separated occupancies do not utilize fire barriers to separate occupancies unless required by the code for a specific use group. Each portion of the building is individually classified by use group. The type of construction required is determined through application of height and area limitations for each of the applicable use groups to the entire building and the most restrictive construction type is used for the entire building.

Based on Table 1 above, the building contains Group A-2, A-3, B, F-1, M and S-1 occupancies. IBC Table 503 indicates that buildings of Type IA construction have the same height, area, and number of story limitations for all applicable occupancies. As such, the non-separated occupancy approach from IBC Section 508.3 may be utilized for these occupancies in the building, provided the most restrictive applicable provisions of IBC Chapter 9 are applied to the building or portion thereof in which the non-separated occupancies are located.

4. BUILDING CONSTRUCTION

4.1. Construction Type I, Fire Resistive

The Terminal building was originally constructed to be Type I, Fire Resistive construction, per the 1991 Denver Building Code, with notable exceptions (e.g., the fabric roof structure). The following table is derived from the original FPLS Report. This table shall be used for any modifications made to existing building elements.

4.2. Fire Resistance of Existing Building

Table 2 – Fire Resistance Ratings (in hours) for Building Elements

Building Elements – Type I, Fire Resistive	HOURS
Structural frame – columns and primary beams	3
Roof construction (Great Hall with roof > 25 ft)	0
Roof construction, other areas	2
Floor construction, mezzanine floors	1
Floor construction, other floors	2
Exterior bearing walls	4
Exterior nonbearing walls	0
Nonbearing interior partitions	0
Shafts and exit stair enclosures	2
Public corridor walls	0
Horizontal Exit Fire Walls	2

4.3. Construction Type IA

Type I, Fire Resistive construction is most closely related to Type IA construction in the 2015 IBC. Any new building elements constructed in the Terminal (that do not support existing building elements) shall comply with the following table for Type IA construction.

4.4. Fire Resistance for New Building Elements

Table 3- Fire Resistance Rating (in hours) Requirements for Building Elements

Building Elements – Type IA	HOURS
Primary structural frame – Including columns, girders, trusses [d]	3 [a]
Bearing exterior walls [c, d]	3
Bearing interior walls	3 [a]
Nonbearing exterior walls and partitions (Fire separation distance ≥ 30 feet)	0
Floor construction – Including secondary beams and joists	2
Roof construction - Including secondary beams and joists	1 ½ [b]
Shaft Enclosures (IBC 713 & IBC 1022)	
Shafts (including exit enclosures) connecting any 4 or more stories	2
Shafts (including exit enclosures) connecting fewer than 4 stories	2
Fire/Smoke Partitions (IBC Table 1020.1)	
Exit Access Corridors	0

Supplemental Notes (IBC Table 601):

a) Fire-resistance ratings of structural framing and bearing walls are permitted to be reduced by 1-hour when supporting a roof only.
b) Fire protection of structural members are not required, including protection of roof framing and decking, where every part of the roof construction is 20 ft. or more above any floor immediately below. Fire-retardant-treated wood members are allowed to be used for such unprotected members.
c) Not less than the fire-resistance rating based on fire separation distance (IBC Table 602)
d) Not less than the fire-resistance rating as referenced in Section 704.10.

4.5. Combustible Construction Materials

All construction materials are to be noncombustible; except where complying with IBC Section 603. Combustible materials are permitted in buildings of Type I non-combustible construction in the following applications:

1) Fire-retardant-treated wood where the required fire-resistance rating is 2-hours or less. It is also permitted in non-load bearing exterior walls. Fire-retardant-treated wood is allowed to be used in roof construction; including girders, trusses, framing and decking; given that the vertical distance from the upper floor to the roof is greater than 20 feet, in accordance with IBC Section 603.1 (1) (1.3).

2) Thermal and acoustical insulation (other than foam plastics) having a flame spread index less than 25. Insulation installed between two layers of noncombustible materials without an intervening airspace is permitted to have a flame spread index up to 100. Insulation installed between a finished floor and solid decking without intervening airspace is allowed to have a flame spread index of not more than 200.

3) Foam plastics in accordance with IBC Chapter 26.

4) Class A, B or C roof coverings.

5) Interior floor finish and floor covering materials installed in accordance with IBC Section 804.

6) Millwork such as doors, door frames, window sashes and frames.

7) Interior wall and ceiling finishes installed in accordance with IBC Sections 801 & 803.

8) Trim installed in accordance with IBC Section 806.

9) Show windows, nailing or furring strips and wooden bulkheads below show windows (including their frames, aprons and show cases) are permitted to be installed no greater than 15 feet above grade.

10) Finish flooring installed in accordance with IBC Section 805.

11) Partitions dividing portions of stores, offices or similar places occupied by no more than one tenant. Partitions must not establish a corridor serving an occupant load of 30 or more shall be permitted to be constructed of fire-retardant-treated wood, 1-hour fire-resistance-rated construction or of wood panels or similar light construction not exceeding 6 feet.

12) Stages and platforms constructed in accordance with IBC Sections 410.3 & 410.4.

13) Combustible exterior wall coverings, balconies and similar projections and bay or oriel windows in accordance with Chapter 14.

14) Blocking such as for handrails, millwork, cabinets and window and door frames.

15) Light-transmitting plastics as permitted by Chapter 26.

16) Mastics and caulking materials applied to provide flexible seals between components of exterior wall construction.

17) Exterior plastic veneer installed in accordance with Section 2605.2.

18) Nailing or furring strips as permitted by Section 803.11.

19) Heavy timber as permitted by Note c to Table 601 (see above) and Sections 602.4.7 & 1406.3.

20) Aggregates, component materials and admixtures permitted by Section 703.2.2.

21) Sprayed fire-resistant materials and intumescent and mastic fire-resistant coatings, determined on the basis of fire resistance tests in accordance with Section 703.2 and installed in accordance with Sections 1705.14 & 1705.15.

22) Materials used to protect penetrations in fire-resistance-rated assemblies in accordance with Section 714.

23) Materials used to protect joints in fire-resistance-rated assemblies in accordance with Section 715.

24) Materials in the concealed spaces for buildings of Types I and II construction in accordance with Section 718.5.

25) Materials exposed within plenums complying with Section 602 of the *International Mechanical Code* (IMC).

26) Wall construction of freezers and coolers of less than 1,000 square feet in size, lined on both sides with noncombustible materials and the building is protected throughout with an automatic sprinkler system in accordance with 903.3.1.1.

5. SPECIAL PROVISIONS

IBC Chapter 4 contains detailed requirements for special building types such as high-rise, airport buildings, and covered mall buildings, as well as unique building features such as atriums. This section discusses the applicability of relevant Chapter 4 requirements.

5.1. Airport Building

IBCA Appendix S contains special detailed requirements related to airport buildings. The following requirements are stated for clarity and will be implemented with the Terminal Redevelopment design unless noted otherwise:

IBCA – Appendix S, Section 4.1.1. Airport terminal buildings shall be Type I or Type II construction, as defined in IBC Chapter 6.

IBCA – Appendix S, Section 4.1.1. Occupancy. The occupancy of the airport terminal building or portions thereof shall be classified in accordance with the requirements of IBC Chapters 3 and 4 and shall comply with the mixed use and occupancy provisions of IBC Section 508. High-hazard Group H occupancy are not permitted in passenger terminal buildings.

IBCA – Appendix S, Section 4.2.1. General. Heating, ventilating and air conditioning systems must be installed in accordance with the provisions of the 2015 International Mechanical Code (IMC) and the 2015 International Fuel Gas Code (IFGC).

IBCA – Appendix S, Section 4.2.6.1. General. Commercial kitchen exhaust ventilation systems for restaurants and flight kitchens shall be provided in accordance with the provisions of IFC Chapter 6 and IMC Chapter 5.

IBCA – Appendix S, Section 4.3. Exits. Airport terminal building means of egress shall conform to the requirements of the IBC.

IBCA – Appendix S, Section 4.5.1.7. General. Utility tunnel and utility spaces or rooms over 1,950 square feet shall be classified as Ordinary Hazard Group 1 – 0.16 gpm/square foot.

IBCA – Appendix S, Section 4.5.1.10. General. New and modified communication and data room shall be provided with automatic sprinkler protection unless the provisions of IFC 903.3.1.1.1 as amended apply.

IFCA Section 903.3.1.1.1. Exempt Locations. Automatic sprinklers shall not be required in the following rooms or areas where such rooms or areas are protected with an approved automatic fire detection system in accordance with Section 907.2 that will respond to visible or invisible particles of combustion. Sprinklers shall not be omitted from a room merely because it is damp, or fire-resistance-rated construction or contains electrical equipment.

1. A room where the application of water, or flame and water, constitutes a serious life or fire hazard.
2. A room or space where sprinklers are considered undesirable because of the nature of the contents, where approved by the fire code official.
3. Fire service access elevator machine rooms and machinery spaces.
4. Machine rooms, machinery spaces, control rooms and control spaces associated with occupant evacuation elevators designed in accordance with Section 3008 of the IBC.

IBCA – Appendix S, Section 4.5.2. Fire Alarm Systems. Fire alarm and smoke detection shall be provided as follows:

1. **Airport Terminal Buildings**

- Smoke detection shall be spaced not to exceed 2,500 square feet per detector in areas with roof/ceiling over 25 feet.
- Manual pull stations shall be provided at required exits and each zone shall be annunciated individually or by zone. There shall be maximum 200 linear feet separation between pull stations within public airport terminal and concourse areas. Locations of manual pull stations in other areas shall comply with the provisions of NFPA 72.
- Smoke detection shall be provided in the following areas:
  - Electrical, transformer, telephone equipment or similar room, elevator machine rooms and all elevator lobbies.
  - Outlet of fans used for pressurization of stairways, hoistways and refuge areas. Activation of smoke detector shall cause a supervisory signal; not an alarm signal at the building annunciator panel.
  - Top of pressurized stairwells and in elevator hoistways where required by this code. These devices shall initiate an alarm condition and illuminate the respective indicator at the graphic annunciator. This alarm condition shall not initiate occupant notification or smoke control systems.
  - Supply air systems with a design capacity exceeding 2,000 cfm and in the supply air duct or plenum downstream of any fan. This alarm condition shall cause a supervisory signal.
  - Main return air exhaust plenum of each air-handling system having a design capacity exceeding 2,000 cfm, in accordance with IMC Section 606.2.1. Where multiple air-handling systems share common supply or return ducts or plenums with a combined capacity exceeding 2,000 cfm, smoke detectors shall be provided in accordance with IMC Section 606.2.2. Activation of duct smoke detectors shall cause a supervisory signal.

2. Tenant Spaces and Similar Rooms Adjoining Airport Terminal Buildings:

- On the tenant side at each opening into the airport terminal building and at each exit from the tenant space. For openings exceeding 30 linear feet, an additional detector shall be installed for 30 linear feet or fraction thereof.
- Electrical equipment rooms equipped with automatic fire sprinkler protection shall be provide with smoked detection. Rooms without automatic fire sprinkler protection shall be provided with smoke and heat detection.
- Manual pull stations shall be installed at all kitchen exits.

IBCA – Appendix S, Section 4.5.2.1. General. Fire alarm system central station monitoring shall be provided with an approved radio communicator capable of transmitting directly to Denver Fire Department dispatch.

IBCA – Appendix S, Section 4.5.2.2. General. Fire alarm system signal annunciation shall be by a computer-based graphic display. All existing and new airport terminal building fire alarm devices shall be integrated into the system. Annunciation of all building fire alarm, trouble and supervisory signals shall be displayed at the computer graphic display and all fire alarm control units. Local annunciators shall be provided for pre-action and clean agent suppression systems in accordance with IFCA Section 907.

IBCA – Appendix S, Section 4.5.2.3. General. New airport terminal buildings shall be provided with an emergency voice/alarm communication system fully integrated into the facility-wide Emergency Communication System (ECS); incorporating audible, visual and textual notification appliances including: flight, gate, baggage and multi-use information displays (FID’s, GID’s and BID’s, MUFID’s), and other large format displays and video displays exceeding 60” measured diagonally. DIA CATV and tenant audio systems shall be shunted upon activation of the emergency communication system

IBCA – Appendix S, Section 4.5.2.3.1. General. The emergency voice alarm evacuation message alert tone shall be a slow whoop or as approved by the fire code official. Evacuation messages shall be manually initiated from the FCC.

IBCA – Appendix S, Section 4.5.2.4. General. The public areas of Airport Terminal Buildings shall be provided with pre-signal fire alarm notification functionality in accordance with NFPA 72.

IBCA – Appendix S, Section 4.5.2.5. General. A firefighter radio communication system shall be provided in accordance with IFCA Section 510 or shall be integrated into the existing DIA Public Safety Communications Network. Two-way wired communication shall also be provided by fixed handsets. Handsets for the Terminal building shall be located at the FCC's on Terminal level 6, Terminal fire pump rooms, and the Life Safety Maintenance room on level 3. Handset shall be capable of communication with all other handsets in the building simultaneously. New Airport Terminal Buildings shall have 2-way wired communication between the FCC and fire pump room(s) as approved.

IBCA – Appendix S, Section 4.6.1 Smoke Control for Airport Terminal Buildings. Requirements. A smoke control system shall be provided to serve airport terminal buildings. Smoke exhaust locations shall be configured in order to prevent accumulation of smoke in any area of the airport terminal building. The smoke control system shall be activated in accordance with Section 4.6.6. Where a space or corridor exceeds 20 feet in length and is connected to an atrium or airport terminal area that has separate smoke control zones, provide supply air to the space or corridor at the farthest location from the point of connection to the atrium or airport terminal area. Tenant spaces less than 5,000 square feet and open to the airport terminal building shall be incorporated into the Airport Terminal Building smoke control exhaust operating sequence. Smoke control systems shall comply with Sections 4.6.1 through 4.6.7.

Exceptions:

1) Ramp service and non-public ramp level tenant areas of airport terminal building.
2) Un-enclosed bag handling tenant areas of airport terminal building.
3) Permanently fixed aircraft loading walkways when separated by one-hour assemblies.

IBCA – Appendix S, Section 4.6.2. Design Criteria. The smoke control equipment for the airport terminal building shall be independent of that serving tenant spaces of 5,000 square feet or more. The airport terminal building smoke removal system shall provide at least four air changes per hour or 20,000 cfm from each smoke zone.

IBCA – Appendix S, Section 4.6.3. General. All continuous tenant spaces adjoin the airport terminal building that exceed 5,000 square feet shall be a separate smoke control zone in accordance with Section 4.6.1.

IBCA – Appendix S, Section 4.6.4. Airport Terminal Building Elevators and Stairs. Pressurized exit stairs, elevator hoistways and exit passageways are required unless otherwise approved by the Building Department and Fire Department.

Exceptions:

1) Elevators and enclosed stairways from the transit way station.
2) Pressurized stairs, elevators and exit passageways shall not be required in existing airport terminal buildings and addition to existing airport terminal building where this system does not presently exist.

IBCA – Appendix S, Section 4.6.5. Airport Terminal Building Baggage Tunnel. The smoke control exhaust system shall be sized to provide a minimum of 4 air changes per hour.

IBCA – Appendix S, Section 4.6.6. System Initiation. Airport Terminal Building smoke control shall be initiated when any automatic device (suppression water flow or automatic detection), activates within a smoke zone. Manual activation of smoke control equipment is required from any FCC fire alarm system workstation.

Exceptions:

1) Activation of any two consecutive automatic devices in the same smoke zone (e.g. suppression water flor or automatic detection), shall be required to initiate the smoke control sequence for Terminal Levels 5 and 6 and any normally occupied public areas of Concourse Level 2. Operation of a manual pull station shall function as a verification device to initiate the smoke control sequence for the smoke zone containing the initial automatic device in alarm.
2) Manual activation from the FCC workstations shall be the only means permitted to initiate the smoke control sequence for the Terminal Great Hall, Baggage Terminal and AGTS Tunnel.

IBCA – Appendix S, Section 4.6.7. Adjacent Zones. Where multiple smoke control zones for the airport terminal building are provided, only the smoke exhaust system for the zone in alarm shall be activated. Smoke exhaust systems for adjacent airport terminal building zones shall not activate.

IBCA – Appendix S, Section 4.7.2. Delayed Egress. Delayed egress shall be permitted to restrict access from an airport terminal building to the restricted areas of the airport.

IBCA – Appendix S, Section 4.7.2.1. Delayed Egress Sequence of Operation. The fire alarm system shall interface all delayed egress systems and unlock these doors based on an approved sequence of operation. All doors shall be capable of being unlocked manually at the FCC fire alarm system workstation.

IBCA – Appendix S, Section 4.7.2.2. Delayed Egress Lock Power. All delayed egress locks shall release upon loss of power.

IBCA – Appendix S, Section 4.7.2.3. Delayed Egress Lock Release. The delayed egress locks shall initiate the irreversible unlocking process after the releasing device has been activated for 3 seconds. Once the unlocking process is initiated, the delayed egress lock shall release in 15 seconds.

IBCA – Appendix S, Section 4.7.2.4. Delayed Egress Lock Relocking. Relocking of the doors shall be permitted to be performed through a centralized system after the fire alarm system has been reset.

IBCA – Appendix S, Section 4.7.2.5. Delayed Egress Lock Signage. All doors provided with delayed egress locks shall be provided with approved signage providing door opening instructions.

IBCA – Appendix S, Section 4.7.2.6. Delayed Egress Lock Emergency Lighting. All new doors provided with delayed egress locks shall be provided with emergency lighting.

IBCA – Appendix S, Section 4.7.2.7. Delayed Egress Lock Listing. Components for the delayed egress lock shall be listed as a complete assembly.

IBCA – Appendix S, Section 4.8.1. Emergency Power. Airport terminal buildings shall be provided with an emergency power source. Emergency power shall be provided by dual utility services or other approved means complying with NFPA 70, (NEC) Article 700 and the International Fire Code. Conditions of utility service availability and system power transfer shall be monitored by the fire alarm system.

IBCA – Appendix S, Section 4.8.2. General. The following equipment shall be provided with emergency power:

- Mechanical equipment for smoke control.
- Emergency egress and exit lighting.
- Emergency elevator power.
- Fire alarm and detection systems.
- Fire pump/jockey pump.
- Emergency communication systems.

IBCA – Appendix S, Section 6.1.3. Aircraft Loading Walkways on Grade Level. Permanently fixed aircraft loading walkways on grade level shall be of Type I or II-A construction as defined in IBC Chapter 6. All exterior doors shall have opening protection with a fire protection rating of not less than ¾ hour. Doors shall be self-closing and shall swing outward. Entrance doors between walkways and the airport terminal building shall swing into the airport terminal and be equipped with automatic closure and panic hardware.

IBCA – Appendix S, Section 6.1.4. Other Aircraft Loading Walkways. Both fixed and moveable aircraft loading walkways shall be constructed in accordance with NFPA 415 Section 6.2 and in compliance with FAA Circular AC 150/5220-12C. Structural loading shall comply with IBC Chapter 16. All walkways shall be provided with a permanently affixed placard certifying compliance with NFPA 415. Requirements of this amendment Section 6.2.1 through 6.2.3 shall not apply.

IBCA – Appendix S, Section 6.2.12. Sprinkler System. Permanently fixed aircraft loading walkways greater than 20 feet in length or at grade level shall be provided with an automatic sprinkler system in accordance with NFPA 415, Section 4.5.1.3.

IBCA – Appendix S, Chapter 7. Subsurface Tunnels.
IBCA – Appendix S, Section 7.2. Sprinkler System Design Occupancy Classifications. Baggage Tunnels (Ordinary Hazard – Group 2) and Utility Tunnels (Ordinary Hazard – Group 1) Shall be sprinklered throughout. Train Service Tunnels (Ordinary Hazard Group 2) shall be sprinklered at the transit stations as approved by the Building Department and the Fire Department.

IBCA – Appendix S, Section 7.3. Smoke Removal System. A smoke removal system shall be provided in accordance with Section 4.6.5.

IBCA – Appendix S, Section 7.4. All life safety systems shall be provided with emergency power. Utility and baggage tunnels shall be provided with visual and textual notification appliances for emergency alarm and ECS integration where applicable. Device locations shall be approved by the fire code official.\

IBCA – Appendix S, Section 7.5. Exits. A walkway with a minimum 74-inch width (2 exit path widths of 22 inches each, plus 12 inches of wall clearance, and an 18-inch platform edge clearance) shall be provided within all people-mover transit tunnels. Exit doors into adjacent protected tunnels shall be provided at a maximum spacing of 200 feet and shall be monitored by the airport operations center.

> **Exception:** The walkway width and exit door spacing may be modified based upon exit study submitted by the Design professional and approved by the Building Department and Fire Department.

IBCA – Appendix S, Section 7.6. Separation. A minimum 2-hour fire-resistance rated fire barrier in accordance with IBC Section 707 shall be provided between tunnels.

IBCA – Appendix S, Section 7.7. Transit Station Separation. The transit way shall be separated from the transit station by minimum two-hour fire resistance rated construction with 1 ½ hour fire-resistance rated doors. Windows within two-hour fire resistance rated construction shall be 1 ½ hour fire-resistance rated windows.

> **Exception:** Fire-resistance rated window openings of ¾ hour may be used when the window assembly is protected with approved directional sprinkler heads spaced 6 feet apart on both sides of the glass.

5.2. Covered Mall

IBC Section 402.1 *applicability* states that the provisions of the Covered Mall Section apply to buildings or structures defined as covered or open mall buildings that do not exceed three levels. This section of code is therefore not applicable to the Terminal building which is six stories in height. Additionally, while Level 5 of the Great Hall will contain a mixture of retail, eating and drinking establishments similar to a mall, occupants will not be in the Terminal building solely for the purpose of shopping. The Terminal also contains a number of unique attributes such as TSA security that would not be present in a mall.

It is understood that there are misunderstandings from original construction that the DEN terminal buildings had been classified as a covered mall building. While many of the covered mail requirements were included in the original Chapter 59, then Appendix N, and now Appendix S, the airport terminal building was never classified as a covered mall.

In conclusion, the Terminal building is not considered a covered mall building. As such, the following issues of note are not applicable to the Terminal Building:

- Automatic sprinkler system zoning requirements of IBC 402.5
- Minimum egress width requirements of IBC 402.8.1
- Occupant load determination requirements of IBC 402.8.2
- Exit access travel distance limitations of IBC 402.8.5
- Exit discharge to garages restrictions of IBC 402.8.6
- Emergency power system requirements of IFCA 604.2.17
- Smoke detection requirements of IFCA 907.2.20.1
- Smoke control system requirements of IFCA 909.14

IBC Section 402 provides requirements for kiosks. The IBC does not provide guidance for these structures anywhere else in the code. The following section discusses the applicability of the covered mall requirements for kiosks.

5.2.1. Kiosks

The IBC does not have a definition for the term kiosk. IBC Section 201.4 states that when a term is not defined, it will have ordinarily accepted meanings based on the context. Retail displays located in the main circulation paths in covered malls are colloquially referred to as kiosks. Such displays are usually less permanent in terms of structure as compared to a tenant store and typically smaller than a tenant store. IBC Section 402.6 limits kiosks in covered malls to an area of 300 sq ft. Additionally, a minimum horizontal separation distance of 20 ft is required, per IBC 402.6.2 (3).

Since the IBC does not specifically define kiosks, it is inferred that a kiosk is defined as a retail space that is somewhat transient in nature, 300 sq ft or less in size, and located in the center of the Great Hall circulation areas (rather than a perimeter tenant space).

The proposed renovation of the 5th level of the Great Hall includes the addition of retail, waiting areas, and restaurant seating areas. These proposed areas are not considered kiosks as they exceed the maximum area restriction of 300 square feet [IBC 402.6.2 (4)] and the minimum horizontal separation distance of 20 feet [IBC 402.6.2 (3)]. Rather, these areas will be required to comply with applicable sections of the code based upon their occupancy and use in terms of construction, egress restrictions, etc.

The design team will be performing fire/smoke modeling to account for the additional fuel load associated with the inclusion of retail vendors, restaurant seating, and waiting areas. The fire/smoke modeling will be utilized to develop an approach for establishing requirements for combustible loading restrictions, sprinkler protection, etc.

5.3. High Rise

The 1988 UBC and the 2015 IBC define a high-rise as a building with occupied floors located 75 feet or more above the lowest level of fire department vehicle access. The original FPLS report considered Level 5 of the terminal to be the lowest level of fire department vehicle access. With Level 6 located only 20 ft above Level 5, the Building was not classified as a high-rise. Currently, Level 6 has been established as the primary level of fire department response for events in the Great Hall area with Level 5 being the secondary level of response.

In 2014-2015, the new Hotel and Transit Center (HTC) was constructed as an addition to the Terminal. HTC was classified as a high-rise building as its highest occupied floor level was located approximately 160 ft above the lowest level of fire department access. Because HTC was built as an addition to the Terminal complex, the Terminal is now considered an unseparated part of an overall building that includes a high-rise. Also, the addition of the T-1 Roadway between the Terminal and HTC provided a means for fire department vehicle access at Level 1 of the Terminal. Level 6 is located approximately 85 ft above the T-1 Roadway.

Despite the new features introduced with the addition of the HTC, the fire department response procedure for the Terminal remains independent from HTC. Primary fire department vehicle response points are on Level 6, where the Fire Command Centers (FCC's) are located, and Level 5, where the Fire Department Connections (FDC's) are located. The fire alarm system also provides separate response for the HTC and the Terminal building addressing these buildings.

According to Section 403.1 of the IBC Code Commentary, 75 ft is considered the effective reach of a 100 ft fire department aerial apparatus, assuming that the vehicle cannot park directly next to the building due to curbs, parked cars, etc. When an occupied floor level is more than 75 ft above the vehicle's elevation, it is assumed that the occupied level is beyond the reach of the fire department and as a result, the fire may need to be fought internally. In the case of the Terminal building, the fire department is able to access all Levels of the Terminal without the need for ladder access.

Due to the ambiguity related to the high-rise classification of the Building, the following section details applicable code sections of the Denver Amendments, the IBC, and the IFC that address the requirements for high-rise structures.

IBC Section 403.2.1. Construction. In buildings that have sprinkler control valves equipped with supervisory initiating devices and water-flow initiating devices for each floor, reductions in fire-resistance rated construction elements are permitted.

Design Compliance:

The Building was originally constructed meeting the requirements for Type I, Fire Resistive construction, meeting the equivalent requirements for Type IA construction in the 2015 IBC; therefore, the design exceeds the high-rise Code requirements for fire-resistance rated construction elements.

IBC Section 403.2.1.2. Shaft Enclosures. For high-rise buildings not exceeding 420 feet in building height, the required fire-resistance rating of the fire barriers enclosing vertical shafts, excluding interior exit stairways and elevator hoistway enclosures, is permitted to be reduced by 1 hour where automatic sprinklers are installed within the shafts at the top and at alternating floor levels.

Design Compliance:

The Building does not exceed 420 feet in building height and stairways and vertical shaft are constructed meeting the requirements for 2-hour fire resistance rated construction; therefore, the design exceeds the high-rise Code requirement.

IBC Section 403.2.2. Seismic Considerations. High-rise buildings must refer to Chapter 16 for seismic considerations.

IBC Section 1615.1. General. High-rise buildings that are assigned to Risk Category III or IV shall comply with the requirements of section 1615. Frame structures shall comply with the requirements of Section 1615.3.

Design Compliance:

The Project will meet IEBC requirements for building modifications.

IBC Section 403.2.3. Structural Integrity of Interior Exit Stairways and Elevator Hoistway Enclosures. For high-rise buildings of Risk Category III or IV in accordance with Section 1604.5, enclosures for interior exit stairways and elevator hoistway enclosures shall comply with Sections 403.2.3.1 through 403.2.3.4.

Design Compliance:

Interior exit stairway and elevator hoistway enclosures were constructed using a combination concrete and masonry materials, meeting the requirements of IBC Section 403.2.3.3.

IBC Section 403.2.4. Sprayed Fire-Resistant Materials (SFRM). The bond strength of the SFRM installed throughout the building shall be in accordance with IBC Table 403.2.4.

Design Compliance:

IBC Table 403.2.4 requires the minimum bond strength for SFRM in buildings less than 420 feet in building height to be 430 pounds per square foot. Any new SFRM applied shall be required to meet the provisions of IBC Table 403.2.4.

IBC Section 403.3. Automatic Sprinkler Protection. Per IBC Section 403.3, high-rise buildings are required to be equipped with an automatic sprinkler system throughout.

Design Compliance:

The Building is provided with automatic sprinkler protection throughout with the exception that sprinkler protection is not provided under the tent at roof level in the Great Hall. At the time of the building construction, this was permitted as documented in the *DIA Terminal Fire Protection Alternatives* letter dated October 11th, 1990 (Memorandum of Understanding #90122800). Currently, IBC Section 404.3 (2) states that where the ceiling of an atrium is more than 55 feet above the finished floor, sprinkler protection at the ceiling is not required. According to the IBC commentary to Section 404.3, 55 feet is the height at which the system is no longer effective. The design team will be performing fire/smoke modeling to validate the omission of sprinklers in this area.

IBC Section 403.3.1. Number of Sprinkler Risers and System Design. Each sprinkler system zone in buildings that are more than 420 feet in building height shall be supplied by at least two risers. Each riser shall supply sprinklers on alternate floors. If more than two risers are provided for a zone, sprinklers on adjacent floors shall not be supplied from the same riser.

Design Compliance:

The Building does not exceed 420 feet in building height; therefore, the above high-rise Code requirement is not applicable.

IBCA Section 403.3.2. Water Supply Serving High-Rise Buildings. Water supply serving high-rise buildings shall be provided in accordance with IFCA Section 507.2.3.

IFCA Section 507.2.3 Water supply serving high-rise buildings. High-rise buildings shall be supplied by connections to a minimum of two public water mains located in different streets. Separate supply piping shall be provided between each water main connection and the building. Required backflow prevention devices and flow switches shall be provided at each water main entry to the structure. Each fire main shall be sized to meet the full demand of the fire protection system at each connection to achieve redundancy.

Exception: Where approved by the fire code official, high-rise buildings without access to different water mains shall have two fire main connections to the same public main. The public main shall have valves such that an interruption of one water source can be isolated so that water supply will continue without interruption through the other connection. The two required fire mains shall have a minimum separation distance from each other of five feet at all points from the public main to the building. Each fire main shall be sized to meet the full demand of the fire protection system at each connection to achieve redundancy.

Design Compliance: The Terminal Building and the Airport Office Building (AOB) are served by independent fire pumps which are supplied by different water mains. The two fire pumps are interconnected for the purpose of providing redundancy in the event that one pump or main is compromised. A normally closed valve must be manually opened in order to allow a single pump to serve both systems. This current design exceeds the intent of this section by providing redundant fire pumps for the building, as well as, redundant water mains. No modification is proposed.

IBC Section 403.3.3. An automatic secondary on-site water supply having a capacity not less than the hydraulically calculated sprinkler demand, including the hose stream requirement, shall be provided for high-rise buildings assigned to Seismic Design Category C, D, E or F as determined by Section 1613. An additional fire pump shall not be required for the secondary water supply unless needed to provide the minimum design intake pressure at the suction side of the fire pump supplying the automatic sprinkler system. The secondary water supply shall have a duration of not less than 30 minutes.

Design Compliance:

The Building is assigned a Seismic Design Category of B in accordance with IBCA Section 1613.3.5.3; therefore, the above high-rise Code requirement is not applicable.

IBC Section 403.3.4 Fire Pump Room. Fire pumps shall be located in rooms protected in accordance with Section 913.2.1.

IBC Section 913.2.1. Protection of Fire Pump Rooms. Fire pumps shall be located in rooms that are separated from all other areas of the building by 2-hour fire barriers constructed in accordance with Section 707 or 2-hour horizontal assemblies constructed in accordance with Section 711, or both.

Exceptions:

1) In other than high-rise buildings, separation by 1-hour fire barriers constructed in accordance with Section 707 or 2-hour horizontal assemblies constructed in accordance with Section 711, or both, shall be permitted in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2.
2) Separation is not required for fire pumps physically separated in accordance with NFPA 20.

Design Compliance:

Fire pumps are located in rooms with 2-hour fire-resistance-rated separation; therefore, the design meets the above high-rise Code requirements.

IBC Section 403.3.4.7. Smoke Removal. Natural or mechanical ventilation is required for the removal of products of combustion to aid in post-fire salvage and overhaul operations by one of the following means:

1. Manually operable windows or panels distributed around the perimeter of each floor at not more than 50-foot intervals. The area of operable windows or panels shall not be less than 40 square feet for every 50 linear feet of perimeter.
2. Mechanical-air handling equipment providing one air change every 15 minutes for the area involved and exhaust air must be moved directly to the outside without recirculation to other portions of the building.

Design Compliance:

The smoke control system provided throughout the Building can be used for ventilation in post-fire salvage operations and is capable of providing a minimum of 4 air changes per hour; therefore, the design is in compliance with the above high-rise Code requirements.

IBC Section 403.4. Emergency Systems. The following emergency systems must be provided:

- Smoke detection in accordance with IFCA Section 907.2.13.1.
- Fire Alarm system in accordance with IFCA Section 907.2.13.
- Standpipe system in accordance with IFCA Section 905.
- Emergency Voice/Alarm Communication system in accordance with IFCA Section 907.2.13.
- Emergency Responder Radio coverage in accordance with IFCA Section 403.4.5.

IFCA 907.2.13. **High-Rise Buildings.** High-rise buildings shall be provided with a fire command center in accordance with Section 508, manual fire alarm boxes located in accordance with IFC Section 907.4.2 and an automatic fire alarm and detection system in accordance with IFC Section 907.2.13.1, as amended, a fire department communication system in accordance with Section 907.2.13.2, and an emergency voice/alarm communication system in accordance with IFC Section 907.5.2.2, as amended, that provides occupant notification of alarm on the fire floor, floor above, floor below and at the level of the FCC.

IFCA Section 907.2.13.1. Automatic Smoke Detection. Automatic smoke detection in high-rise buildings shall be in accordance with Sections 907.2.13.1.1 & 907.2.13.1.2.

IFCA Section 907.2.13.1.1. Area Smoke Detection. Area smoke detectors shall be provided in accordance with this section. Smoke detectors shall be connected to an automatic fire alarm system. Activation of any detector required by this section shall activate the emergency voice/alarm communication system in accordance with Section 907.5.2.2. In addition to smoke detectors required by Sections 907.2.1 through 907.2.10, smoke detectors shall be installed in the following locations:

1. Mechanical equipment, electrical, transformer, telephone equipment or similar rooms not provided with automatic sprinkler protection.

2. Elevator machine rooms and elevator lobbies.

3. Interior corridors serving as means of egress for Group R-1, R-2 and R-4 occupancies with an occupant load greater than 10 persons.

4. Not less than one foot but no more than three feet on the occupied side of each door that enters a refuge area, elevator lobby and exit stairway which does not directly exit from a refuge area, for occupancies other than R-1, R-2 and R-4.

5. Top of stairwells and in elevator hoistways (heat detectors in accordance with Section 907.3.3). Devices shall initiate an alarm condition and illuminate the respective indicator at the graphic annunciator. They shall not initiate occupant notification or the smoke control sequence.

6. Where unenclosed vertical openings are permitted by IBC Section 712, smoke detectors shall be located around the perimeter of the opening, on each level, not less than four feet from the edge of the opening. Unenclosed stairway and escalator openings shall comply with this Section and IBC 712.1.3. Two-story openings in other than I-2 and I-3 occupancies shall comply with IBC Section 712.1.9.

Design Compliance:

Electrical and communications room without automatic sprinkler protection, elevator machine rooms and elevator lobbies are provided with smoke detection; therefore, the design meets the above high-rise Code requirements of IFCA Section 907.2.13.1.1 (1) & (2).

The Building does not contain any R-type occupancies served by corridors; therefore, the above high-rise Code requirements for R occupancies are not applicable.

The six interior exit stairwells are provided with smoke detection. The two north stairwells and elevator hoistways do not have smoke detection. Detection is compliant with IBCA Appendix S, Section 4.5.2-3 Bullet 3 and will be maintained.

The building contains unenclosed vertical openings that are not provided with perimeter smoke detection. Applicable section in the IBCA was not in effect at the time of the fire alarm replacement project. DEN requests additional discussion regarding this issue.

IFC Section 907.2.13.1.2. Duct Smoke Detection. Duct smoke detectors complying with Section 907.3.1 shall be located as follows:

1. In the main return air and exhaust air plenum of each air-conditioning system having a capacity greater than 2,000 cubic feet per minute. Such detectors shall be located in a serviceable area downstream of the last duct inlet.

2. At each connection to a vertical duct or riser serving two or more stories from a return air duct or plenum of an air-conditioning system.

Design Compliance:

Duct smoke detection is provided in both return and supply ducts, as well as at each connection to vertical ducts and risers serving two or more stories from a return air duct or plenum of an air-conditioning system; therefore, the design meets and exceeds the above high-rise Code requirements.

IFCA Section 905.1. General. Standpipe systems shall be provided in new buildings and structures in accordance with this section. Fire hose threads used for connection to standpipe systems shall be approved and shall be compatible with Denver Fire Department hose threads (2.5-inch hose thread is national standard; 1.5-inch hose thread is a special 11.5 threads per inch). The location of Fire Department hose connections shall be approved by the fire code official. Where standpipe valve outlets are installed in stair enclosures, outlets and ancillary equipment shall not reduce the required width of the stairway landing.

Design Compliance:

Standpipes with hose connections are located in the corridor leading to each of the six interior stairwells; therefore, the design is in compliance with the above high-rise Code requirement. The project will ensure that new floor areas such as the Level 6 bridge expansions are within NFPA 14 required hose reach distances.

IFC Section 907.4.2. Manual Fire Alarm Boxes. Where a manual fire alarm system is required by another section of this Code, it shall be activated by fire alarm boxes installed in accordance with Section 907.4.2.1 through 907.4.2.6.

Design Compliance:

The Building is provided with manual pull stations.

IFC Section 907.5.2.2. Emergency Voice/Alarm Communication Systems. Emergency voice/alarm communication systems required by this code shall be designed and installed in accordance with NFPA 72. The operation of any automatic fire detector, sprinkler waterflow device or manual fire alarm box shall automatically sound an alert tone followed by voice instructions giving approved information and directions for a general or staged evacuation in accordance with the building’s fire safety and evacuation plans required by Section 404. In high-rise buildings, the system shall operate on at least the alarming floor, the floor above and the floor below. Speakers shall be provided throughout the building by paging zones. At a minimum, paging zones shall be provided as follows:

1. Elevator Groups
2. Interior Exits Stairways.
3. Each floor.

4. Areas of refuge, as defined by Chapter 2.

Design Compliance:
The Building is provided with a fire alarm and Emergency Communication System (ECS) that is better suited to the needs of the Terminal Building.

IFCA Section 907.2.13.2. Fire Department Communication System. Two-way telephone communication services shall be connected to a UL 864 listed fire alarm system. Design of the fire department communications system shall consist of both the following:

1. Hardwired components, in accordance with Section 907.2.13.2.1, consisting of permanent handsets, amplifiers and cable system for selective and “all-call” operation. Components shall be listed under UL product category code designation UOXX.

2. Radio communications using the emergency responder Radio Communications Enhancement System (RES) in accordance with Section 510, designed and installed for full coverage in accordance with Section 510.1.1.

IFCA Section 907.2.13.2.1. Hardwired Systems. A two-way, Fire Department communication system shall be provided for Fire Department use, each phone on the two-way Fire Department communication system shall have a separate control switch on the fire alarm control unit which distinctly identifies the location of the phone in use. The vertical riser and distribution wiring shall be installed in accordance with the National Electrical Code and shall comply with the pathway survivability requirements of NFPA 72 Section 24.5.

IFCA Section 907.2.13.2.1.1. Handsets. Permanently mounted telephone handsets shall be provided. Each permanently mounted handset shall initiate a signal from the handset to the FCC. Permanently mounted telephone handsets shall be provided in the following locations:

1. Each mechanical room with fans used for smoke control
2. Emergency and standby power rooms
3. Each fire pump room
4. Each elevator equipment room

Design Compliance:
Existing fire department communication systems comply with the IBCA Appendix S, Section 4.5.2.5 requirements for emergency responder communication systems.

IFCA Section 907.2.13.3. Alarm Notification. Alarm notification in high-rise buildings shall comply with IFC Section 907.5, as amended, and notify occupants on the floor in alarm, the floor above, the floor below and at the level of the fire command center (FCC). Silence function shall be provided to independently silence notification appliances at the level of the FCC. This function shall be accomplished by an approved switch located in the FCC.

Design Compliance:
The Building is provided with a fire alarm and Emergency Communication System (ECS) that is better suited to the needs of the Terminal Building.

IFCA Section 907.2.13.4. Smoke Control System Activation. Smoke control systems shall be automatically activated by alarm-initiating devices including return riser duct detectors, water flow switches, manual pull stations, and manual operation from the fire command center (FCC), in accordance with Section 907.2.13.4.1 and 907.2.13.4.2. After the initial alarm activation, any subsequent automatic alarm activation on another floor shall initiate the floor exhaust sequence in accordance with Section 907.2.13.4.2.

Exception: Main sprinkler system water flow, heat or smoke detectors located in stair or hoistway enclosures, kitchen hood suppression activation and sprinkler system water in building service chutes or shafts.

Design Compliance:

All smoke control systems in the Building are automatically activated with the exception of the smoke control system in the Great Hall. Fire/smoke modeling has been performed to justify manual activation of the smoke control system in the Great Hall. See Appendix B of this report.

IFCA Section 907.2.13.4.1. Activation of Pressurization. Activation of stair and elevator hoistway enclosure pressurization shall be initiated by activation of any alarm-initiating device in accordance with Section 907.2.13.4 above.

Design Compliance:

Stairwell and hoistway pressurization is automatic by a single alarm device.

IFCA Section 907.2.13.4.2 Smoke Control Exhaust. Exhaust in a smoke control zone shall be automatically activated by any automatic fire alarm or sprinkler initiating device within the respective smoke control zone. Unless otherwise approved by the fire code, each floor of a high-rise building shall be considered a separate smoke zone.

Exception: Kitchen hood suppression activation.

Design Compliance:

Exhaust is automatically activated by any fire alarm or sprinkler initiating device within the respective smoke control zone. Smoke control zones are separated by floor throughout the building with the exception of the Great Hall open atrium.

IFCA Section 907.2.13.5. Annunciation. Graphic annunciation in accordance with Section 907.6.4.1.2 or computer graphic annunciation in accordance with Section 907.6.4.1.3 shall be provided.

Design Compliance:

Graphic workstations are provided.

IFCA Section 907.2.13.6. Elevator Status/Control Panel. An elevator status/control panel shall be provided. The elevator status/control panel shall comply with Denver Fire Department policy and:

1. Identify each elevator cab alphanumerically and on the floors it serves. Identify corresponding cab number in elevator cab.
2. Indicate elevators that are operating on emergency power. Visual indicators in accordance with ASME A17.1 are required.
3. Have a placard at elevator status/control panel stating how many elevators can operate under emergency power simultaneously.
4. Indicate elevator car position.
5. Have key switches as required for selective activation of cars if all are not capable of simultaneous operation on secondary power.

IFCA Section 907.2.13.6.1. Fire Service and Occupant Evacuation Elevator Status Panel. Status of designated fire service and occupant evacuation elevators shall be displayed on an approved standard emergency services interface in accordance with Section 919. These indications may be combined with the requirements of Section 907.2.13.6 as approved by the fire code official.

Design Compliance:

Elevator status monitoring is provided as was required at the time of installation.

IFCA Section 907.2.13.7. Emergency Generator Status Panel. An emergency generator status panel shall be provided. The emergency generator panel shall show the following:

1. Operating status (on-off) and malfunction indication as required by NFPA 110.
2. Indication of transfer switch position (normal-emergency)
3. Indication that generator is in automatic mode

4. Main fuel oil storage tank low fuel level alarm

Design Compliance:
There are no emergency generators in the Building; therefore, the above high-rise code requirement is not applicable.

IFCA Section 907.2.13.8. Fire Pump Status Panel. A fire pump status panel shall be provided. The fire pump panel shall have the following:

1. Remote operating status indication as required by NFPA 20.
2. Motor/engine running/on or off. Pump running indication shall be transmitted to the fire alarm control panel as a supervisory signal and distinctly annunciated.
3. Low fuel level alarm for fire pump fuel tank.

Design Compliance:
Fire pump status panels are provided as required at the time of installation.

IBCA Section 403.4.5. Emergency Responder Radio Coverage. Emergency responder radio coverage shall be provided in accordance with IFCA Section 916.1.

IFCA Section 916.1. Where Required. Buildings shall have approved radio coverage in accordance with Section 510 for emergency responders as follows:

1. High-rise buildings
2. Underground buildings (constructed in accordance with IBC Section 405)
3. Airport buildings and structures
4. In accordance with Section 916.1.1

IFCA 916.1.2. Emergency Responder Coverage in Existing Buildings. For existing high-rise, underground buildings, I-1, I-2 & I-3 occupancies and airport buildings, when undergoing an upgrade to install a Mass Notification System (MNS) or complete fire alarm head-end equipment replacement, the building shall be tested to Section 510 for public safety radio coverage and where deficient, RES coverage shall be provided. Buildings with currently acceptable signal strength shall be retested at five-year intervals in accordance with Section 510.2.1.1 to ensure continued complaint radio coverage. Where it is determined by the fire code official the radio coverage is not needed, written documentation of the adequacy of existing radio coverage shall be maintained on site.

Design Compliance:
Fire department communication systems are provided in accordance with IBCA Appendix S, Section 4.5.2.5 requirements for emergency responder communication systems.

IBCA Section 403.4.6. Fire Command Center. A fire command center shall be provided in accordance with IFCA Section 508.

IFCA Section 508.1. Fire Command Center (FCC). Where required by Section 907, buildings shall be provided with an FCC in accordance with this section. No piping, ducts or equipment foreign to required fire operations shall be permitted to enter, pass through or be installed within the FCC. Scale drawings of the FCC showing the location of all equipment and features, in plan and elevation views, shall be submitted for approval prior to installation.

IFCA Section 508.1.1 Location and Access. The FCC Shall:

1. Be on the ground floor.
2. Have a secured entrance directly accessible to and in immediate proximity of the main building entrance.
3. Have access within the building to all fire service access elevators.

Design Compliance:

The Building is provided with two fire command centers located on Level 6 at the NE and SW corners of the Terminal as approved by the Denver Fire Department. The original fire command center is located in Level 3 and is maintained as a backup FCC and for maintenance operations.

IBCA 403.4.7. Smoke Control. Smoke control shall be provided in accordance with IFCA Section 909.

IFCA Section 909. Smoke Control Systems
IFCA Section 909.1. Scope and Purpose. This section applies to mechanical smoke control systems when they are required by other provisions of this code. The purpose of this section is to establish minimum requirements for the design, installation and acceptance testing of smoke control systems that are intended to provide a tenable environment for the evacuation or relocation of occupants. Smoke control systems regulated by this Section serve a different purpose than the smoke – and heat-venting provisions found in IFC Section 910. Mechanical smoke control systems shall not be considered exhaust systems under Chapter 5 of the *International Mechanical Code.*

Exceptions:

1) This provision does not preclude application of the performance based design calculations.
2) Stairway and hoistway pressurization system designs in high-rise buildings where the uppermost occupiable floor is more than 250 feet above the lowest level of fire department vehicle access, and all healthcare occupancy groups, shall be performed by an engineering analysis.

IFCA Section 909.2. General Design Requirements. Buildings, structures or parts thereof required by this code to have a smoke control system or systems shall have such systems design in accordance with Section 909 and the generally accepted and well-established principles of engineering relevant to the design. The construction documents shall include sufficient information and detail to adequately describe the elements of the design necessary for the proper implementation of the smoke control systems. These documents shall be accompanied by sufficient information and analysis to demonstrate compliance with these provisions.

Design Compliance:

The Terminal building is provided with a smoke control system designed to provide a minimum of four air changes per hour as required by IBCA Appendix S for airport buildings. The project will maintain the current smoke control system design.

IFCA Section 909.3. Smoke Control Systems. As required by other sections of this code, smoke control systems shall be provided for all high-rise buildings, atriums, covered malls, underground buildings, assemble occupancies with smoke-protected seating, stages and area in accordance with IBC Section 410, airport buildings in accordance with IBCA Appendix S, and assembly occupancies with an aggregate of 1,000 or more occupants in high-rise buildings.

IFCA Section 909.3.1. Unenclosed Vertical Openings. Where unenclosed vertical openings are provided as permitted by IBC Section 712, buildings with a smoke control system shall have the floor openings between smoke zones protected by draft curtains and closely spaced sprinklers installed in accordance with NFPA 13 and smoke detectors located at the floor side of the opening.

Design Compliance:

The building contains unenclosed vertical openings that are not provided with perimeter smoke detection. Applicable section in the IBCA was not in effect at the time of the fire alarm replacement project. DEN requests additional discussion regarding this issue.

IFCA Section 909.15.3 Smoke Exhaust Systems.
IFCA Section 909.15.3.3 Design Criteria. The general building smoke exhaust system(s) for each floor/smoke zone shall be sized in accordance with the following:

1. The assumption that make-up air will be available to the smoke zone in alarm.

2. The smoke exhaust system shall be sized to remove a minimum of five air changes per hour on the fire floor in Occupancy Groups A, B, E and M.

3. The smoke exhaust system shall be sized to remove a minimum of 15 air changes per hour in the typical floor corridors, the typical floor corridors/elevator lobbies, or the typical floor elevator lobbies in Occupancy Groups R-1, R-2, I-1 and I-3. Amenity spaces less than 3,000 sf in Groups R-1 and R-2 occupancies are not required to be provided with a separate smoke exhaust system.

4. That appropriate consideration shall be made for damper leakage on non-fire floors connected to a central riser system, when selecting the smoke exhaust fan(s).

5. Smoke exhaust systems shall be in ducts constructed in accordance with Section 909.13.8.

Design Compliance:

The Terminal building is provided with a smoke control system designed to provide a minimum of four air changes per hour as required by IBCA Appendix S for airport buildings. The project will maintain the current smoke control system design.

IBCA Section 403.4.8. Emergency Power. An emergency power system complying with IBC Section 2702 shall be provided for the emergency power loads specified in IBCA Section 403.4.8.3 (see below).

IBCA Section 403.4.8.1. Equipment Room. If the emergency power system includes a generator set inside a building, the system shall be located in a separate room enclosed with 2-hour fire barriers.

IBCA Section 403.4.8.2. Fuel Line Piping Protection. Fuel lines supplying a generator set inside a building shall be separated from areas of the building other than the room the generator is located in by an approved method or assembly that has a fire-resistive rating of not less than 2 hours. Where the building is protected throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2, the required fire-resistance rating shall be reduced to 1 hour.

IBCA Section 403.4.8.3. Emergency Power Loads. The following are classified as emergency power loads:

- Power and lighting for the fire command center, as required by Section 403.4.6.
- Ventilation and automatic fire detection equipment for smokeproof enclosures.
- Elevators.
- Where elevators are provided in a high-rise building for accessible means of egress, fire service access or occupant self-evacuation, the standby power system shall also comply with Sections 1009.4, 3007 or 3008, as applicable.
- Exit signs and means of egress illumination require by Chapter 10.
- Elevator car lighting.
- Emergency voice/alarm communication systems.
- Fire alarm systems.
- Electrically powered fire pumps.
- Smoke control equipment.

Design Compliance:

The Building is provided with emergency power using dual ended switchgear, as permitted by IBCA Appendix S, Section 4.6. Refer to Memorandum of Understanding #90052901 for the airport emergency power basis of design.

IBC Section 403.5.1. Remoteness of Interior Exit Stairways. Required interior exit stairways shall be separated by a distance not less than one-fourth of the length of the maximum overall diagonal dimension of the building or area to be served, whichever is less. The distance shall be measured in a straight line between the nearest points of the enclosure surrounding the interior exit stairways. In buildings with three or more interior exit stairways, no fewer than two of the interior exit stairways shall comply with this section. Interlocking or scissor stairs shall be counted as on interior exit stairway.

Design Compliance:

The interior exit stairwells meet the high-rise Code requirements for exit stairway remoteness. The six interior exit stairwells are pressurized. The two north exit stairs are not smokeproof enclosures. Luminous egress path markings were not required at the time of construction and such markings will not be installed as part of this project.

IBC Section 403.5.2. Additional Interior Exit Stairway. For buildings other than Group R-2 that are more than 420 feet in building height, one additional interior exit stairway meeting the requirements of Sections 1011 and 1023 shall be provided with in addition to the minimum number of exits required by Section 1005.1. Scissor stairways shall not be considered the additional interior exit stairway required by this section.

Exception: An additional interior exit stairway shall not be required to be installed in buildings having elevators used for occupant self-evacuation in accordance with Section 3008.

Design Compliance:

The Building does not exceed 420 feet in building height; therefore, the above high-rise Code requirement is not applicable.

IBCA Section 403.5.3. Stairway Door Operation. Locking of stairway doors shall be in accordance with IBCA Appendix Q Access control systems.

Design Compliance:

Exit doors that separate public, sterile, and restricted areas of the Airport are configured in accordance with Appendix Q with specific modification addressed by Administrative Modification.

IBC Section 403.5.4. Smokeproof Enclosures. Every required interior exit stairway serving floors more than 75 feet above the lowest level of fire department vehicle access shall be a smokeproof enclosure in accordance with Sections 909.20 and 1023.10.

Design Compliance:

The interior exit stairwells meet the high-rise Code requirements for exit stairway remoteness. The six interior exit stairwells are pressurized. The two north exit stairs are not smokeproof enclosures.

IBC Section 403.5.5. Luminous Egress Path Markings. Luminous egress path markings shall be provided in accordance with Section 1025.

Design Compliance:

Luminous egress path markings were not required at the time of construction and such markings will not be installed as part of this project.

IBC Section 403.5.6. Emergency Escape and Rescue. Emergency escape and rescue openings specified in Section 1030 are not required.

IBCA Section 403.5.7. Accessible Means of Egress and Area of Rescue Assistance. Accessible means of egress shall comply with this section. One accessible means of egress is required in buildings subject to the requirements of Section 403 and possessing hoistway pressurization conforming to the provisions of IFCA Section 909.15.2. Where the travel distance from any accessible space to the area of rescue assistance exceeds the maximum travel distance permitted for the occupancy in accordance with Section 1017.1, additional areas of refuge shall be provided. Every required area of refuge shall be provided with direct access to an elevator complying with Section 1009.4. Where occupant evacuation elevators are provided in accordance with Section 403.6.2, areas of rescue assistance shall be located at these elevators.

IBCA Section 403.5.7.1. Group A, B, E and M occupancies. In Group A, B, E and M occupancies, an elevator complying with Section 1009.4 and an area of rescue assistance/elevator lobby providing direct access to the elevator shall serve as the accessible means of egress. The area of rescue assistance shall be sized in accordance with Section 1009.6.3. Each area of rescue assistance shall be separated from the remained of the story by a smoke barrier complying with Section 709.

IBCA Section 403.5.8. Area of Rescue Assistance/Elevator Lobby Pressurization. The area of rescue assistance/elevator lobby shall be pressurized by the transfer of air from the pressurized hoistway through the leakage at the elevator doors.

Design Compliance:

The Building was not provided with areas of rescue assistance at the time of building construction. It is not the intent of the Terminal Redevelopment project to modify this condition.

IBC Section 403.6. Elevators. Elevators in high-rise buildings must meet the requirements of IBC Chapter 30 and Sections 403.6.1 & 403.6.2. In buildings with floors occupied more than 120 feet above the lowest level fire department vehicle access, at least two fire service access elevators with a weight capacity of at least 3,5000 pounds shall be provided in accordance with section 300. When installed in accordance with Section 3008, passenger elevators for general public use shall be permitted to be used for occupant self-evacuation.

Design Compliance:

No floors in the Building exceed 120 feet above the lowest level of fire department vehicle access; therefore, no fire service access elevators are required. At the time of installation, the elevators are assumed to have complied with the applicable chapters of the IBC.

6. FIRE PROTECTION SYSTEMS

6.1. Sprinkler Systems

The Terminal Building is provided with automatic sprinkler protection throughout with the exception that sprinkler protection is not provided under the tent at roof level in the Great Hall. At the time of the building construction, this was permitted as documented in the *DIA Terminal Fire Protection Alternatives* letter dated October 11th, 1990 (Memorandum of Understanding #90122800).

Currently, IBC Section 404.3 (2) states that where the ceiling of an atrium is more than 55 feet above the finished floor, sprinkler protection at the ceiling is not required. It is understood that the code allows this omission on the basis that sprinklers at a height of 55 feet or greater will not have a significant impact on a fire event. Furthermore, preliminary fire/smoke modeling performed for the Great Hall demonstrates that without sprinkler system control, the Great Hall is capable of maintaining tenable conditions for a period of at least 30 minutes. Refer to Appendix B.

6.2. Standpipe Systems

Standpipes with hose connections are located in the corridor leading to each of the six interior stairwells. The Terminal Redevelopment project will maintain the current standpipe system design. The project will ensure that new floor areas such as the Level 6 bridge expansions are within NFPA 14 required hose reach distances.

6.3. Fire Pump

The Terminal Building and the Airport Office Building (AOB) are served by independent fire pumps which are supplied by separate feed mains. The two fire pumps are interconnected for the purpose of providing redundancy in the event that one pump or feed main is compromised. A normally closed valve must be manually opened in order to allow a single pump to serve both systems. This current design exceeds the code intent by providing redundant fire pumps for the building, as well as, redundant water mains. No modification is proposed.

6.4. Fire Detection, Alarm, and Communication Systems

The fire detection and alarm system devices to be installed in the project areas will be part of the overall Emergency Communications System (ECS) provided for the DEN Complex. The system as developed to date integrates traditional fire detection and alarm equipment with the facility's communications systems (e.g., public address, visual screens, etc.) to form an ECS. The project will maintain the overall fire alarm and ECS design approach which was recently implemented in the Terminal building.

6.5. Smoke Control

Current smoke control system design for the Terminal areas outside of the Great Hall provides four air changes per hour in accordance with Appendix S. The project will maintain the current smoke control system design. The Great Hall is provided with an exhaust system that has been recently evaluated through fire/smoke modeling by the design team (See Appendix B). Although preliminary fire/smoke modeling shows that the smoke exhaust system may not be necessary, the project intends to maintain the current smoke control system design.

6.6. Stair Pressurization

The six interior exit stairwells located in the Great Hall are provided with stairwell pressurization. The project does not intend to modify the stairwell pressurization design.

6.7. Hoistway Pressurization

Elevator hoistways in the Great Hall are pressurized. The project does not intend to modify the hoistway pressurization design.

7. MEANS OF EGRESS

7.1. Occupant Loads

Occupant loads calculated for each area will be based on the area use and occupant load factors of IBC Table 1004.1.2, as shown below in Table 4.

Table 4: Occupant Load Factors.

Occupancy Use	Occupant Load Factor [sq ft/person]	Area Type
Assembly Unconcentrated, tables and chairs	15	Net
Assembly Concentrated, chairs only	7	Net
Assembly Standing space	5	Net
Business Areas	100	Gross
Industrial Areas	100	Gross
Accessory Mechanical and Storage Spaces	300	Gross
Airport Terminal Baggage Claim	20	Gross
Airport Terminal Baggage Handling	300	Gross
Airport Terminal Concourse	100	Gross
Airport Terminal Waiting areas	15	Gross
Mercantile	60	Gross
Mercantile, Storage, stock, shipping areas	300	Gross

The following occupant loads are based upon the latest occupant load calculations performed by the project team, utilizing the occupant load factors listed above.

Table 5: Occupant Loads by Level

Level	Occupant Load
4	1,174
5	10,531
6	8,678

7.2. Number of Exits

Design and construction of egress components will be in accordance with the means of egress requirements of IBC Chapter 10. These requirements will vary by occupancy, with the most restrictive requirements taking precedence throughout the building.

IBC Section 1006.2.1.1 requires three exits or exit access doorways be provided for any space with an occupant load of 501 to 1,000 and four exits or exit access doorways are required for an occupant load greater than 1,000. Based upon the calculated occupant loads, Levels 4, 5, and 6 all require at least four exits. The total number of exits needed is driven by exit access travel distance.

7.3. Exit Access Travel Distance and Exit Capacity

Per IBC Table 1017.2, the maximum allowable travel distance to an exit from fully sprinklered Group A, B, F-1, M, and S-1 occupancies is as follows:

- Group A, F-1, S-1, M: 250 ft
- Group B: 300 ft

The maximum exit access travel distance will be in compliance with the limitations of IBC Table 1017.2; except that in the Great Hall a maximum travel distance of 300 feet will be used. At the time of building construction, an extended travel distance of 300 ft was approved for Levels 5 and 6 of the Great Hall as documented in the *DIA Terminal Fire Protection Alternatives* letter dated October 11th, 1990 (Memorandum of Understanding #90122800). The Terminal Redevelopment Project intends to maintain and/or improve the existing exit access travel distance conditions.

To justify exit access travel distances from the Great Hall, an ASET/RSET analysis will be performed (Available Safe Egress Time versus Required Safe Egress Time). ASET is the amount of time that elapses between fire ignition and the development of untenable conditions. The RSET is the amount of time from the time of ignition for all occupants to exit the building or space. Egress design will be considered acceptable if the ASET is greater than the RSET.

As a preliminary assessment, Maximum Specific Flow was calculated for levels 5 and 6 to determine how much time is takes for occupants to exit the building. The calculation considers the total calculated occupant load, the available egress width, and the amount of time required to move the entire occupant load through the available exit doors. See Appendix A for Maximum Specific Flow calculations.

7.4. Exit Discharge

Exterior exit doors on Levels 4, 5, and 6 discharge to the upper open roadway and to the lower covered roadway. The roadways are protected with automatic sprinkler protection and they are open to the exterior on both sides. Once occupants exit the terminal onto the public way, their exit path is completed. Emergency responder personnel will have ready access to building occupants once they reach this point.

This exit discharge condition is documented in the *DIA Terminal Fire Protection Alternatives* letter dated October 11th, 1990 (Memorandum of Understanding #90122800) which explains that “once the occupants have exited the Terminal onto the Public Way (i.e. the curbside) their exit path is accomplished. At the curbside, which is about 20 ft wide, the [sic] are at the point where emergency vehicles and personnel have ready access to them.” Denver Building and Fire Prevention agreed to this condition, provided the roadway was protected by a dry pipe sprinkler system.

A. EXIT CAPACITY TIMED EGRESS CALCULATION

Exit Capacity Timed Egress Calculation Using Maximum Specific Flow, F_{sm}

The following calculations were performed in accordance with *The SFPE Handbook of Fire Protection Engineering, Fourth Edition.*

Specific Flow, F_s, is the flow of evacuating persons past a point in the exit route per unit of time per unit of effective width of the route involved. The Maximum Flow, F_{sm}, is the maximum achievable specific flow rate for specific components of egress. Table 3-13.5 of the *SFPE Handbook of Fire Protection Engineering* gives Maximum Specific Flow values for corridors, aisles, ramps, doorways and stairs.

Using the value presented in Table 3-13.5 for doorways, it's possible to calculate the estimated time for all occupants to exit the building or area. See calculations below for a break down by floor of egress times for the Great Hall.

Level 5

F_{sm}= Persons/Minute/foot of effective width

24.0 persons/min/ft. of effective doorway width (SFPE Handbook of Engineering Table 3-13.5)

24.0 persons/min/ft. of effective width = 2 persons/min./inch of effective width

1,768 inches of available width

884 persons/minute

10,531 occupants + 1,174 occupants (level 4 platform occupant load) = 11,705 total occupants

Time to full egress = 11,705 persons/884 persons/min. = **13 minutes 15 seconds.**

Level 6

F_{sm}= Persons/Minute/foot of effective width

24.0 persons/min/ft. of effective width (SFPE Handbook of Engineering Table 3-13.5) = 2 persons/min./inch of effective width

1,624 inches of available width

812 persons/minute

8,678 total occupants

Time to full egress = 8,678 persons/812 persons/min. = **10 minutes 42 seconds.**

Based upon the size and number of available exterior exit doors, the calculations provided above show that the calculated Terminal Building occupant load can pass through the exit doors in as quickly as 20 minutes (assuming a safety factor of 1.5). Note that this is a preliminary assessment for determining an order of magnitude egress time. More detailed egress calculations will be necessary for an ASET/RSET analysis.

B. GREAT HALL SMOKE CONTROL SYSTEM FIRE/SMOKE MODELING ANALYIS

DENVER INTERNATIONAL AIRPORT

GREAT HALL SMOKE CONTROL SYSTEM

FIRE/SMOKE MODELING ANALYSIS

REVISION 0

PREPARED FOR:

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1. INTRODUCTION

At the direction of Denver International Airport (DEN), Jensen Hughes has conducted this theoretical analysis of the existing Terminal Building Great Hall smoke exhaust system. This report provides a starting point for understanding the rate at which maximum expected fires would fill the Great Hall volume with smoke. The results of this analysis will be utilized to support the pending Terminal Redevelopment Project, to inform whether the smoke control system is necessary, whether manual activation of the smoke control system is appropriate, and to facilitate discussion regarding frequency of testing.

The DEN Terminal tent structure creates a sizeable natural well for accumulation of smoke during a fire event. Terminal Level 6, the highest occupied level, is located nearly 90 ft below the highest tent peaks. Original design documentation is not clear regarding how the exhaust fans were sized or the overriding requirements for system performance with four air changes being the only documented performance requirement. Our approach in this analysis was to ensure that the smoke volume is maintained at least 10 feet above Level 6. Ten feet is the height of the draft curtains which separate the open Great Hall area from the East and West ticketing areas. Maintaining the smoke layer at this height also maintains the smoke volume above Level 6 occupant head height.

This analysis obtains an order of magnitude timeline from fire ignition to the point in time that the smoke layer descends below the draft curtains and begins migrating east and west towards the ticketing areas.

2. CFD SMOKE MODELING

2.1. Fire Dynamics Simulator

Fire Dynamics Simulator 6.5 [McGrattan et al., 2016] was the model chosen to simulate the fire conditions in the building. The first version of this software was released to the public in February of the year 2000 [McGrattan et al., 2016] but this model and its predecessors have been under development at the National Institute for Standards and Technology since circa 1985 (see [McGrattan et al., 2016] and [McGrattan, Rehm and Baum, 1994]). This software incorporates hydrodynamic, combustion and radiation transport mathematical models assembled specifically for the task of modeling fire-driven flow and related phenomena. As such, it is well-suited for the task at hand. The model is specifically designed with fire scenarios in mind and continues to be improved and to have its results verified. FDS has undergone verification and validation exercises as described in numerous publications [McDermott et al. 2016; McGrattan et al. 2016]. Various versions of the model have been applied to a number of outdoor and indoor fire scenarios. The current version of the model is intended to handle isolated and spreading fires in human habitable spaces in the presence of obstacles such as furniture, overhead ceiling obstructions, and other structural members. Fuel properties and burning rates of a fire are user-defined. The model can handle both passive and forced vents (i.e., smoke exhaust). Validation studies for FDS are described in the fire protection literature.

The FDS model requires that the space under consideration be divided into smaller volumes or mesh cells in order to resolve the smoke and heat transport equations. The exact size of these volumes is a compromise between speed and accuracy.

FDS has undergone extensive verification and validation. FDS is developed as an open-source, public domain software program. Configuration management utilizes Subversion via Google's code hosting service and Dr. Kevin McGrattan at NIST is the configuration manager.

Copies of the FDS theory manual, user's guide, verification report, validation report, and configuration management plan are available from http://fire.nist.gov/fds/documentation.html.

A companion program, Smokeview, is available for visualizing the results of an FDS computation.

2.2. FDS Model Construction

The simulation grid was constructed from a total of 4,677,855 cube-shaped mesh cells which are 60 cm (23.6 in) in length. Simplifications must be made when complex geometric objects are to be included in the model and conform to the rectilinear grid. All major features that can impede smoke movement such as the stairs, walls, and balconies were included in the model. Areas and floors that are not open to the Great Hall were not included. The model includes the Great Hall only; areas adjacent to the Great Hall such as the baggage claim areas are not included in the model, and the openings to these areas are treated as open to the exterior. Treating the connections to adjacent areas as open does not significantly impact the model results, as the critical height has been defined based on keeping the smoke layer above the bottom of the draft curtains (taken to be 10 ft above Level 6).

The Great Hall in DEN has unique features from a smoke movement perspective. The roof of the Great Hall was designed to resemble the peaks of the famous Rocky Mountains. A series of masts supporting a Teflon-coated fiberglass roof result in multiple sloping peaks. These peaks create pockets and flow paths that provide a large volume of smoke reservoir in the Great Hall space. The smoke reservoir includes the volumetric capacity above the critical height (10 ft above level 6) to the tops of the peaks created by the masts.

The Great Hall geometry is shown in Figure through 6. Note that part of the geometry may be removed or transparent in these figures for clarity.

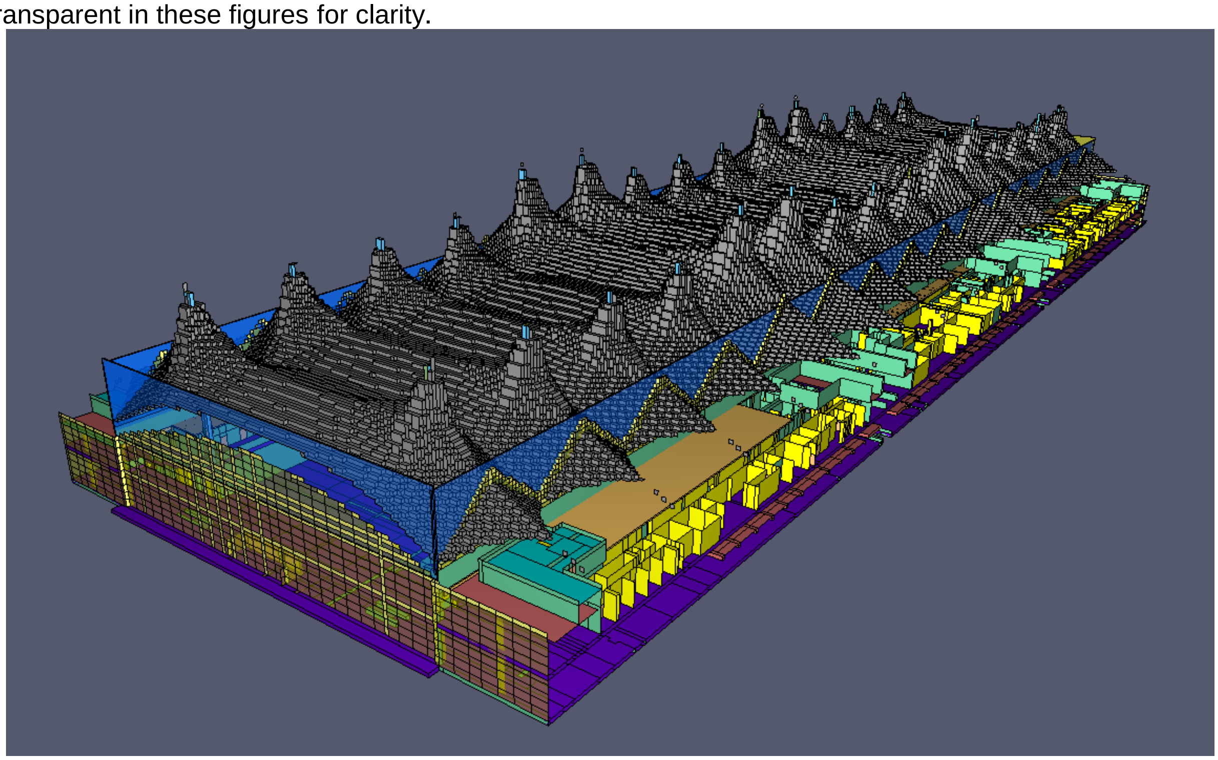

Figure 1 – Overall View of the Great Hall Geometry

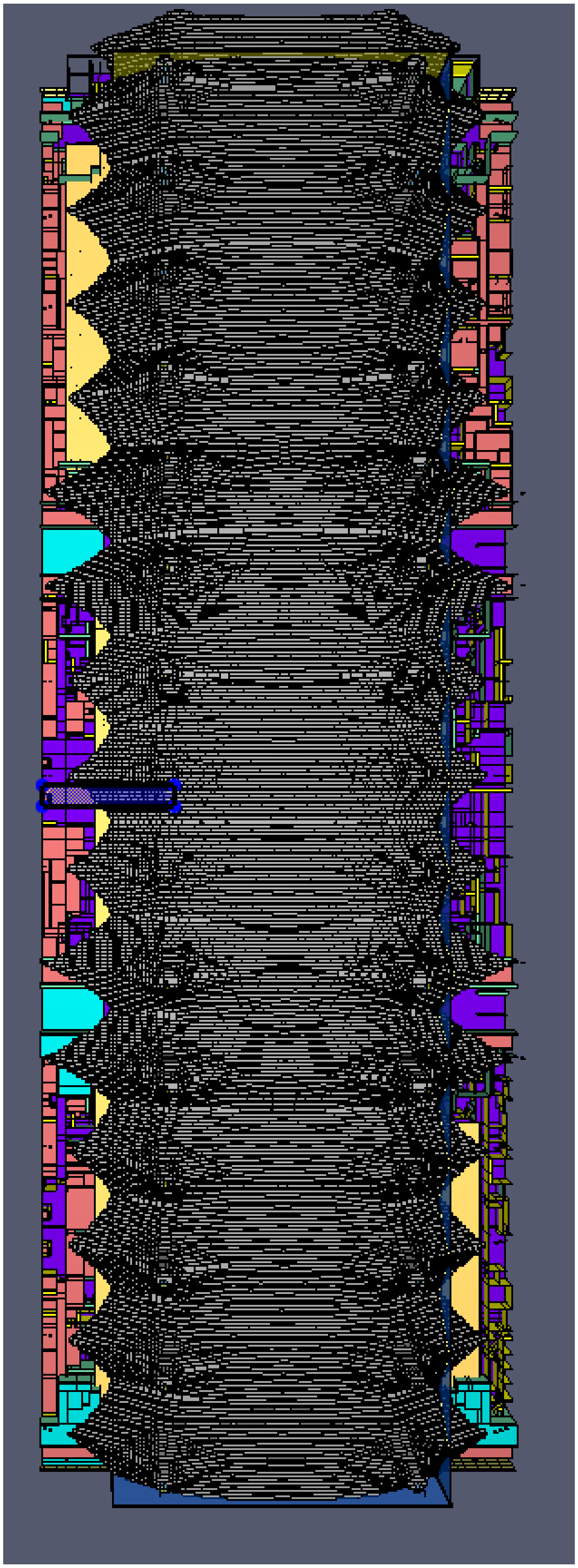

Figure 2 – Plan View of the Great Hall Geometry

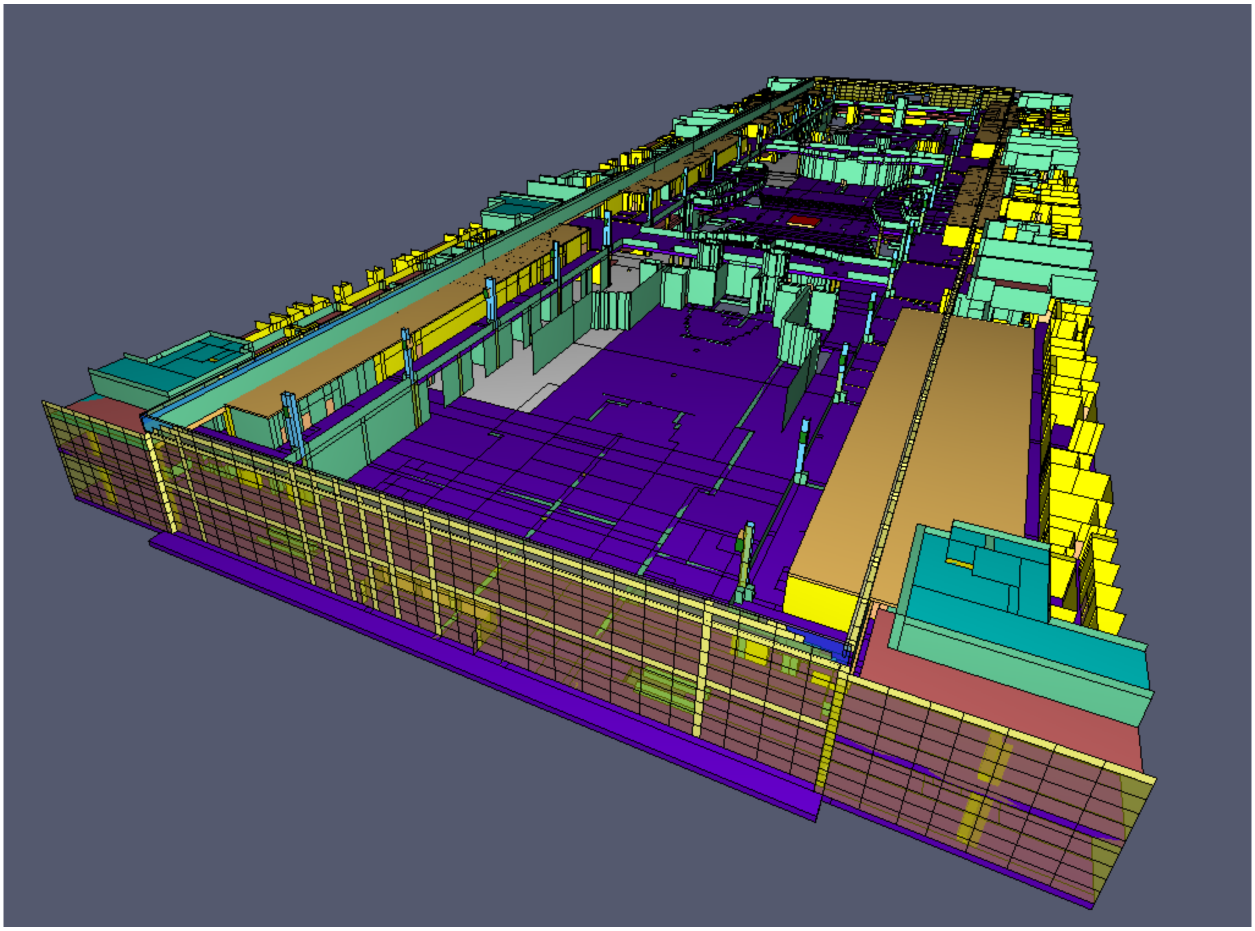

Figure 3 – Isometric View of the Great Hall Geometry (Roof Removed)

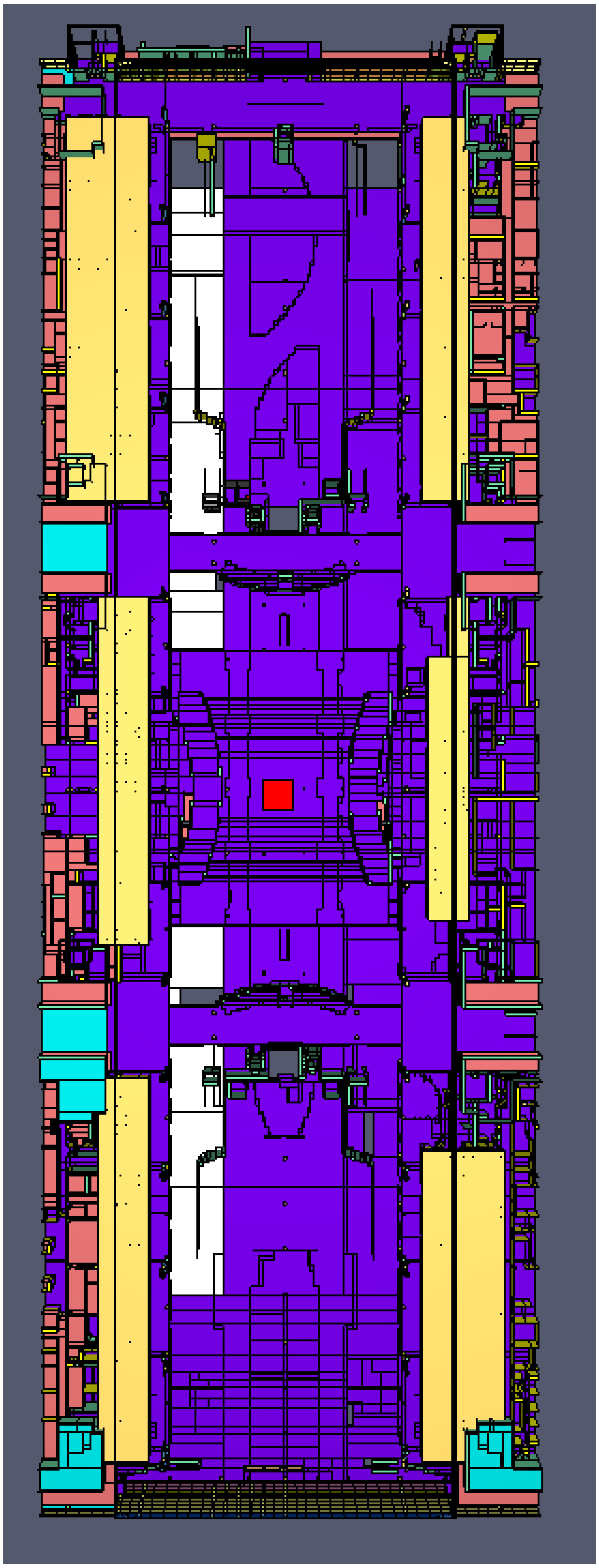

Figure 4 – Plan View of the Great Hall Geometry (Roof Removed)

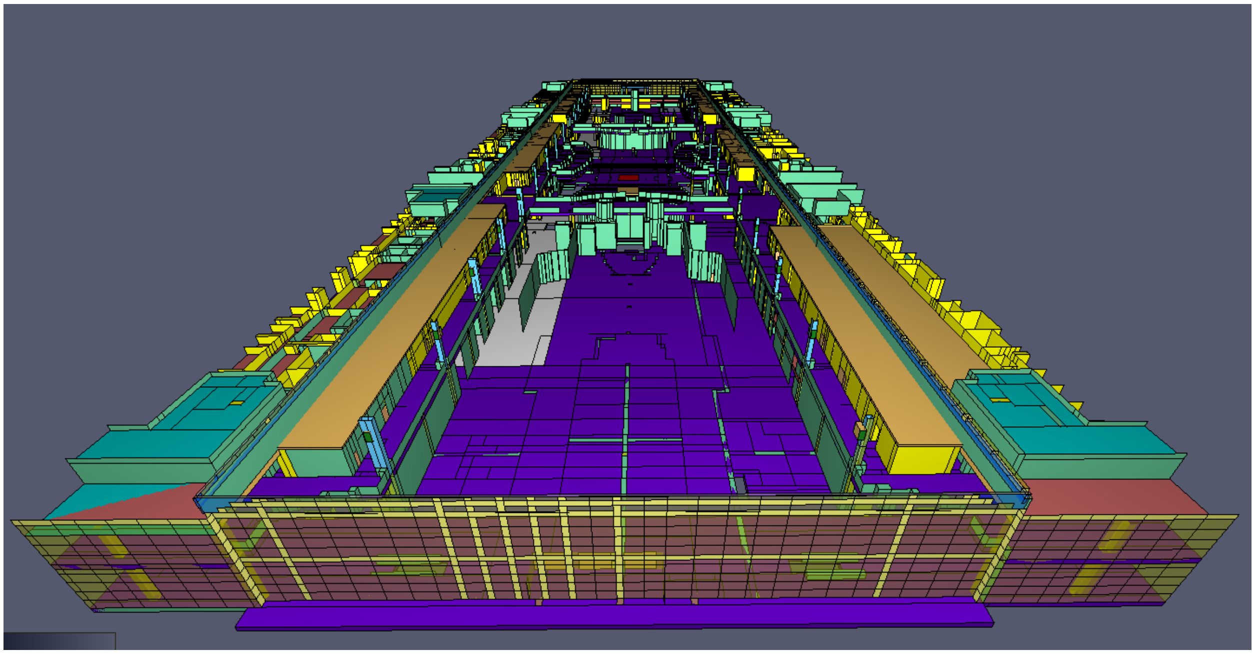

Figure 5 –South – North View Great Hall Geometry (Roof Removed)

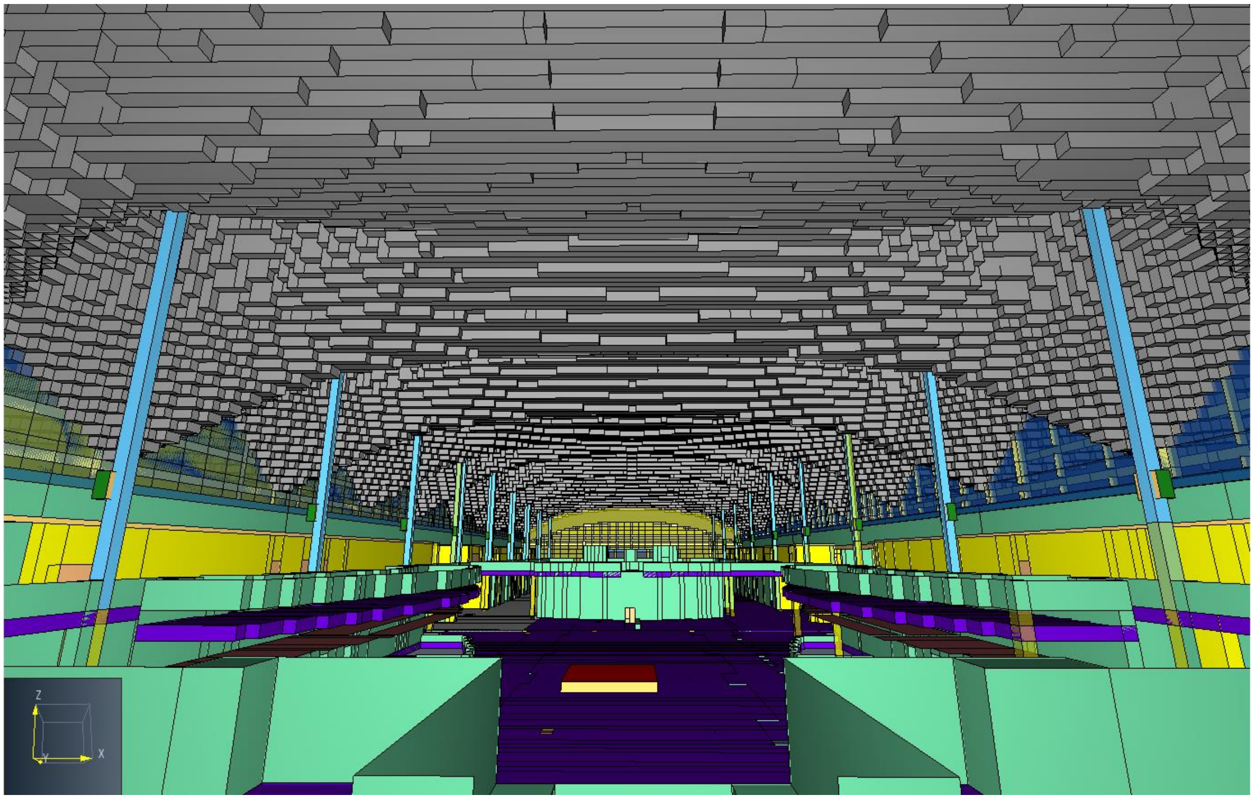

Figure 6 –Center – North View Great Hall Geometry

2.3. Smoke Control System

The existing smoke control system consists of a series of mechanical exhaust fans combined with natural makeup air. The exhaust inlets, simplified to account for mesh resolution, were modeled as two vents per mast (for a total of 60 vents) facing the north and south direction of the model. Each vent would provide an exhaust capacity of 6,000 CFM (12,000 CFM per mast) resulting in a total exhaust capacity in the Great Hall of 360,000 CFM. Exhaust inlets were sized as not to exceed an airflow rate of 5 m/s. Make-up air for the Great Hall was conservatively modeled as open vents located where there are walkways that lead from the Great Hall space to the ticketing areas. Both floors 5 and 6 are open in these locations. This allows air to flow to the fire on the lower floor without blocking smoke movement to the exterior on the upper floor. By providing a large capacity of make-up air to the Great Hall, the design fire is supplied with ample oxygen to avoid an oxygen limited fire scenario. It should be noted that architectural leakage is also accounted for to provide make-up air in this scenario. Exhaust and make-up air equipment locations are shown in Figure and Figure . Figure 7 denotes the location of the masts where the vents are mounted.

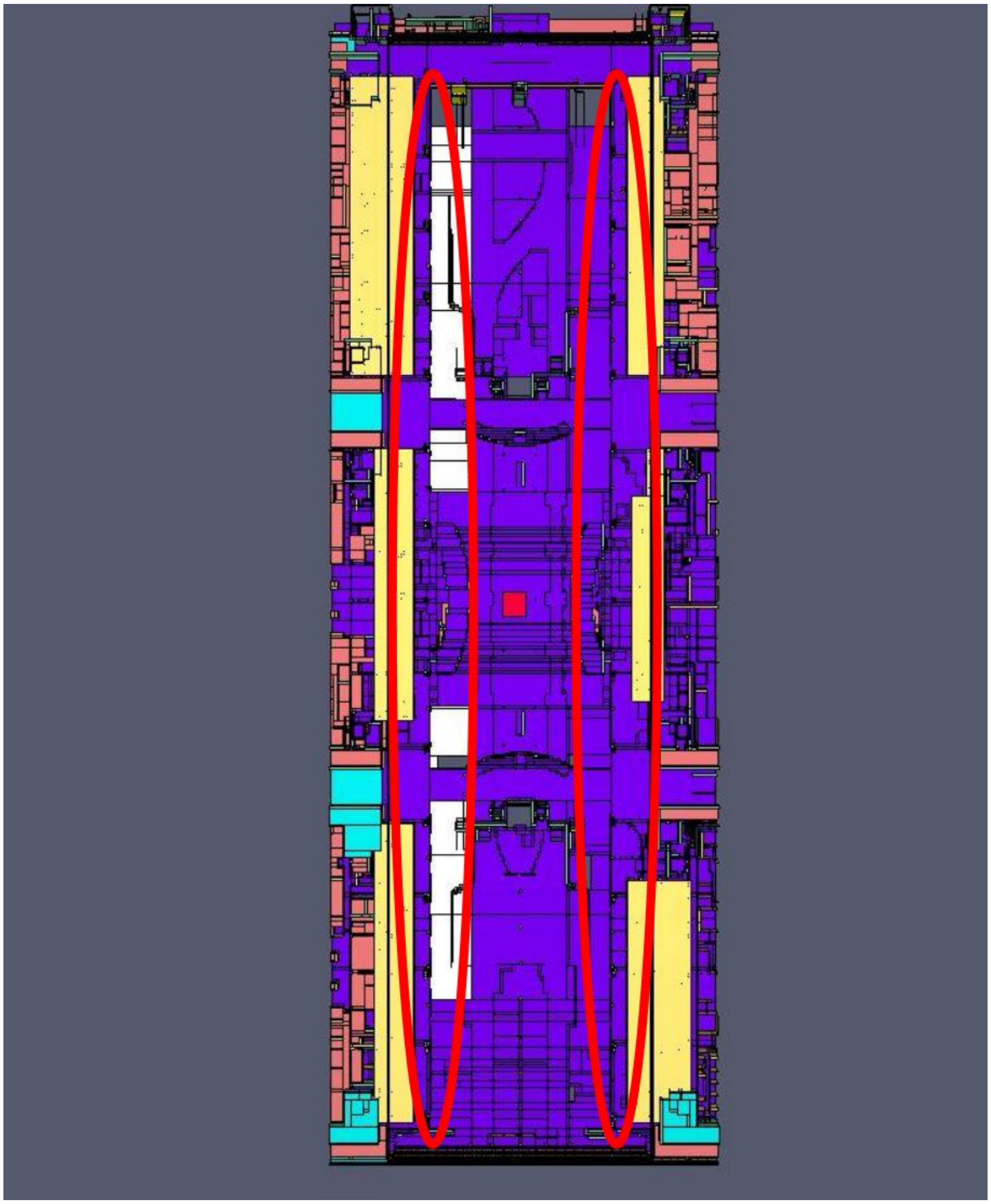

Figure 7 – Main Great Hall Exhaust Location (Circles Indicated Location of Masts on which Exhaust is Mounted)

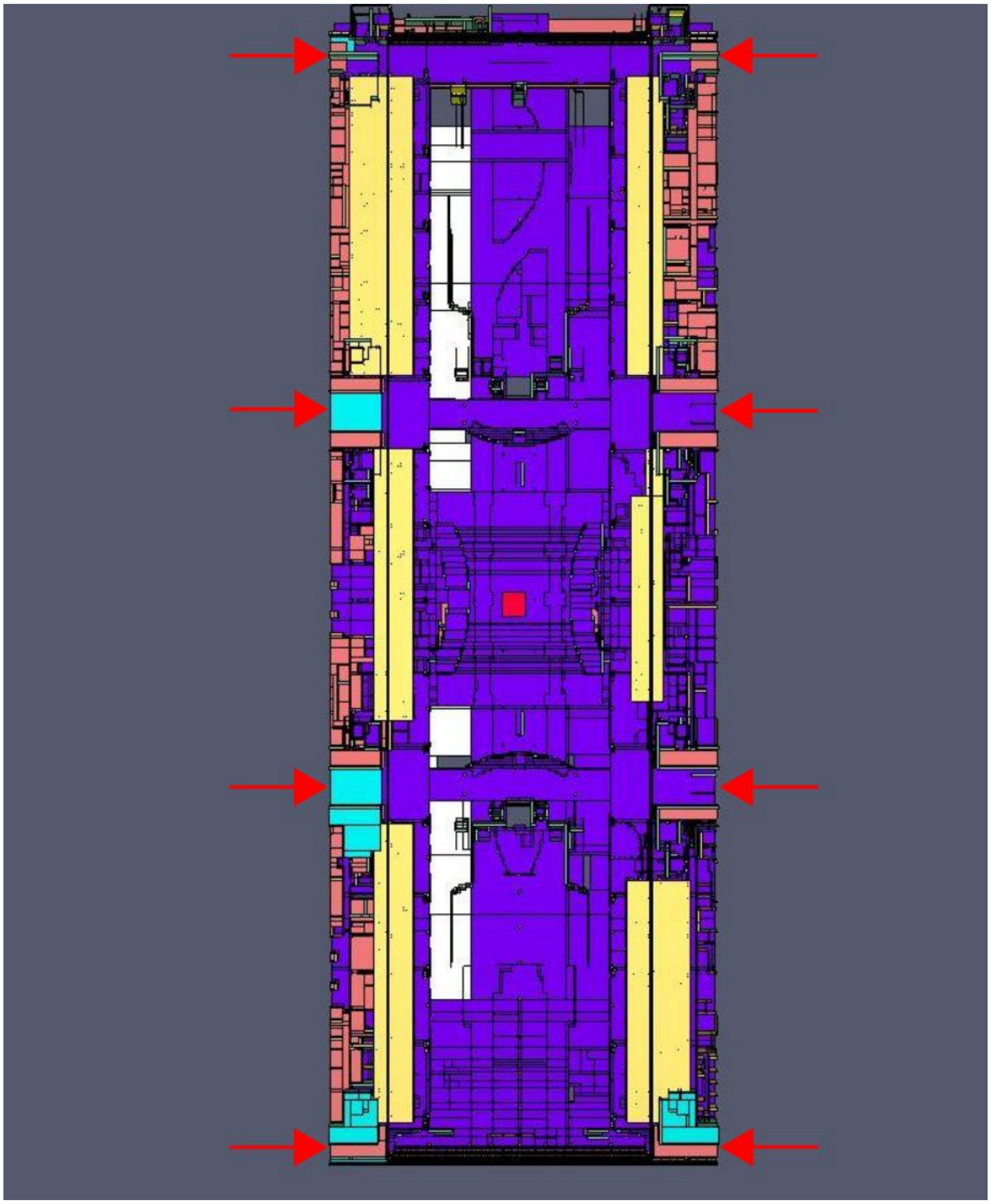

Figure 8 – Natural Makeup Air Locations

The smoke control system is activated manually by responding fire department personnel. This analysis assumes that, upon actuation of beam detectors, there will be a 10 minute delay during which time the fire department will receive notification of the alarm, respond to the alarm, investigate the alarm, and then manually activate smoke control.

3. SMOKE LAYER ANALYSIS CRITERIA

The purpose of this analysis is to evaluate the smoke filling capacities of the Great Hall. In the event of a large unabated fire incident it's important to know that the Great Hall can remain tenable conditions above occupied floors for an extended period of time. The smoke layer can be described by temperature thus providing an accurate calculation of the smoke layer height. For this analysis, the smoke layer was considered anywhere the air temperature in the Great Hall was above 104 ºF (40 ºC). This criteria is a conservative approach relative to the method for calculating smoke layer height in FDS. Smoke layer calculation in FDS can be described as follows:

$$(H - z_{\text{int}})\, T_u + z_{\text{int}}\, T_l = \int_0^H T(z)\, dz = I_1$$

$$(H - z_{\text{int}})\, \frac{1}{T_u} + z_{\text{int}}\, \frac{1}{T_l} = \int_0^H \frac{1}{T(z)}\, dz = I_2$$

Solve for z_{int}:

$$z_{\text{int}} = \frac{T_l\,(I_1 I_2 - H^2)}{I_1 + I_2 T_l^2 - 2 T_l H} \qquad (16.8)$$

Let T_l be the temperature in the lowest mesh cell and, using Simpson's Rule, perform the numerical integration of I_1 and I_2. T_u is defined as the average upper layer temperature via

$$(H - z_{\text{int}})\, T_u = \int_{z_{\text{int}}}^H T(z)\, dz \qquad (16.9)$$

4. FUEL PROPERTIES

The main fuel properties that are necessary to perform this evaluation include the yields of soot and CO, and the heat of combustion. From a hazard evaluation standpoint, the heat of combustion and the soot yield determine the quantity of smoke produced based upon the heat release rate. The primary fuel may involve a variety of materials including merchandise, packaged foods, artwork, furniture, etc. Therefore JENSEN HUGHES used a fuel that represents a typical mixture of ordinary combustibles that includes both plastic and cellulosic fuels.

The properties for the fuel are shown in Table 1 [Tewarson, 2008]. The radiant release fraction is conservatively assumed to be 0.3, typical of most materials. The heat of combustion for the wood/plastic mix is not explicitly specified, instead it is calculated by FDS to be approximately 19.5 MJ/kg based on the fuel chemistry.

Table 1 – Fuel Chemistry and Species Yields

Material	**Carbon Monoxide Yield (kg/kg)**	**Soot Yield (kg/kg)**	**Hydrogen Carbon Oxygen (Chemical Formula)**
Wood/Plastic Mix	0.038	0.05	C=1.00 H=2.00 O=0.59

5. DESIGN FIRES

The following list is a list of combustibles that may be expected in the Great Hall:

- Kiosks with clothing, food, electronics, books and newspapers
- Holiday Displays
- Artwork Displays
- Seating/Waiting Areas
- Vehicle Displays/Advertising
- Restaurants
- Gift Shops

Fire data is not available to represent the exact combustible fuel configurations anticipated in the Great Hall. However, fire data is available for some individual components that can be anticipated in the Great Hall areas. A design fire, defined by a heat release rate (HRR), is used by fire protection engineers to determine the volume of smoke produced by the fire in the computer model. Table 2 below lists peak heat release rates found during fire testing of several commodities that may be anticipated in the Great Hall.

Table 2 –Peak Heat Release Rates from Commodity Fire Tests

Design Fire Item	**Peak Heat Release Rate (MW)**	**Reference**
Kiosk	2 MW	H.E. Mitler 1997
Douglas Fir Christmas Tree	3 MW	V. Babrauskas, et al
Upholstered Furniture (Couch)	3 MW	V. Babrauskas, et al 1982
Small Passenger Car	8 MW	M. Shipp, et al 1995
School Bus	30 MW	C. Steinert, 1994
Shop Displays	6 MW	M. Arvidson, 2005
Truck/Heavy Equipment	30 MW	Tarada, 2011

Two very conservative design fire sizes were chosen for this theoretical analysis. Although we do not expect buses, large machinery, or trucks in the Great Hall, a design fire as large as 30 MW maintains a conservative approach for the filling analysis. A second fire, sized for comparison, was modeled as 15 MW. As demonstrated in Table 2 above, even a 15 MW fire represents a highly conservative approach, assuming for example, that five (5) couches were to simultaneously ignite.

The 30 MW and 15 MW design fires have also been modeled to reach their peak HRR and then maintain that energy output for the duration of the analysis. Normally, in a fire event, the HRR will eventually decay as the fire uses needed fuel and oxygen to burn. This conservative approach compensates for any unknown design characteristics in the model. The heat release rate per unit area method assumes that the area in question is a continuous fuel package, with the entire surface burning. A fire on the lowest level would result in the highest fire plume and therefore the highest volume of smoke. Therefore, the design fire involves large machinery on the 5th floor of the Great Hall.

A conservative fast growth rate fire was assumed for both design fires, using a t-squared approximation. A t-squared fire is defined by:

$$\dot{Q} = \alpha \times t^2$$

where $\dot{Q}$ is the heat release rate (kW) at time t (sec) and α is the growth constant (kW/s^2), which is 0.047 kW/s^2 for a fast growth rate fire. The heat release rate curves of the design fires and sample commodities are plotted in

Figure 9 below.

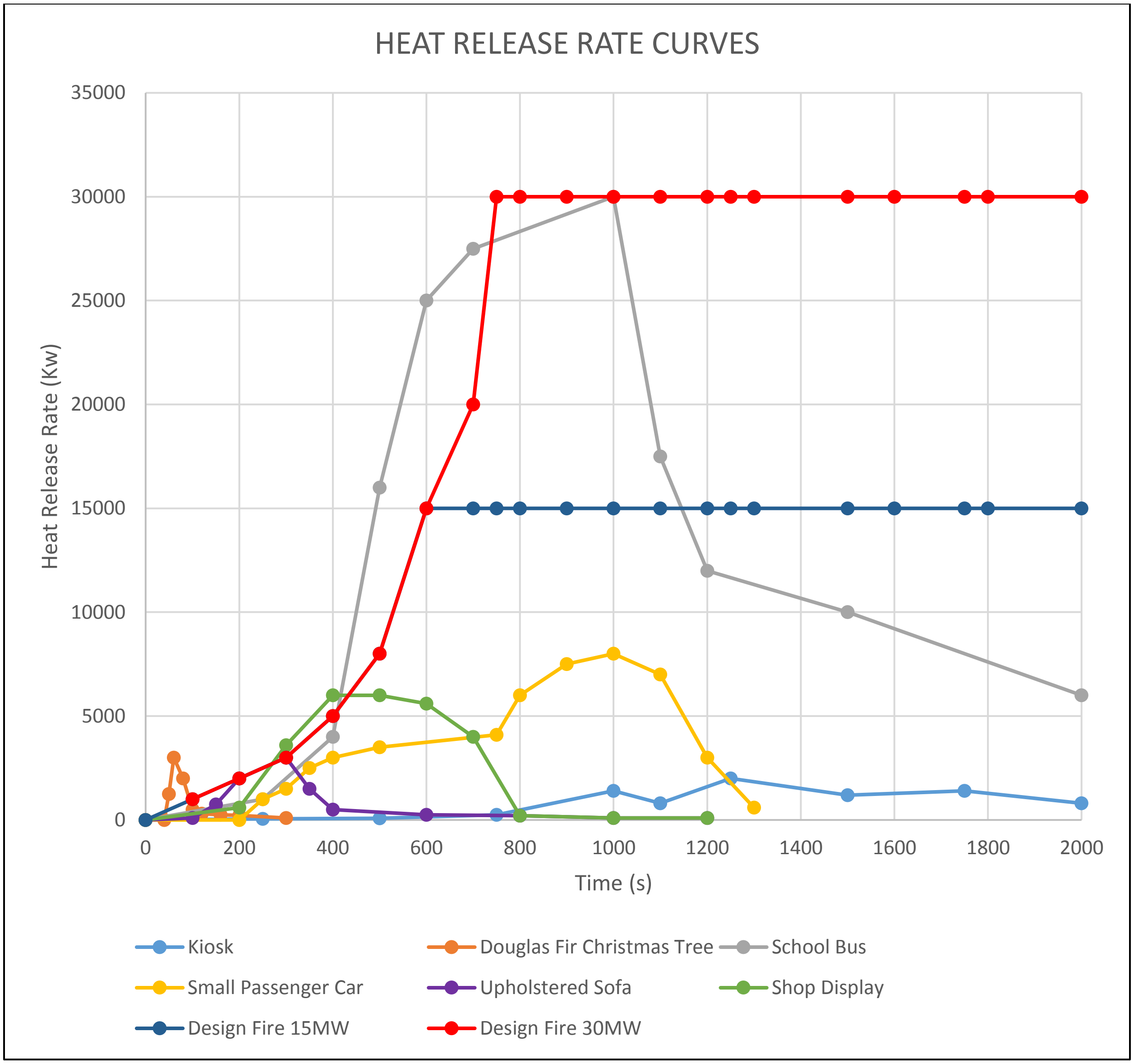

Figure 9 – Design Fire Heat Release Rate Curves

As shown above in Figure 9, the peak Heat Release Rates and curves for the individual components anticipated to be within the Great Hall are much smaller and shorter in duration than the design fires modeled. The 15 MW and 30 MW design fires were chosen to represent the worst-case fire scenario and a catastrophic fire event respectively.

6. DESIGN CONSIDERATIONS

The purpose of this analysis is to evaluate smoke layer height in the Great Hall. Given this narrow scope, considerations of stack effect and wind effects are anticipated to have little to no influence on the results of this analysis and were therefore not included in the model.

7. MODELING RESULTS

The figures below show the temperature slice file through the center of the Great Hall at the corresponding time. The figures are marked with a black line at the critical smoke layer temperature of 40 °C. This line designates the lowest point of the smoke layer. It is meant to show only the interface between the smoke layer and clear space and does not account for the smoke capacity in the space. It is assumed that the interface and the volume above the interface are filled with smoke. The temperature slice files were captured every 10 minutes for each scenario. Along with the temperature slice files, there are plots that show how the smoke layer height changes relative to the critical height of 10 ft above floor 6. Data was captured every 5 minutes to provide a clear representation of how the smoke layer height descends with respect to time.

For scenarios 1 and 2, manual smoke control was not utilized in the test of the two different fire sizes. Scenarios 3 and 4 fires were located in between beam detectors and manual smoke exhaust fans were activated 10 minutes after beam detection actuation. Scenario 5 fire was located directly below the beam smoke detector and manual smoke exhaust fans were activated 10 minutes after beam detection actuation.

7.1. Scenario 1: 15 MW Fire with No Ventilation

The first model considered a 15 MW fire in the Great Hall without any smoke control system. The axi-symmetric fire, located in the center of the Great Hall, was evaluated based on how it filled the Great Hall without any smoke exhaust system activation. The results are shown below by slice files in Figures 10 through 15. The figures show the temperatures through the center of the Great Hall providing a good representation of the depth of the smoke layer as it descends. Following Figure 15 is a plot that was generated by analytically evaluating the smoke layer height across the Z-plane of the Great Hall. The plot, Figure 16, more accurately describes the smoke layer height as it was calculated in FDS.

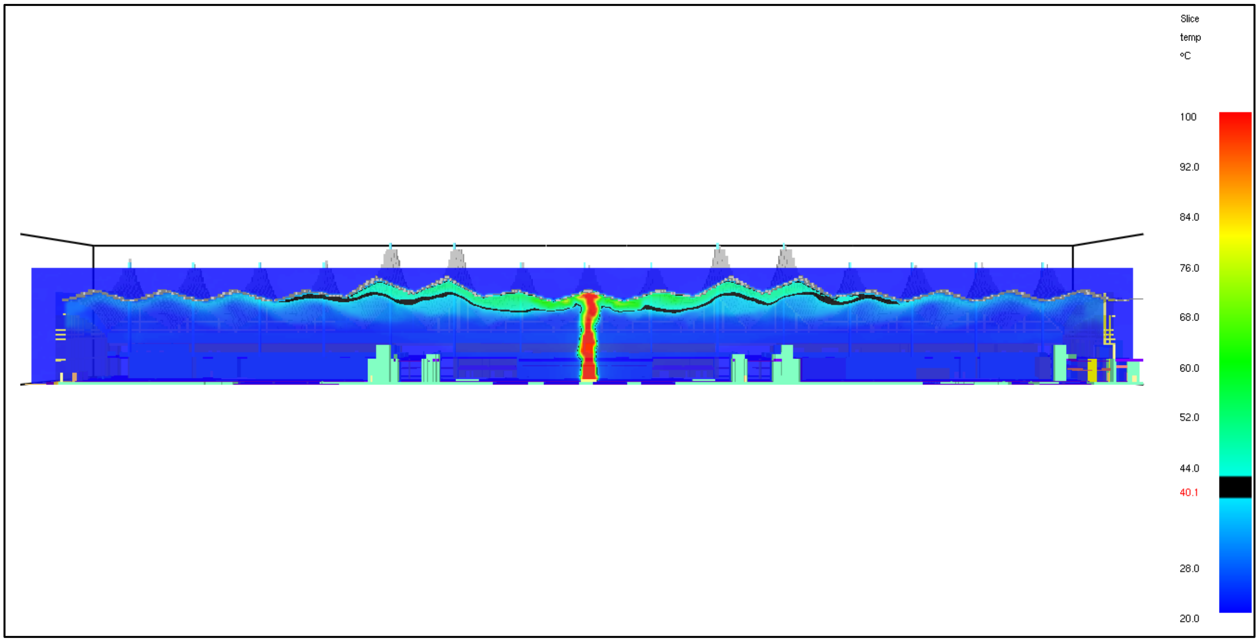

Figure 10 – Scenario 1: Section View Smoke Layer at 10 Minutes

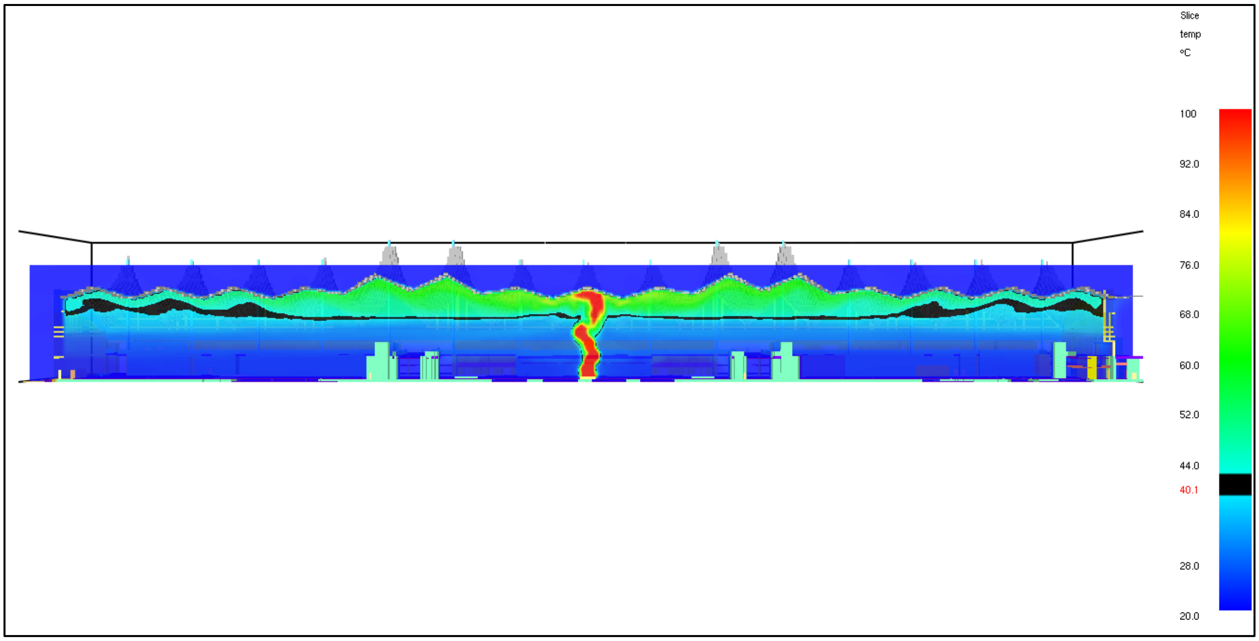

Figure 11 – Scenario 1: Section View Smoke Layer at 20 Minutes

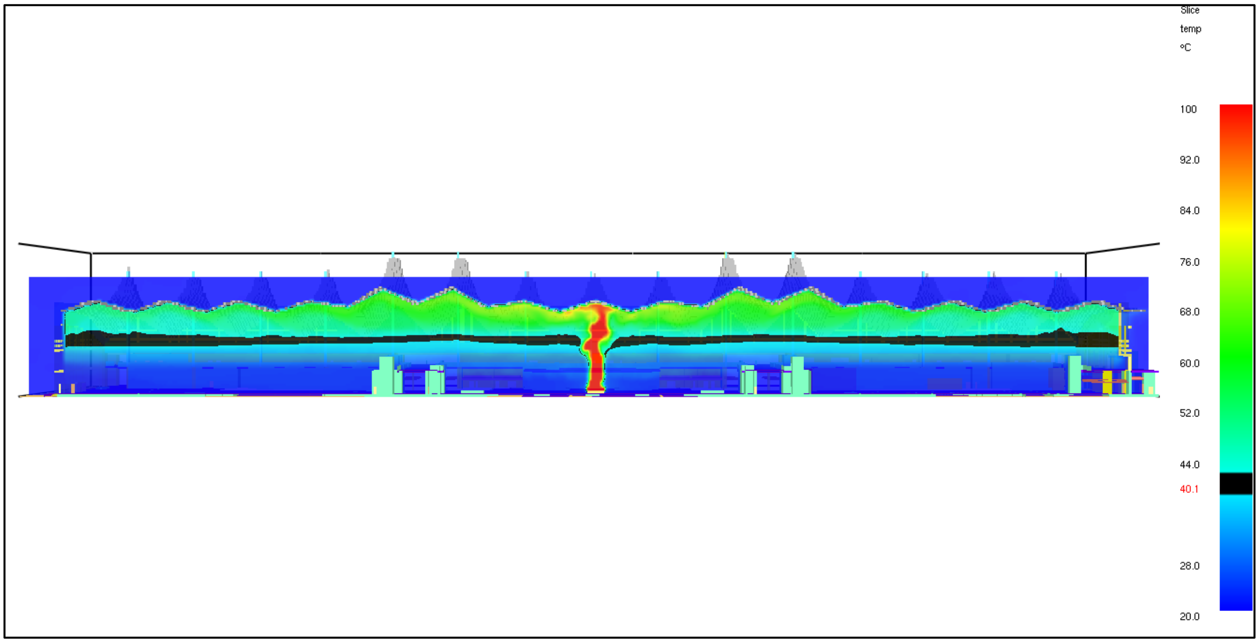

Figure 12 – Scenario 1: Section View Smoke Layer at 30 Minutes

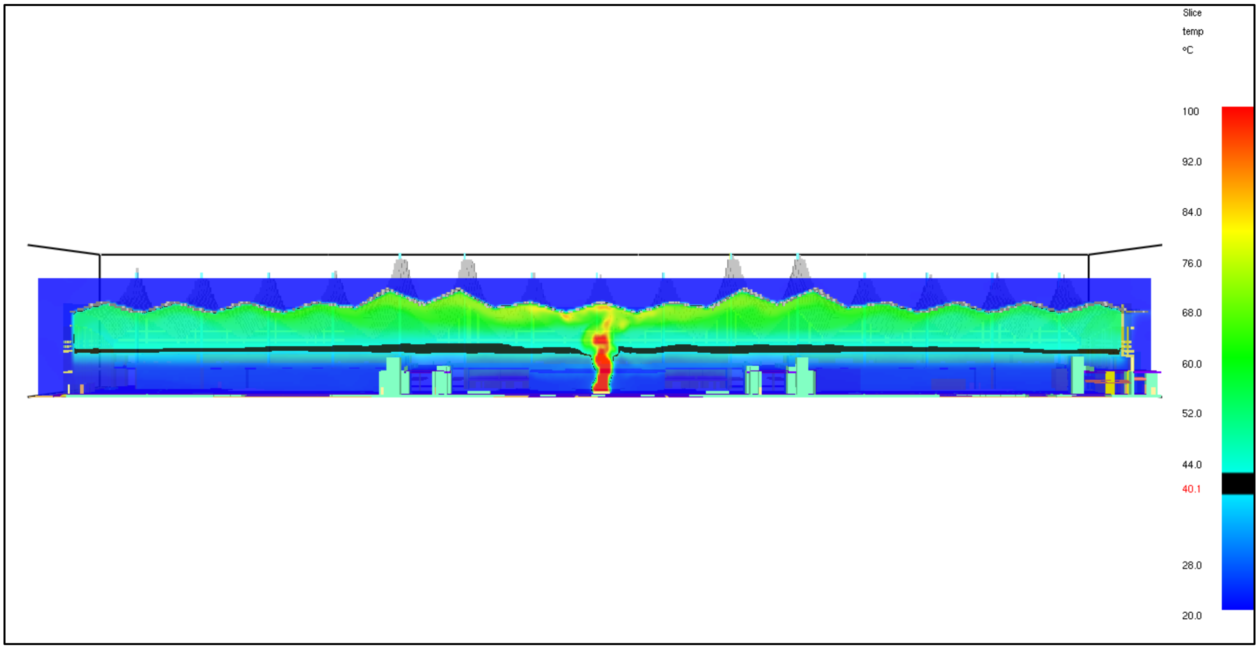

Figure 13 – Scenario 1: Section View Smoke Layer at 40 Minutes

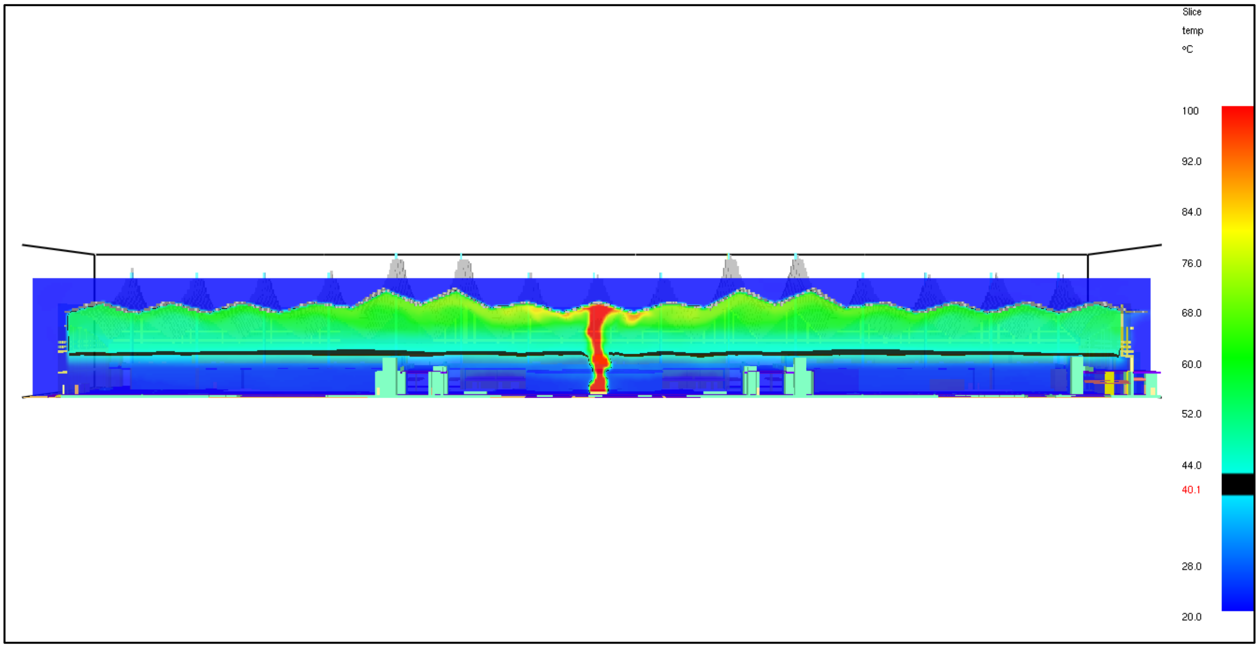

Figure 14 – Scenario 1: Section View Smoke Layer at 50 Minutes

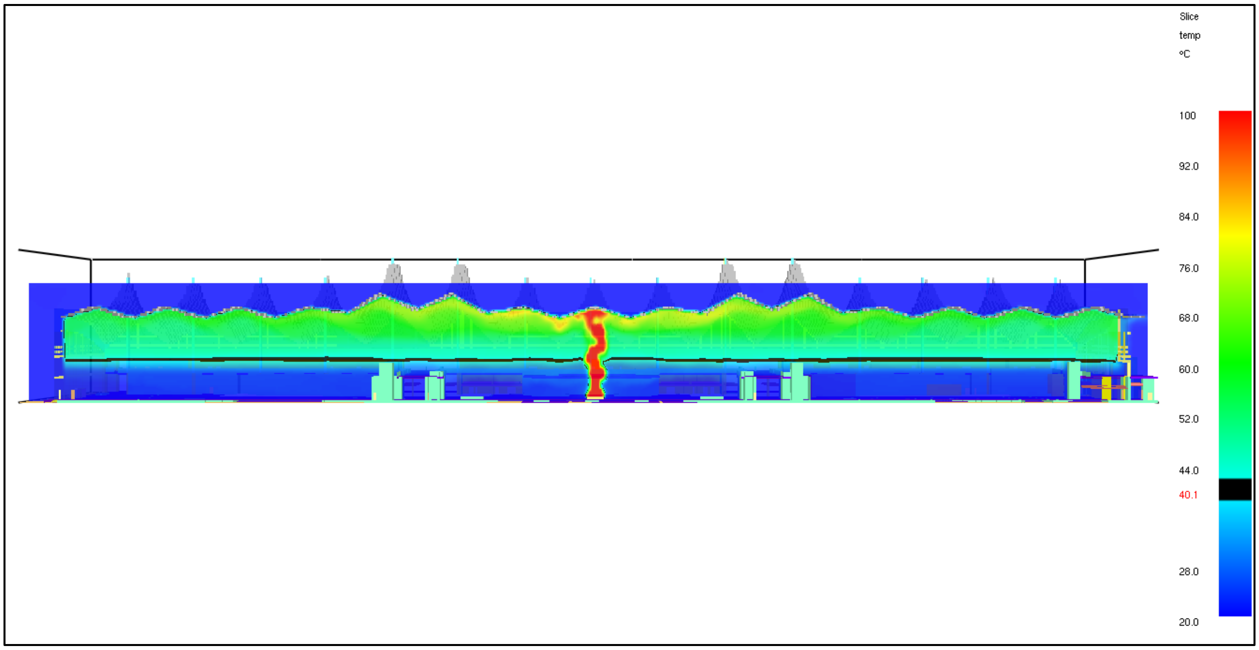

Figure 15 – Scenario 1: Section View Smoke Layer at 60 Minutes

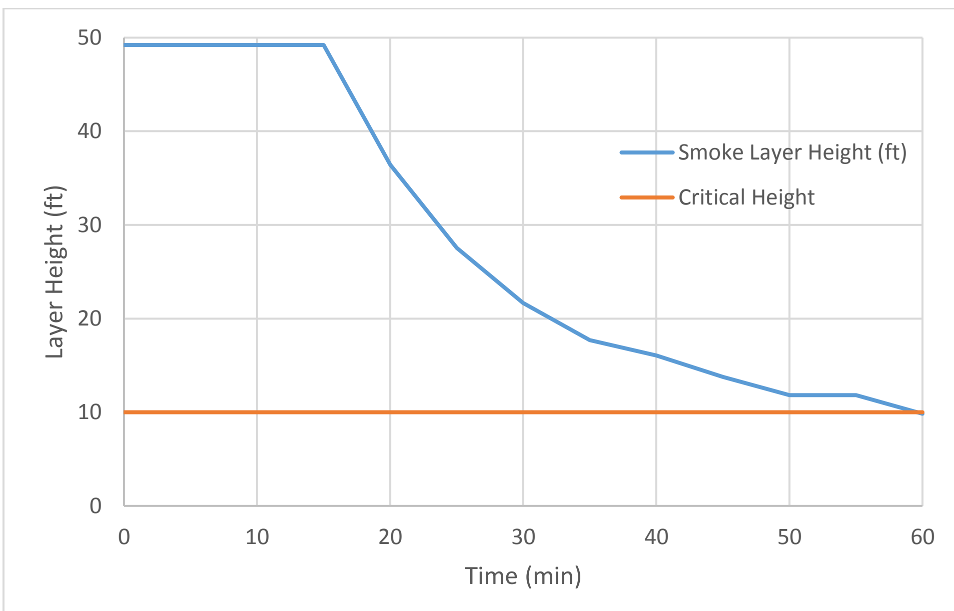

Figure 16 – Scenario 1: Smoke Layer Height

7.2. Scenario 2: 30 MW fire with No Ventilation

Scenario 2 considered a 30 MW fire in the Great Hall without any smoke control system. The axi-symmetric fire, located in the center of the Great Hall, was evaluated based on how it filled the Great Hall without any smoke exhaust system activation. The results are shown below by slice files in Figures 17 through 22. The figures show the temperatures through the center of the Great Hall providing a good representation of the depth of the smoke layer as it descends. Following Figure 22 is a plot that was generated by analytically evaluating the smoke layer height across the Z-plane of the Great Hall. The plot, Figure 23, more accurately describes the smoke layer height as it was calculated in FDS.

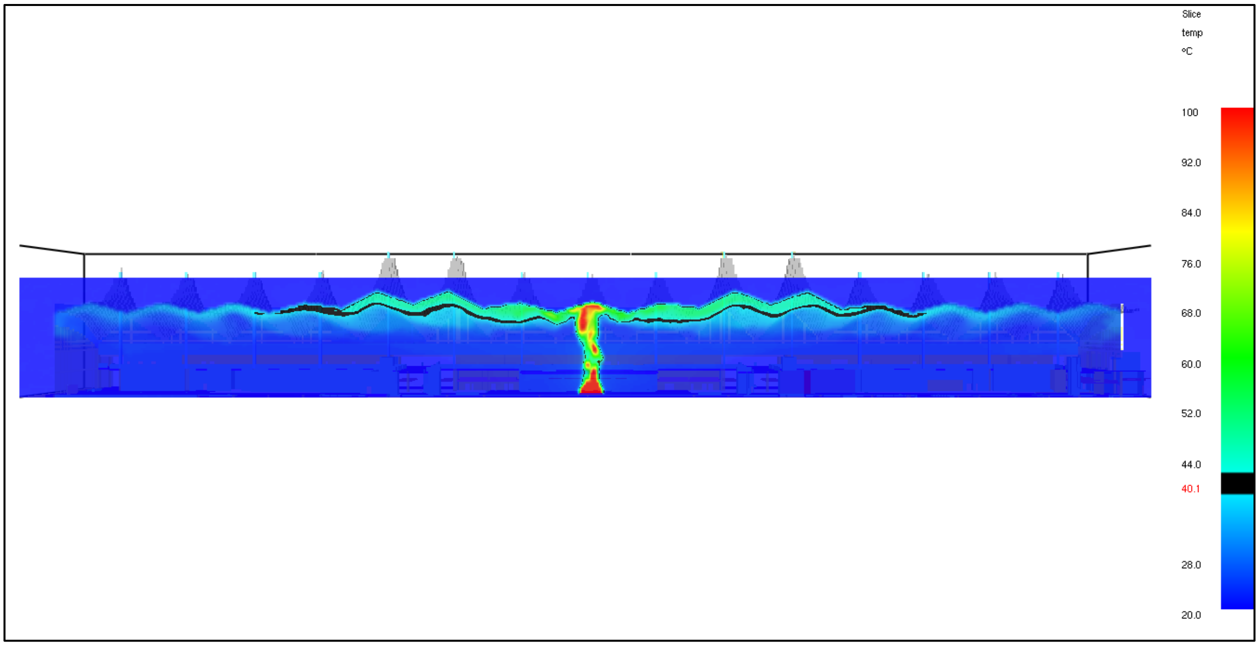

Figure 17 – Scenario 2: Section View Smoke Layer at 10 Minutes

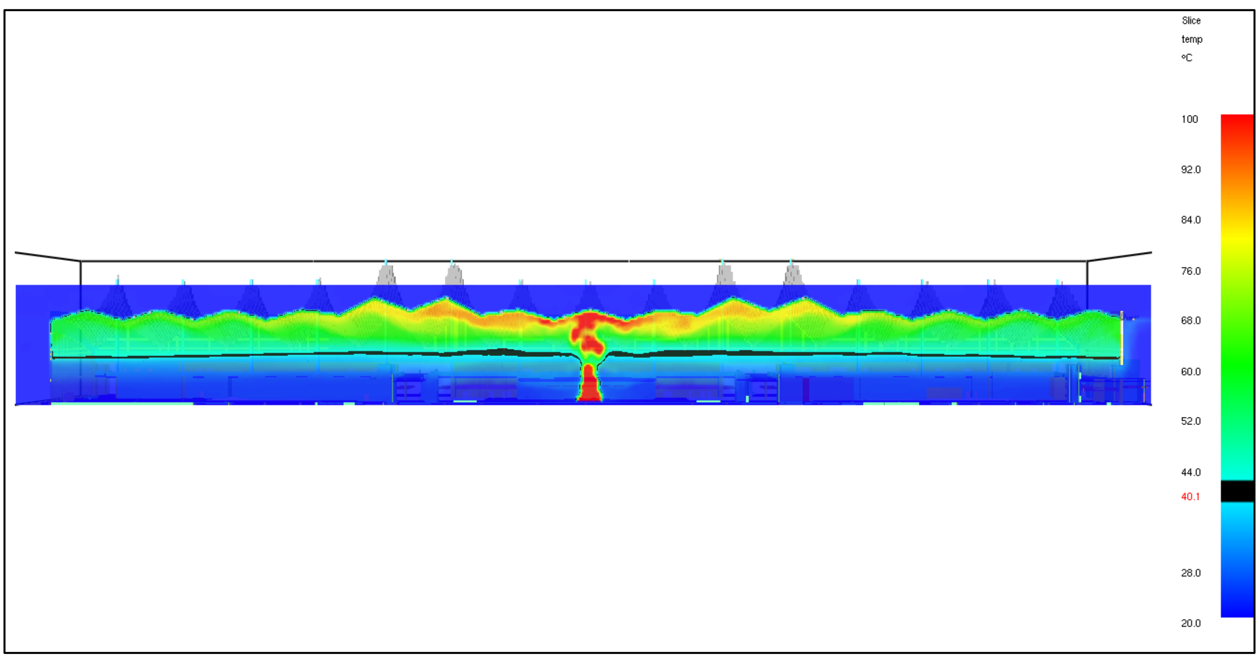

Figure 18 – Scenario 2: Section View Smoke Layer at 20 Minutes

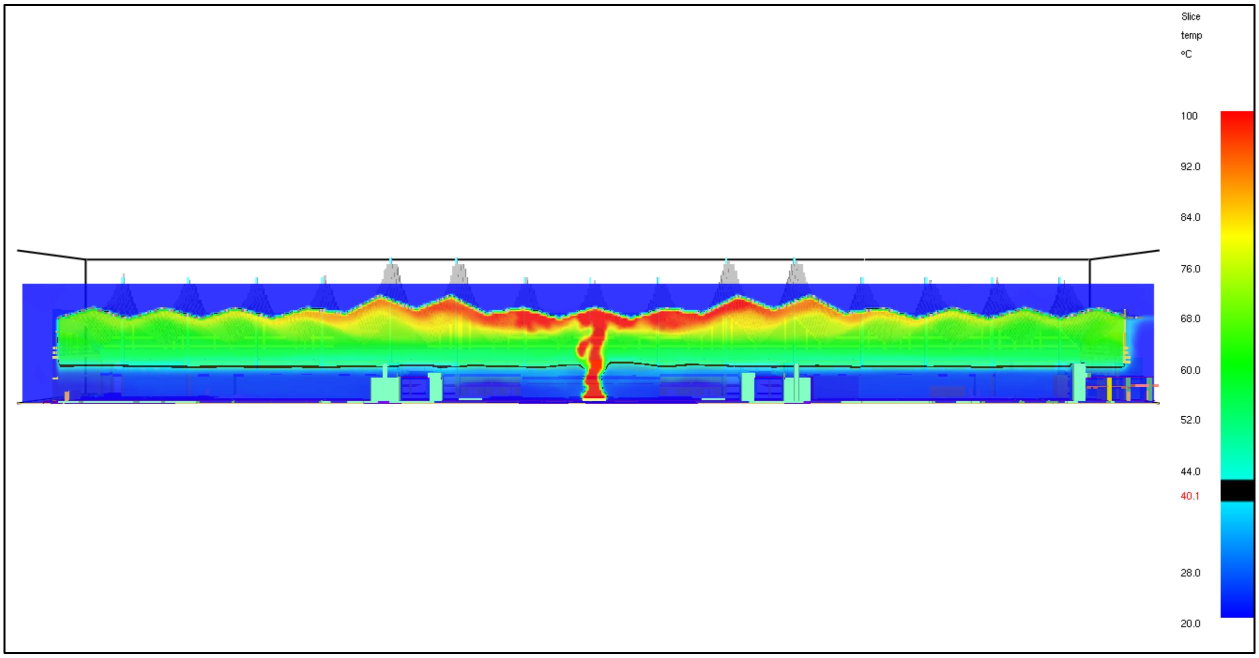

Figure 19 – Scenario 2: Section View Smoke Layer at 30 Minutes

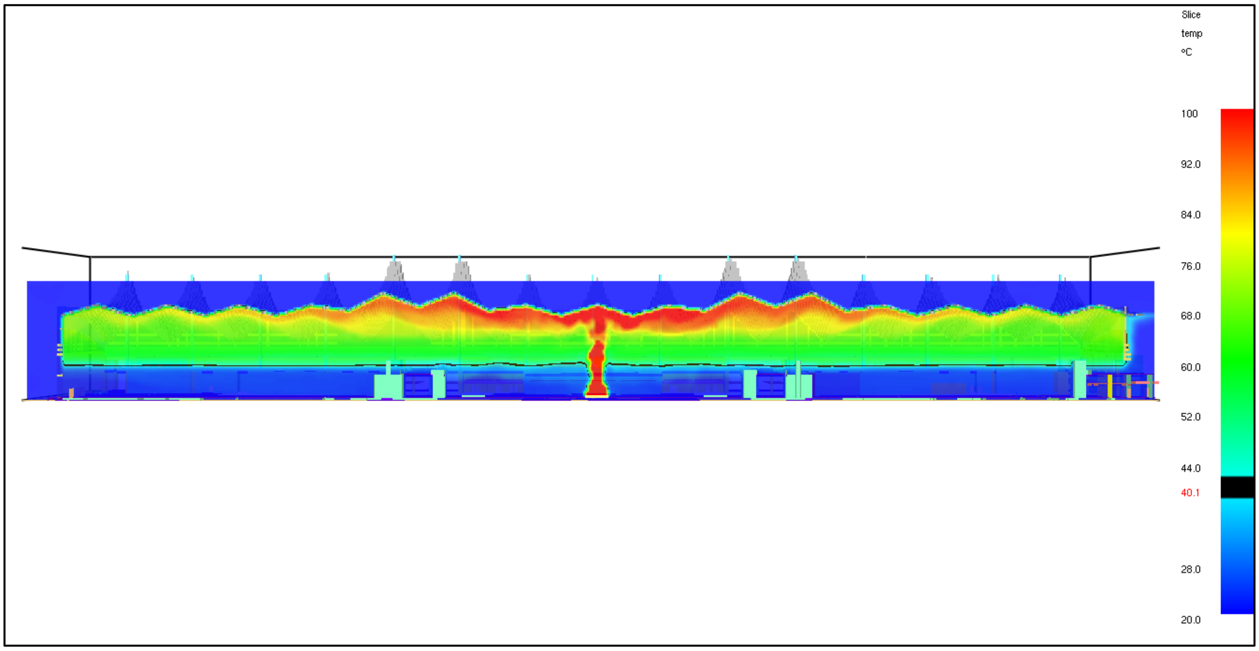

Figure 20 – Scenario 2: Section View Smoke Layer at 40 Minutes

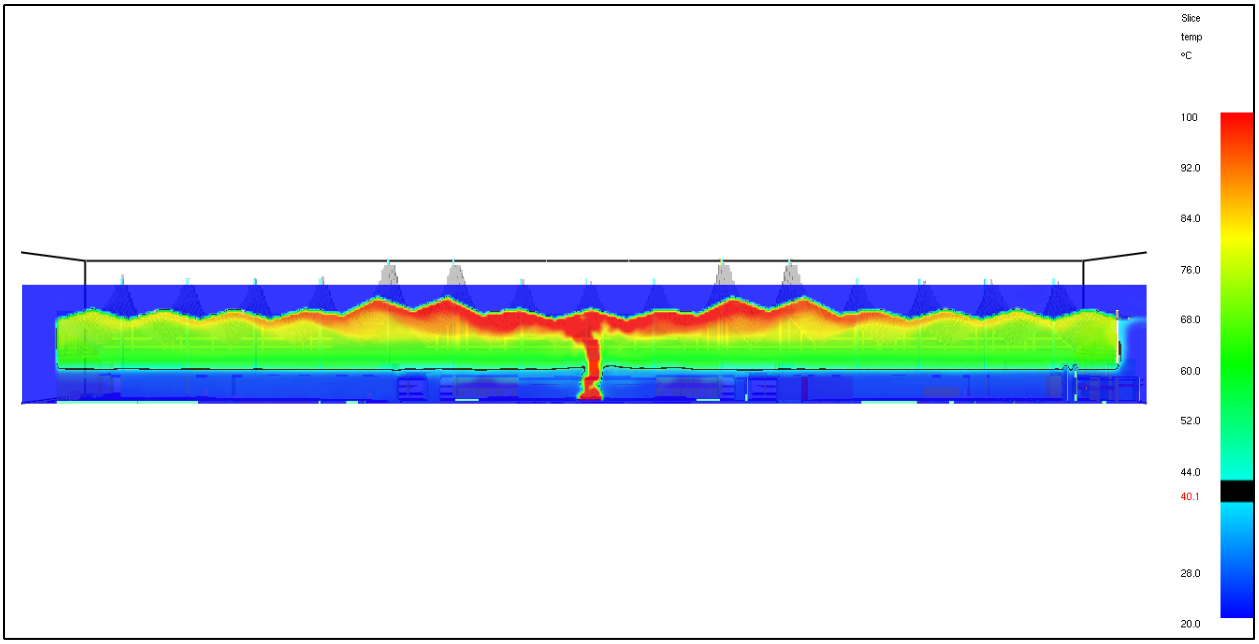

Figure 21 – Scenario 2: Section View Smoke Layer at 50 Minutes

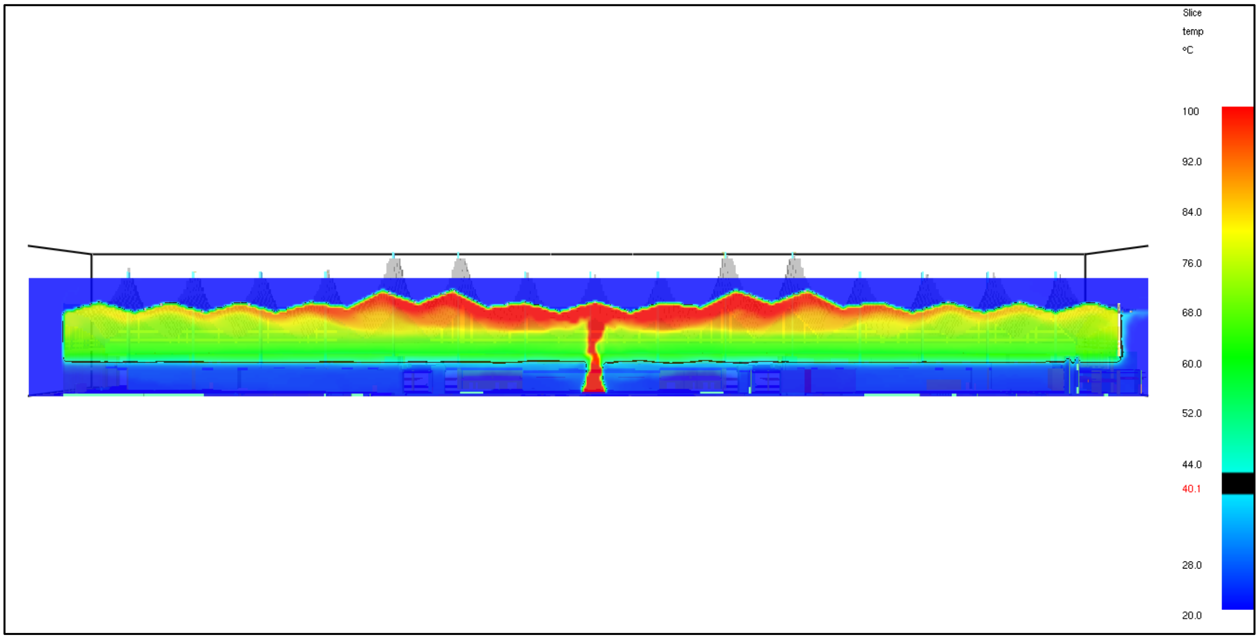

Figure 22 – Scenario 2: Section View Smoke Layer at 60 Minutes

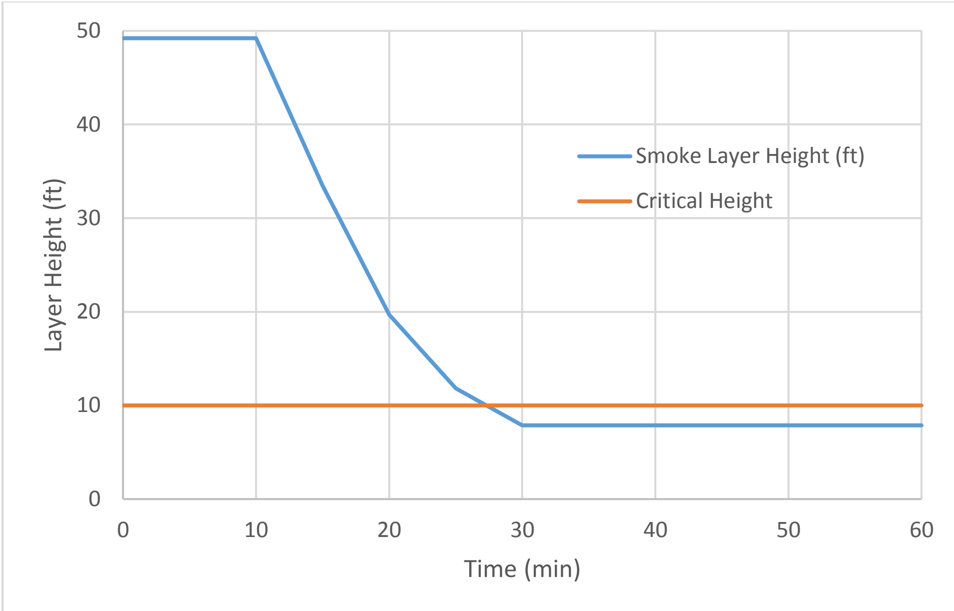

Figure 23 – Scenario 2: Smoke Layer Height

7.3. Scenario 3: 15 MW Fire with Smoke Control

Scenario 3 evaluated the effects of a smoke exhaust system on a 15 MW fire scenario. The axi-symmetric fire, located in the center of the Great Hall, was evaluated based on how it filled the Great Hall when smoke control detection and manual activation were applied to the model. In this scenario, the design fire is located in between beam detectors and manual smoke exhaust fans were activated 10 minutes after beam smoke detector actuation. The results are shown below by slice files in Figures 24 through 29. The figures show the temperatures through the center of the Great Hall providing a good representation of the depth of the smoke layer as it descends. Following Figure 29 is a plot that was generated by analytically evaluating the smoke layer height across the Z-plane of the Great Hall. The plot, Figure 30, more accurately describes the smoke layer height as it was calculated in FDS.

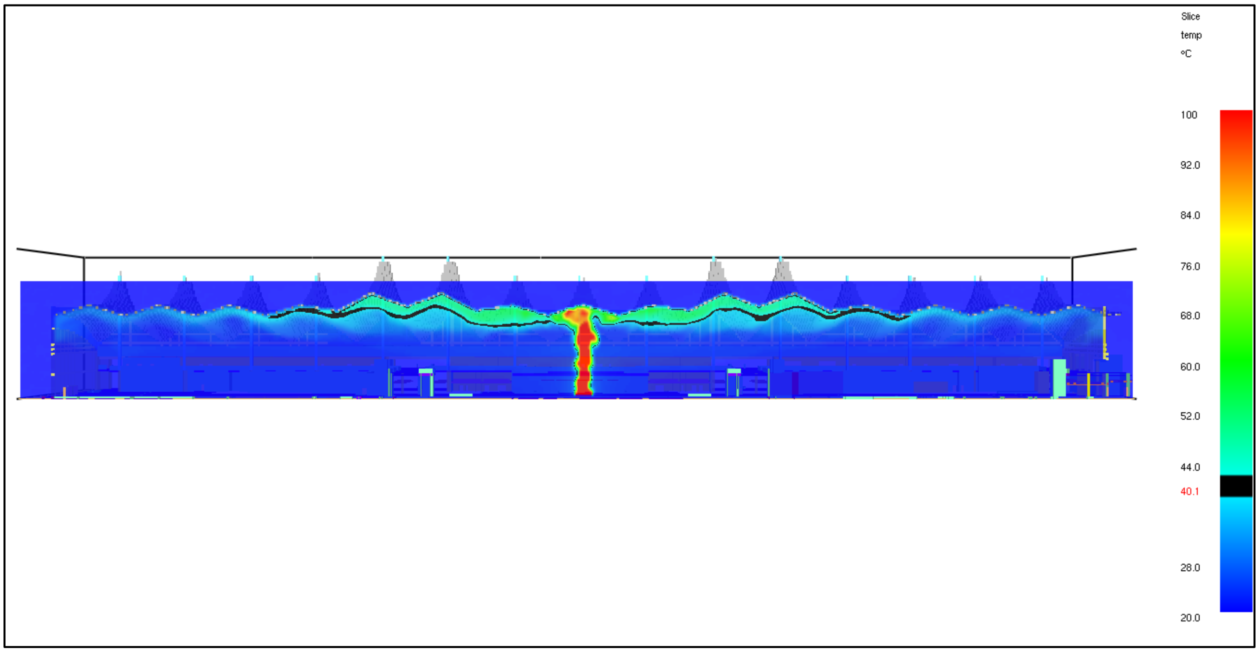

Figure 24 – Scenario 3: Section View Smoke Layer at 10 Minutes

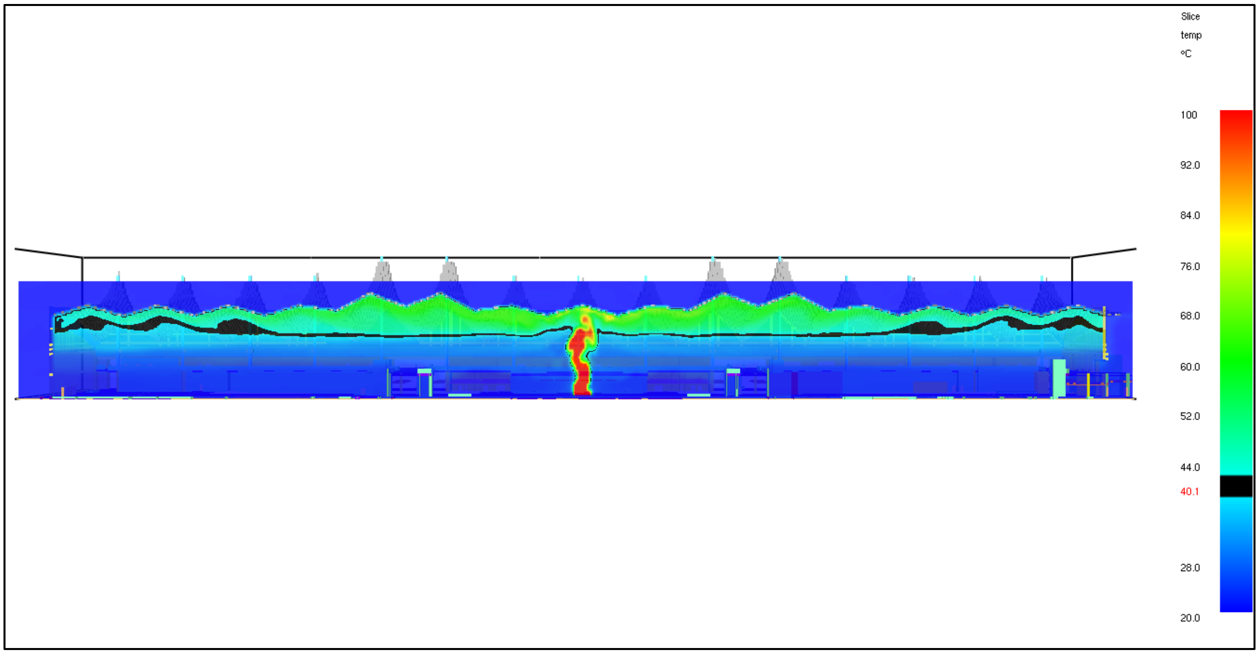

Figure 25 – Scenario 3: Section View Smoke Layer at 20 Minutes

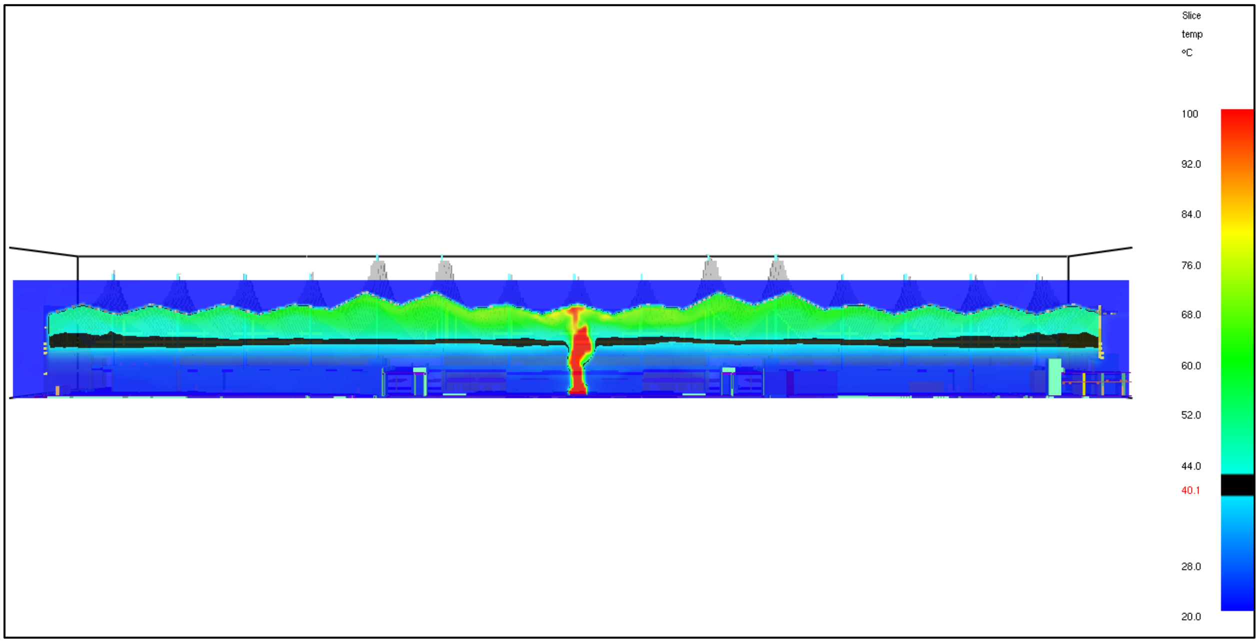

Figure 26 – Scenario 3: Section View Smoke Layer at 30 Minutes

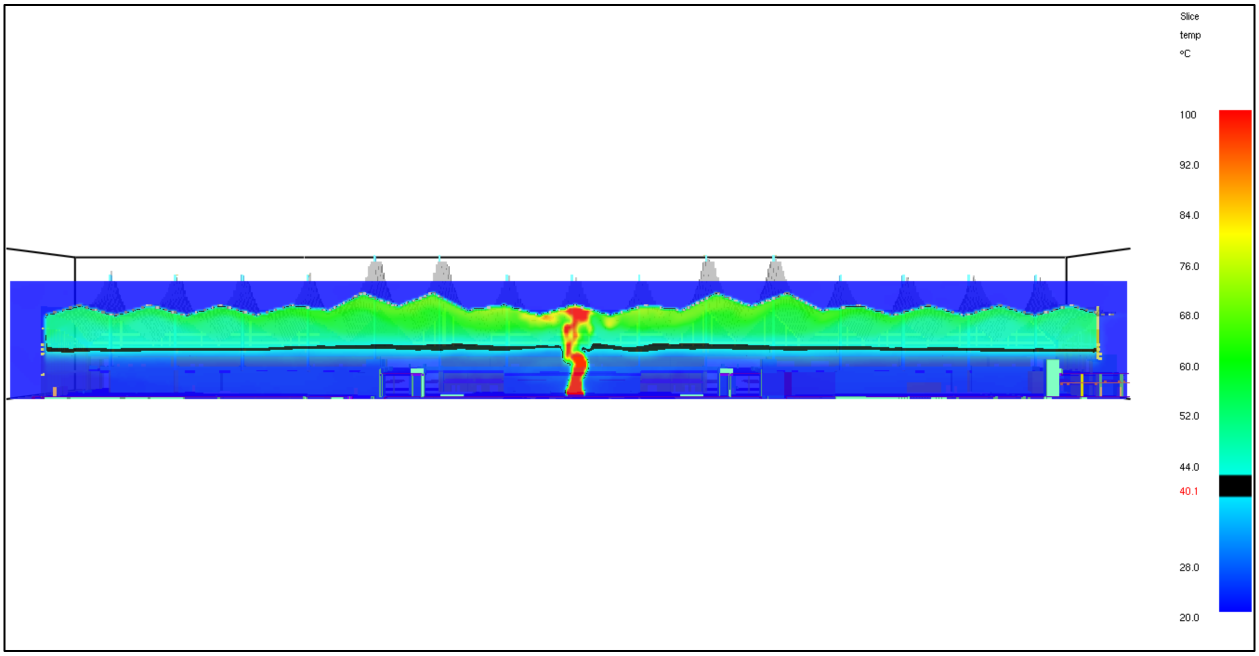

Figure 27 – Scenario 3: Section View Smoke Layer at 40 Minutes

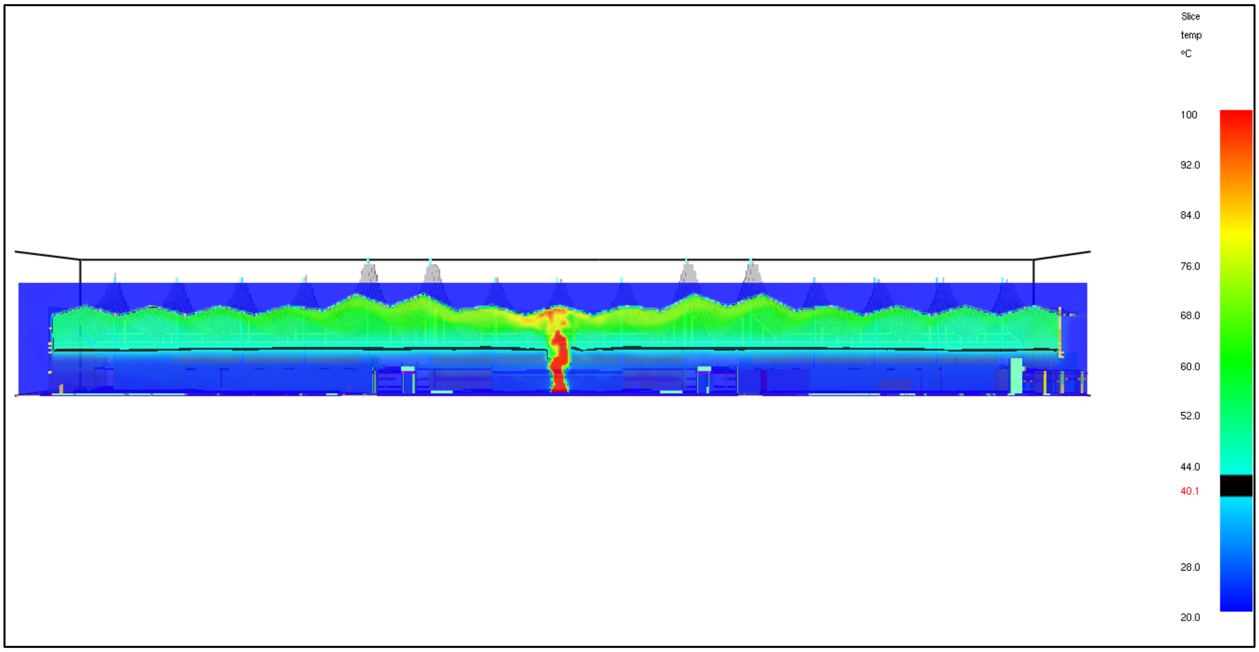

Figure 28 – Scenario 3: Section View Smoke Layer at 50 Minutes

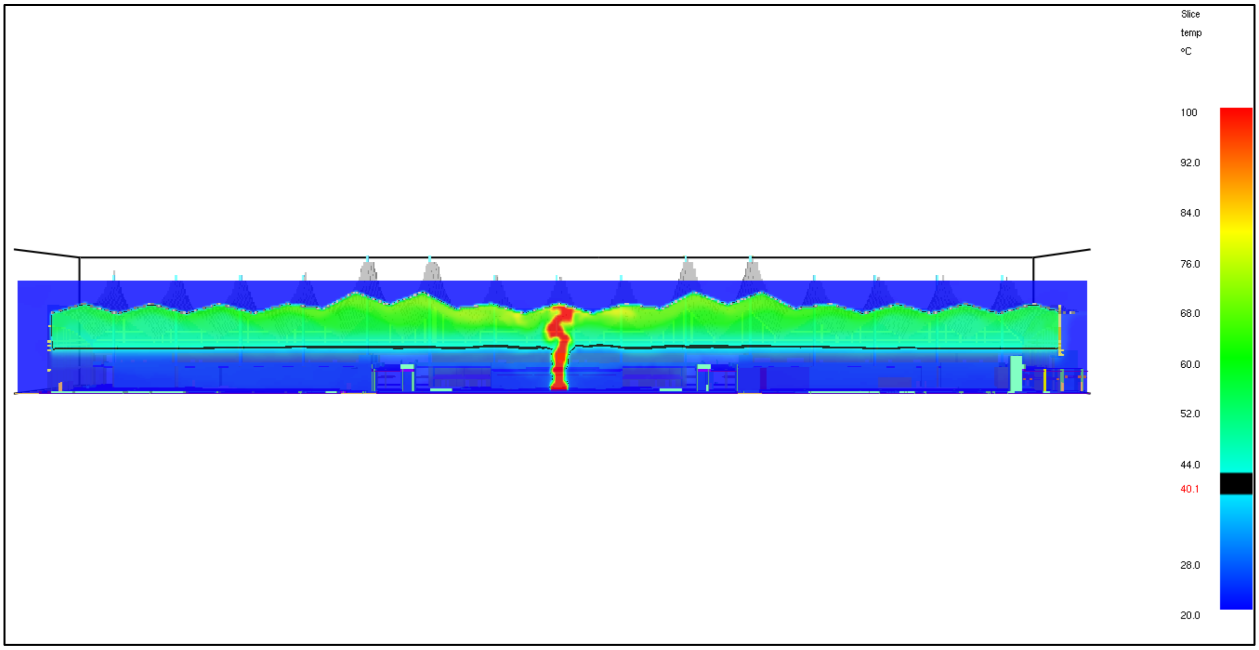

Figure 29 – Scenario 3: Section View Smoke Layer at 60 Minutes

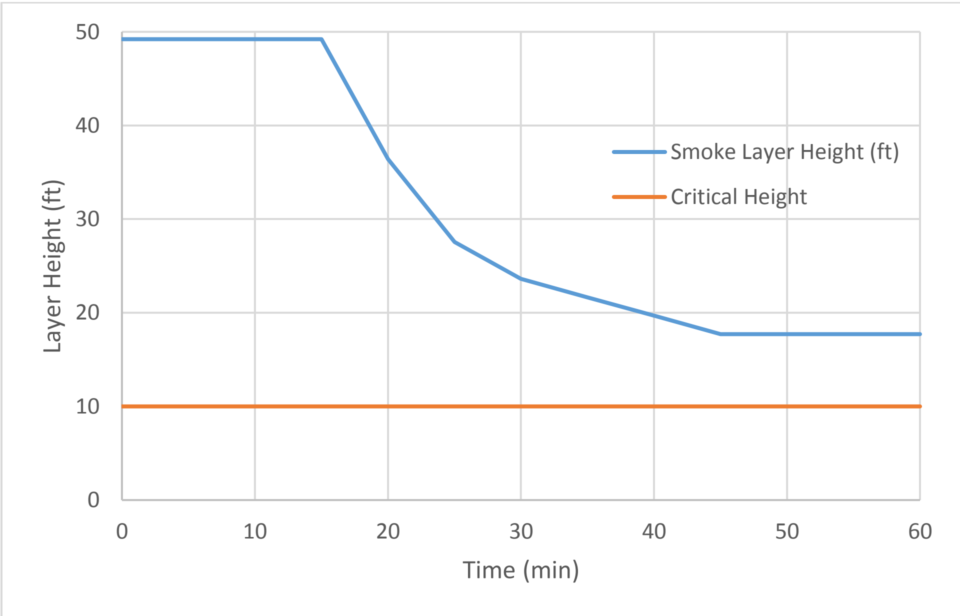

Figure 30 – Scenario 3: Smoke Layer Height

7.4. Scenario 4: 30 MW Fire with Smoke Control

Scenario 4 evaluated the effects of a smoke exhaust system on the larger 30 MW fire scenario. The axi-symmetric fire, located in the center of the Great Hall, was evaluated based on how it filled the Great Hall when smoke control detection and activation were applied to the model. In this scenario, the design fire is located in between beam detectors and manual smoke exhaust fans were activated 10 minutes after beam smoke detector actuation. The results are shown below by slice files in Figures 31 through 36. The figures show the temperatures through the center of the Great Hall providing a good representation of the depth of the smoke layer as it descends. Following Figure 36 is a plot that was generated by analytically evaluating the smoke layer height across the Z-plane of the Great Hall. The plot, Figure 37, more accurately describes the smoke layer height as it was calculated in FDS.

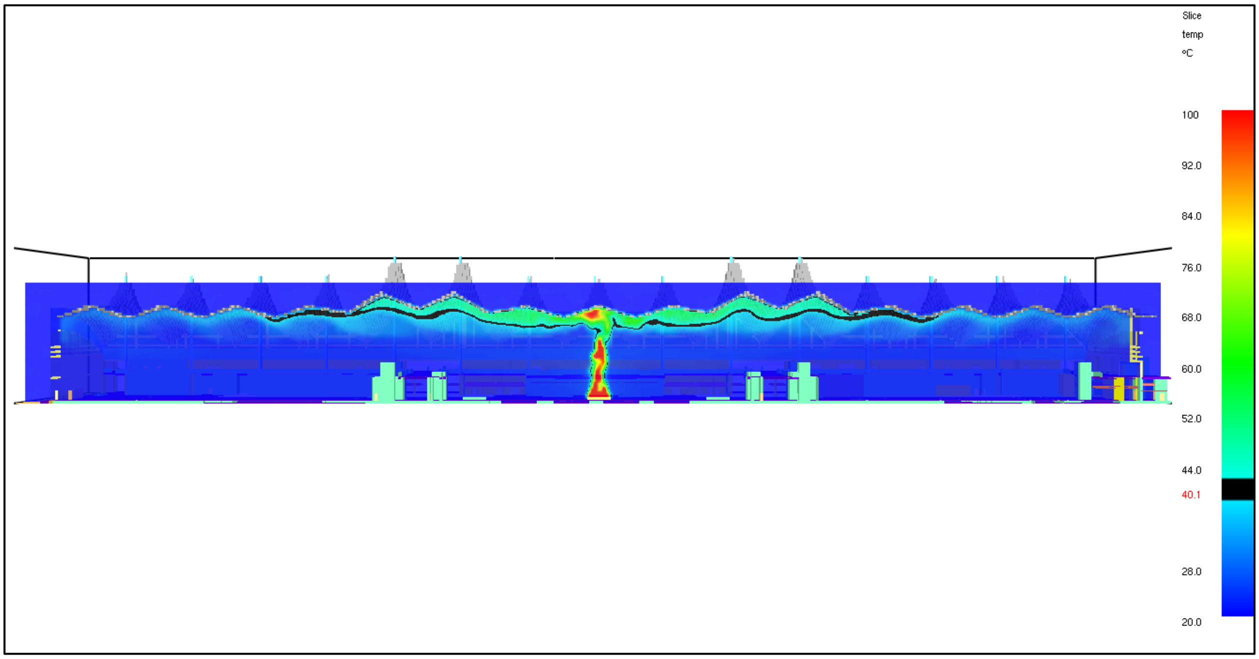

Figure 31 – Scenario 4: Section View Smoke Layer at 10 Minutes

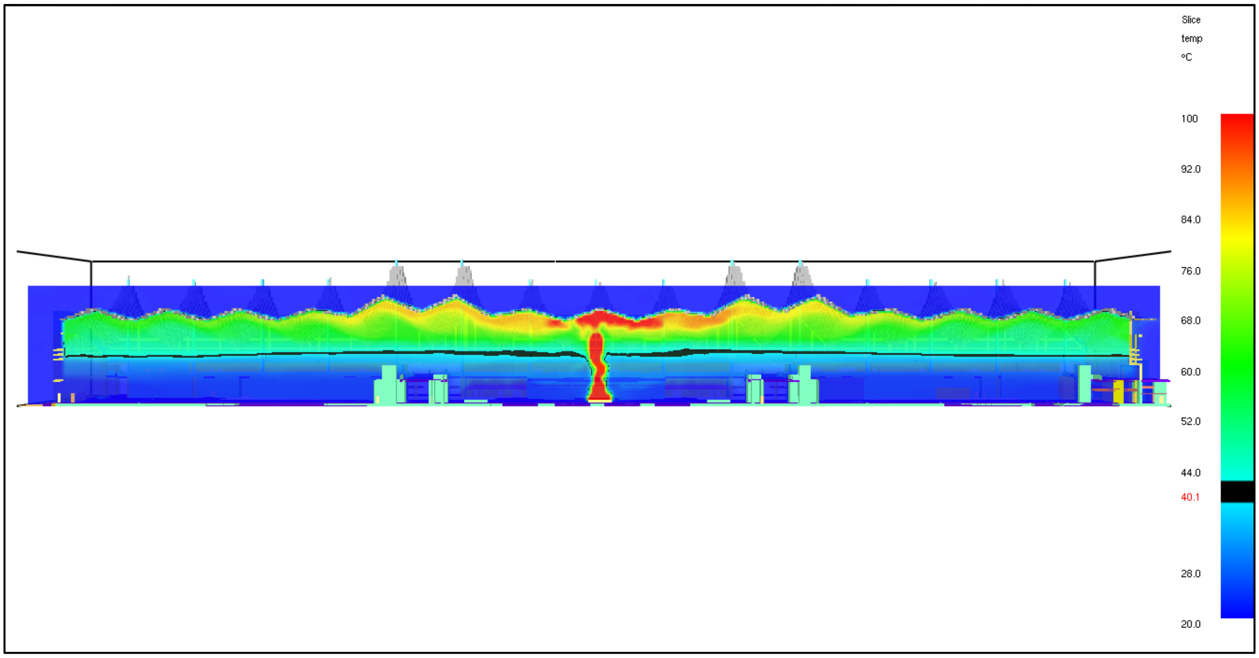

Figure 32 – Scenario 4: Section View Smoke Layer at 20 Minutes

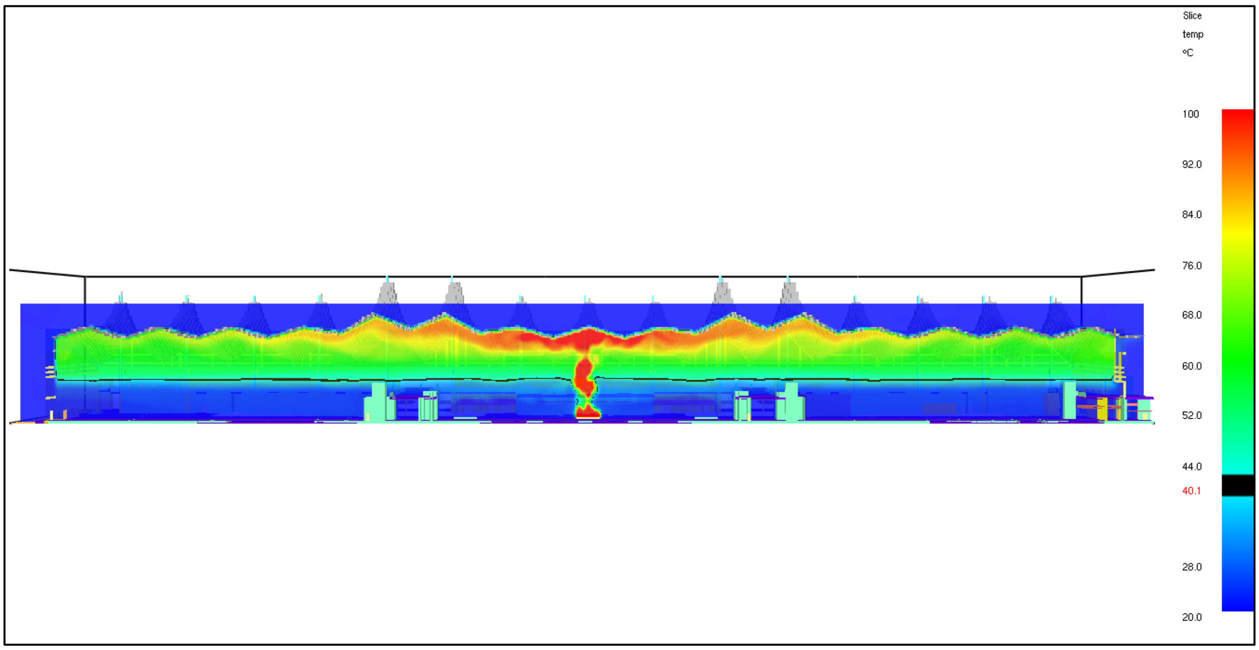

Figure 33 – Scenario 4: Section View Smoke Layer at 30 Minutes

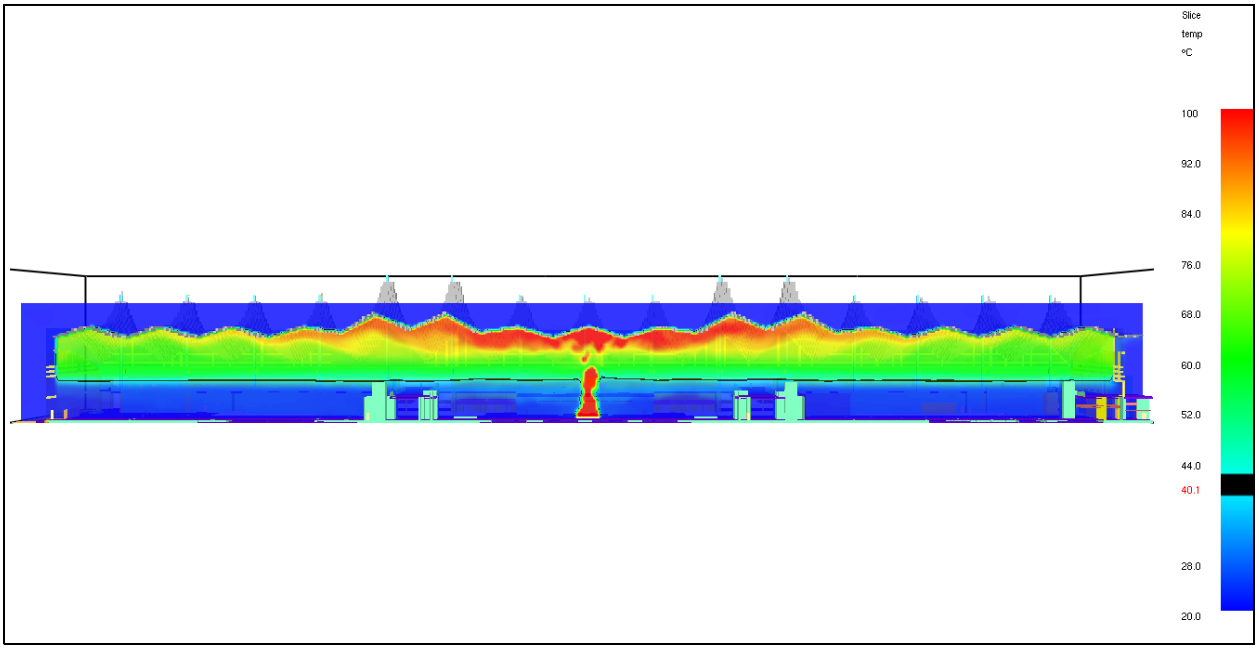

Figure 34 – Scenario 4: Section View Smoke Layer at 40 Minutes

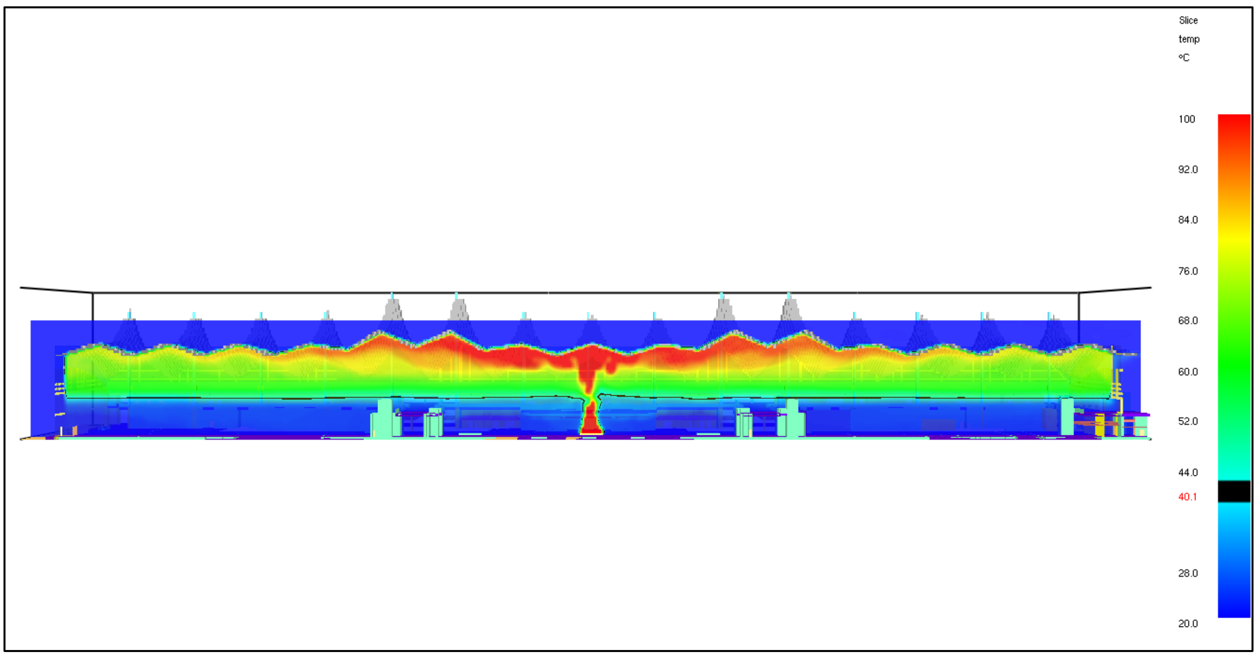

Figure 35 – Scenario 4: Section View Smoke Layer at 50 Minutes

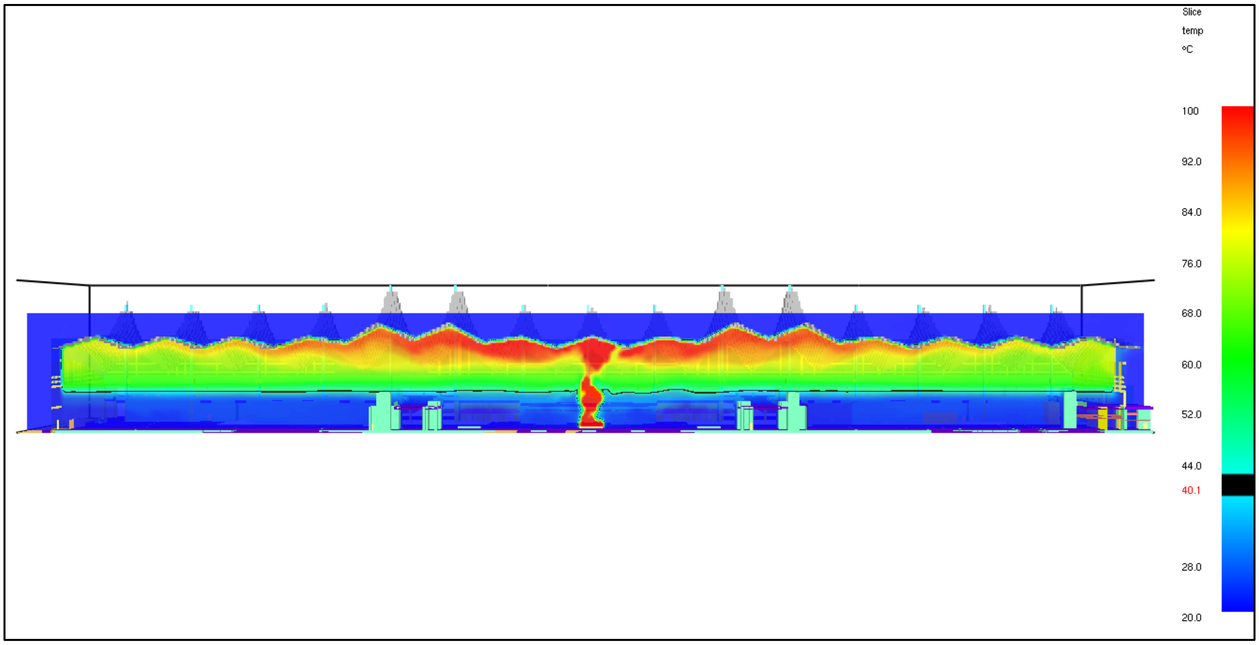

Figure 36 – Scenario 4: Section View Smoke Layer at 60 Minutes

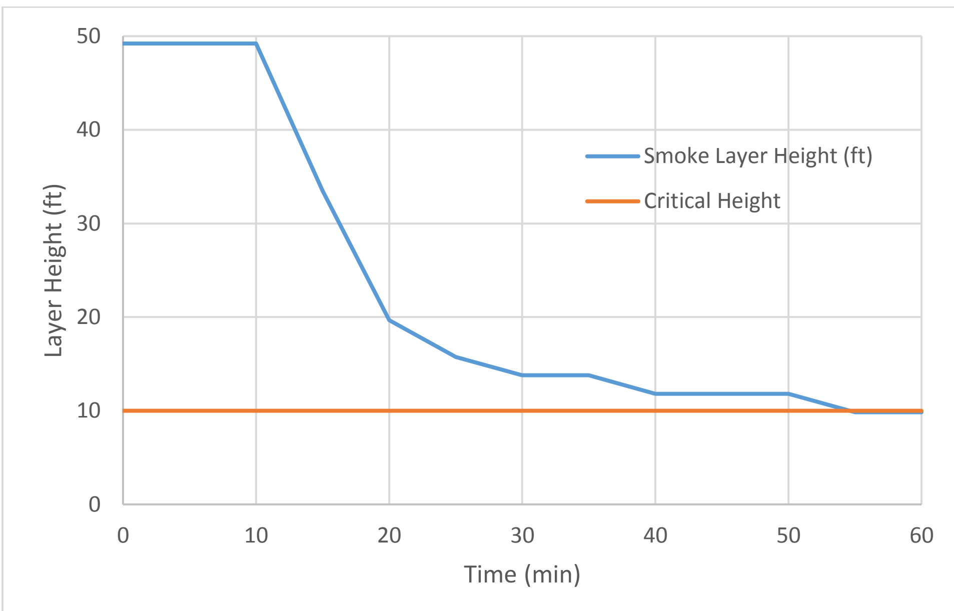

Figure 37 – Scenario 4: Smoke Layer Height

7.5. Scenario 5: 30 MW Fire with Smoke Control under Beam Detector

The final run, Scenario 5, evaluated the effects of a smoke exhaust system on the larger 30 MW fire in the event that the fire was located directly under the beam detector and manual smoke exhaust fans were activated 10 minutes after beam detector actuation. This scenario aimed to evaluate the smoke control system in the event that detection occurred almost immediately after the fire incident began. The axi-symmetric fire, located near the center of the Great Hall space under a beam detector, was evaluated based on how it filled the Great Hall when smoke control detection and activation was applied to the model. The results are shown below by slice files in Figures 38 through 43. The figures show the temperatures through the center of the Great Hall providing a good representation of the depth of the smoke layer as it descends. Following Figure 43 is a plot that was generated by analytically evaluating the smoke layer height across the Z-plane of the Great Hall. The plot, Figure 44, more accurately describes the smoke layer height as it was calculated in FDS.

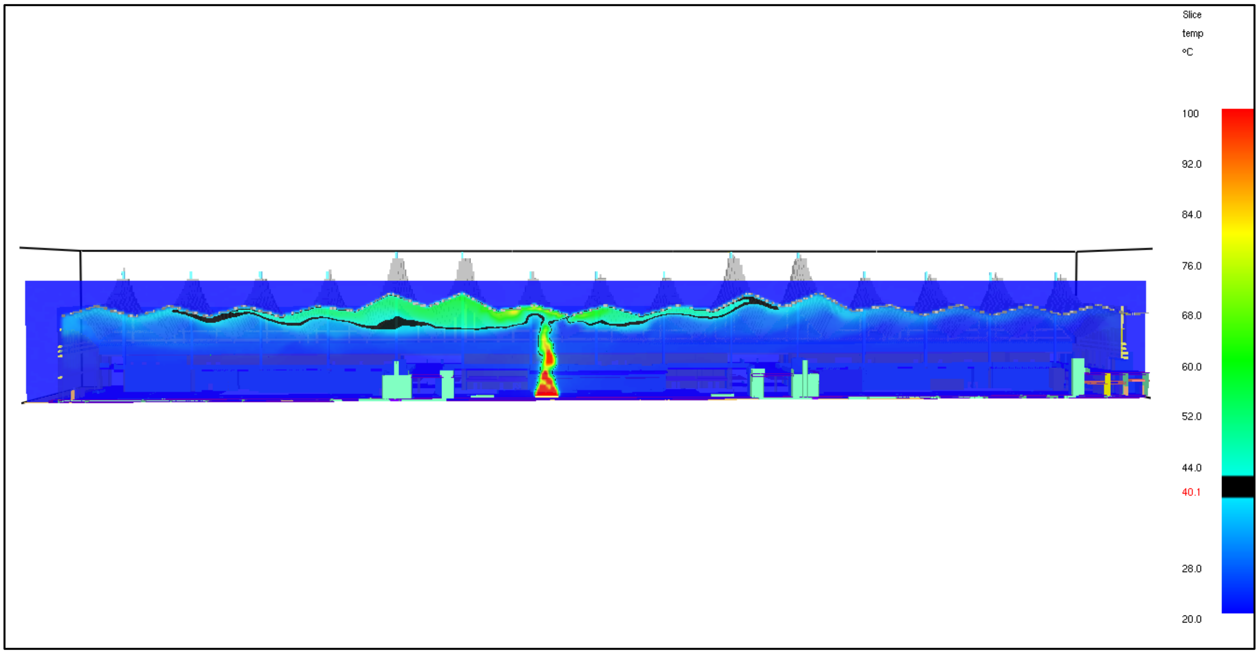

Figure 38 – Scenario 5: Section View Smoke Layer at 10 Minutes

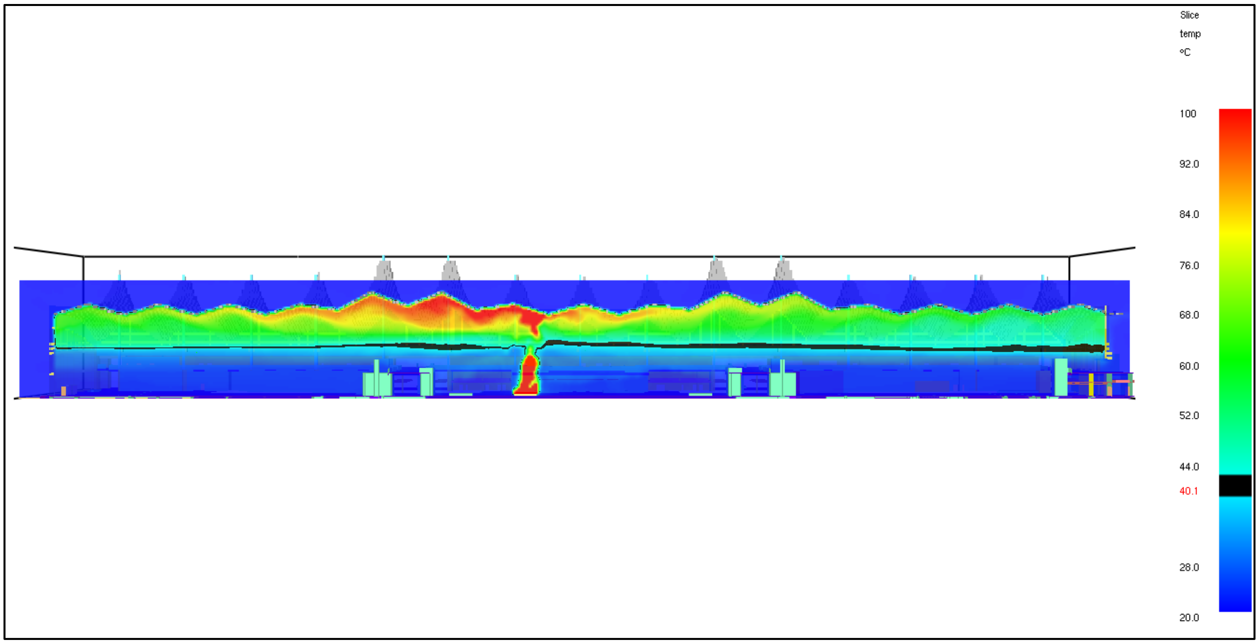

Figure 39 – Scenario 5: Section View Smoke Layer at 20 Minutes

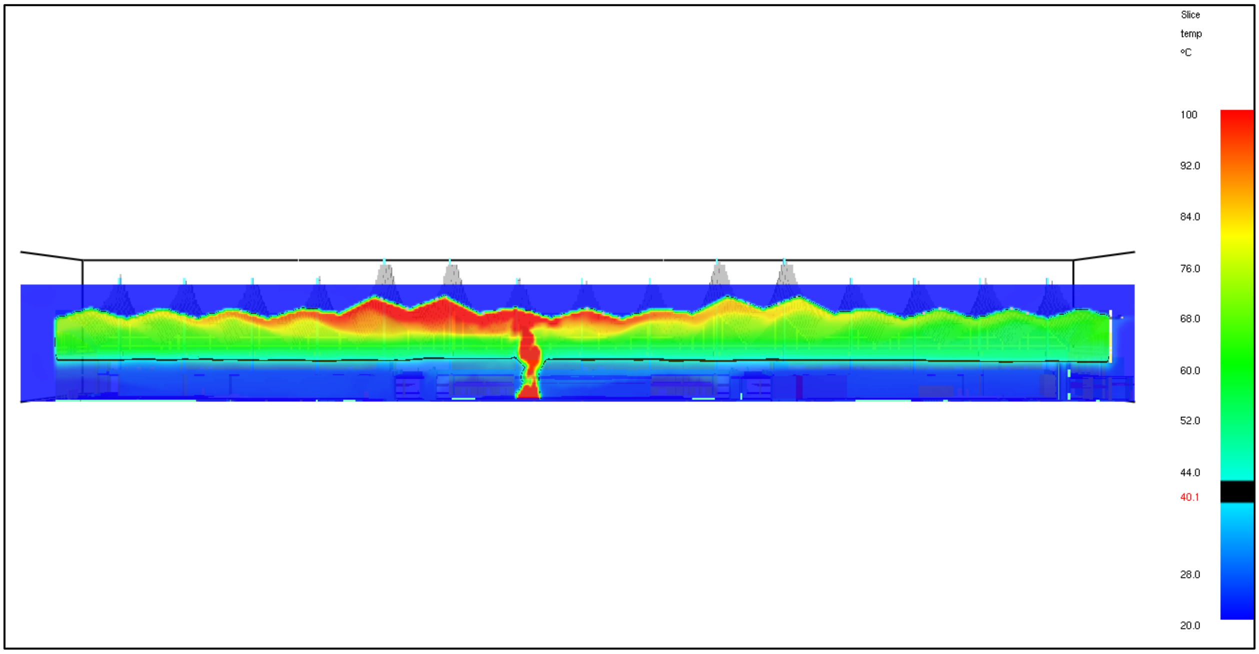

Figure 40 – Scenario 5: Section View Smoke Layer at 30 Minutes

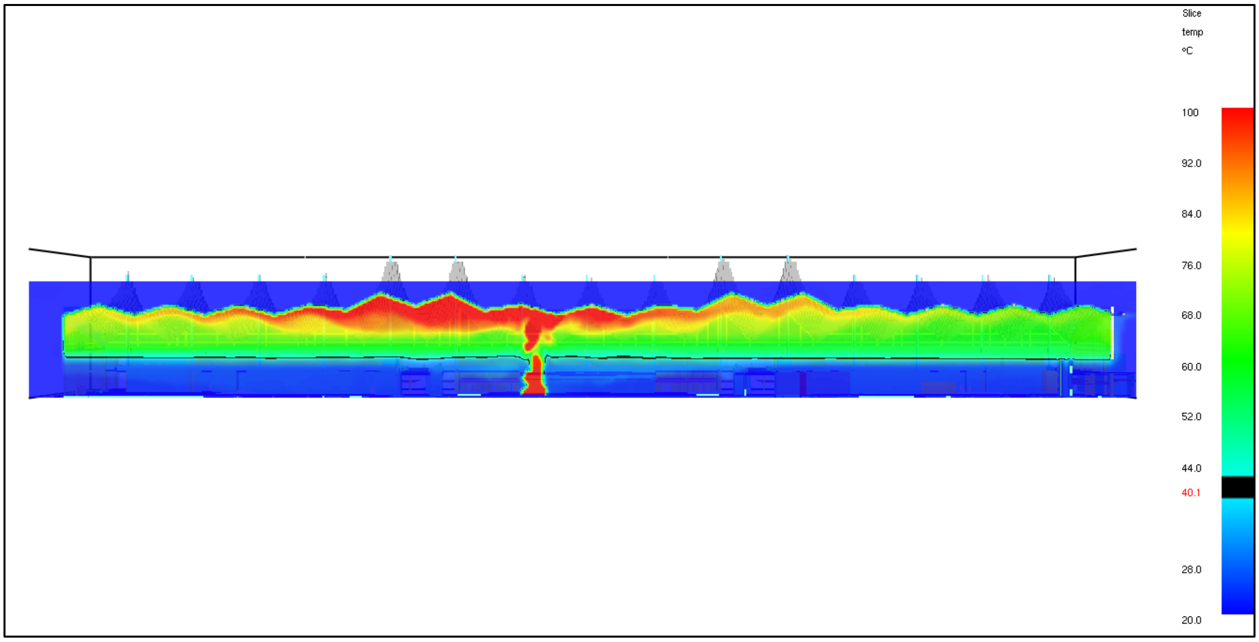

Figure 41 – Scenario 5: Section View Smoke Layer at 40 Minutes

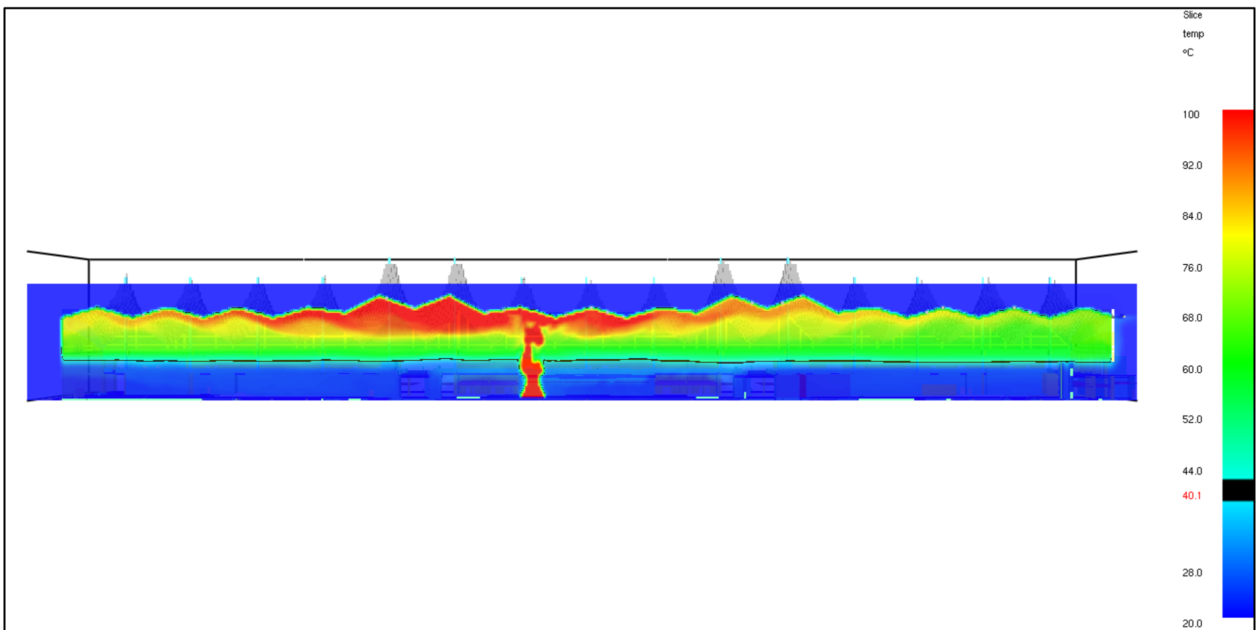

Figure 42 – Scenario 5: Section View Smoke Layer at 50 Minutes

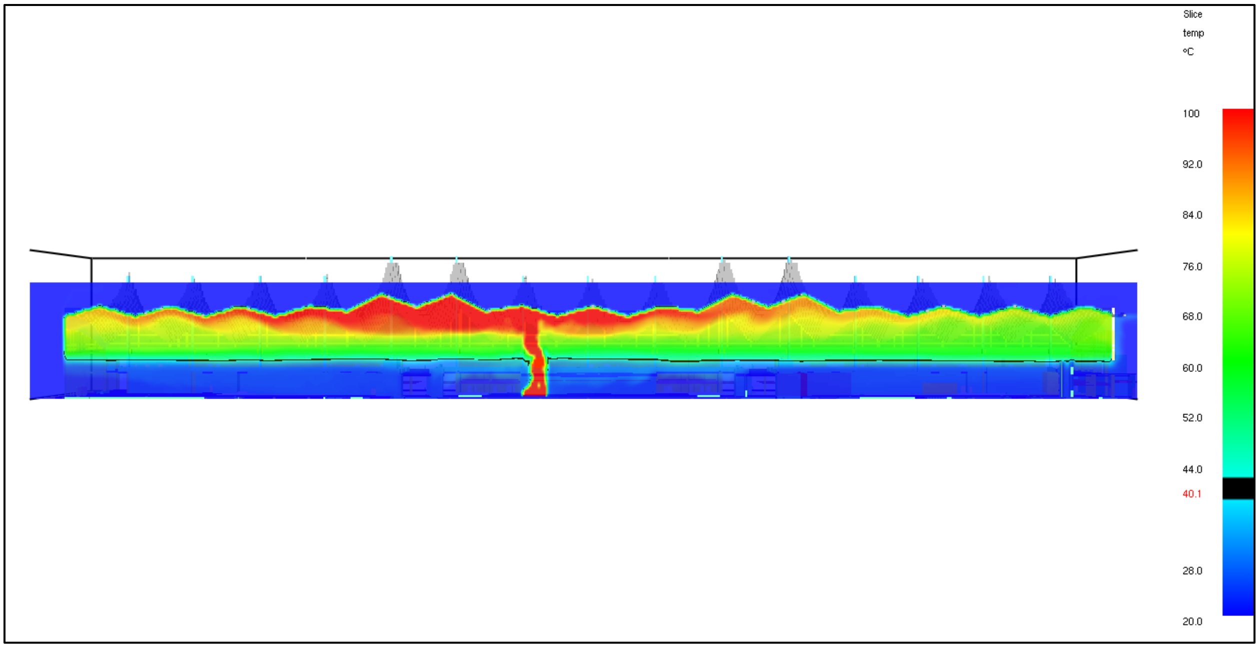

Figure 43 – Scenario 5: Section View Smoke Layer at 60 Minutes

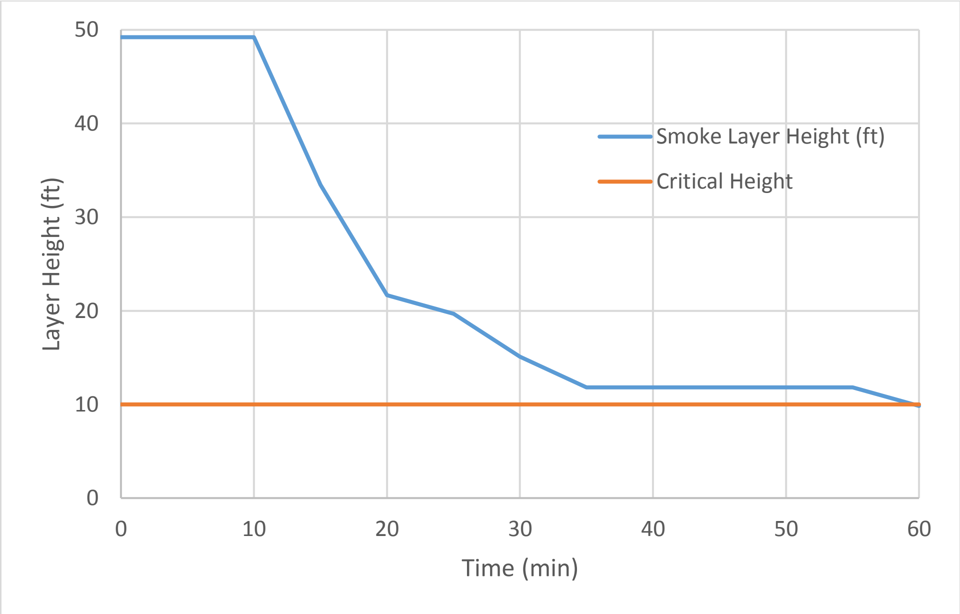

Figure 44 – Scenario 5: Smoke Layer Height

8. SUMMARY

Table 3 provides a summary of the five (5) FDS scenarios simulated including the fire size, presence of smoke control, location of the fire with respect to the beam detector, and the time for the smoke layer to reach the critical height. As shown below, Scenario 2 resulted in the fastest smoke layer decent time (28 minutes) to reach the critical height (10 feet above the mezzanine level). This result is expected, as Scenario 2 involves the largest fire (30 MW) and no smoke exhaust. When comparing Scenario 2 to Scenario 4, the benefits of smoke control (smoke exhaust) is evident, as the time for the smoke layer to reach the critical height approximately doubles (from 28 to 60 minutes). Comparing Scenario 4 to Scenario 5 shows the benefit of earlier smoke detection and activation of the smoke control system as the time for the smoke layer to reach the critical height increases by approximate 5 minutes (from 55 to 60 minutes).

Table 3 – Summary of Modeling Results

Scenario	Fire Size (MW)	Smoke Control (Y/N)	Beam Detector Directly Above Fire (Y/N)	Time to Critical Height (min)
1	15	N	N	60
2	30	N	N	28
3	15	Y	N	>60
4	30	Y	N	55
5	30	Y	Y	60

9. CONCLUSIONS

The FDS modeling analysis predicts, for large fire sizes of 15 MW and 30 MW, the smoke layer interface will remain above the established critical height (10 feet above the mezzanine level) for approximately 30 minutes when no smoke control is employed. Furthermore, the 15 MW design fire, which is considered a conservative but realistic fuel load, maintains the smoke layer above critical height for 60 minutes without activation of the smoke control system. Depending upon the time required to evacuate the Great Hall, these results may demonstrate that the smoke control system is not necessary.

Further analysis will be necessary in order to determine Great Hall evacuation time. Should further analysis demonstrate that the smoke control system is not necessary for maintaining a safe egress environment, there may be a potential for discussion regarding the easing of code-required system inspections and testing procedures.

10. REFERENCES

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