Life Safety Report
Adams 14 High School
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Statement of Disclaimer

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Executive Summary

The purpose of this Life Safety Report (LSR) is to provide a prescriptive based analysis of the Adam County High School based on the existing codes that the building was constructed under. This will included exterior and interior building construction, fire protection systems, and egress requirements. Additionally, this report will evaluate selected performance based design scenarios for the High School. Findings and recommendations to the performance based design scenarios, along with any deficiencies, are noted at the conclusion of the report.

The prescriptive analysis of this report will focus on the International Building Code requirements with emphasis on Chapters 4 – 10. Other chapters will also be referenced, but not as in depth. These requirements are outlined within this report, will details on how the project building will be meeting or exceeding the code minimums.

The performance based analysis of this report will focus on two Life Safety Code design scenarios, and their respective impact on the occupants and building. While the Life Safety Code was not used when the building was designed and built, it was used during the performance based analysis as a guideline and reference related to the scenarios and portions of this degree program.

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INTRODUCTION

Description of Project

This project building is a new high school constructed near the western edge of the Rocky Mountain Arsenal Wildlife Refuge. The building will accommodate roughly 1,600 students plus the teachers and administration employees. The building is being built to provide schooling for the expanding urban development in the area. The building will be split into two stories with a basement, for a total of 292,358 square feet. This was completed in 2009, opening for the school year.

The picture below is a rendering / model of the building to help illustrate the layout and features of the project.

*Picture 1 - Adams County High School Front Entrance*
The floor levels, areas and uses are as follows:

### Table 1 - Floor Areas

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>GROSS FLOOR AREA (SF)</th>
<th>OCCUPANCY DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>14,457</td>
<td>E, STORAGE S-2, ACCESSORY USE</td>
</tr>
<tr>
<td>1</td>
<td>79,812</td>
<td>E, ASSEMBLY A-1,2,4, STORAGE S-2, B, ACCESSORY USE</td>
</tr>
<tr>
<td>2</td>
<td>79,458</td>
<td>E, STORAGE S-2, B, ACCESSORY USE</td>
</tr>
</tbody>
</table>

These are discussed further in the report.

### Project Codes and Standards

The outline and review of the applicable building codes and standards included in this report are:

- International Mechanical Code (IMC) – 2006 Edition
- ASHRAE / IESNA Standard 90.1-1999
- National Fire Protection Association Standards

Although many codes are outlined above, this report is primarily an architectural review of the building and fire code impacts on the project. Mechanical, plumbing and electrical code issues are best addressed with consultants who are experts in those disciplines. This report cannot cover all the detail with the provisions in the code and standard references. The design team should refer to source references for complete details on design issues.

This report will cover the prescriptive code requirements for the project building, and how those are achieved. This will include building areas and heights, structural fire protection, fire-resistive-rated construction, fire protection systems, included fire sprinklers and fire alarm, interior finish requirements and means of egress. This report will also cover performance based design scenarios, including the methods and objectives for the performance design.

The key features of these references are outlined in this report. Detailed compliance with these references will need to be contained in the construction documents and followed by the contractors.
Report Objectives

The purpose of this report is to provide members of the design team a review of applicable code requirements for fire and life safety features of the building. This report will assist members of the design team in coordinating required design features between the design disciplines.

Underlined entries generally identify project specific requirements.

*Italics typically identify defined or special terms in the codes and standards or code references.*

This report should be used in conjunction with the attached plans. The plans, as of this report date, include Life Safety sheets, Fire Alarm sheets and Fire Protection sheets, although at this time not all may be submitted. The Life Safety sheets provide occupancy classifications, occupant load and egress width provisions, and also information on the separation assemblies (smoke barriers, fire partitions, etc.). The Fire Alarm sheets provide information on the NFPA 72 required initiating and notification devices; finally the Fire Protection sheets provide information on the water based suppression system installed in the Project building.

This Project building was designed and built under the prescriptively based International set of Codes. Performance objectives pertaining to the CalPoly FPE program are identified and outlined in later sections of the report.
EXTERIOR FIRE PROTECTION AND LIFE-SAFETY REQUIREMENTS

Site Plan and Fire Service Features

Fire Department Access

Access Roads

IFC section 503 contains the requirements for fire apparatus access roads. Access roads are required for every building and must extend within 150-feet of every portion of the exterior wall of the first-story of the building. The access is measured by a route approved by the fire department around the exterior of the building. The Fire Code Official is authorized to require additional access roads based upon the potential for impairment of a single road by vehicle congestion, terrain, climatic conditions or other factors that could limit access.

Fire apparatus access road specifications and dimensions for the Project are as follows:

- The minimum unobstructed vertical clearance is 13 feet, 6 inches.
- Minimum unobstructed road width is 20-feet
- The surface of access roads must provide all-weather driving capabilities and support the load of the fire apparatus. The surface may be asphalt, concrete or other approved surface.
- Turning radii on access roads shall be determined by the fire code official.
- Dead ends on access roads are limited to 150 feet in length. Lengths greater than this require an approved area for turning fire apparatus.
- The grade is limited to a slope that shall be determined by the fire code official.

The Adams 14 High School site was an empty lot prior to construction. Access to the building complies with the above requirements and is compliant and adequate.
**Building / Roof Access**

*IFC section 504* contains requirements for access to building openings and roofs. Per 504.1 Exterior doors and openings shall be maintained readily accessible for emergency access by the fire department. Per 504.2 if the door is rendered non-functional, signage must be affixed stating “THIS DOOR BLOCKED”.

IBC Section 1009.11.1 provides that for unoccupied roofs, the access hatch shall be permitted to be a roof hatch or trap door not less than 16 square feet in area with a minimum dimension of 2 feet.

There are seven (7) roof access points on the Project building. All are compliant with the requirements set forth in the IFC and IBC.

**Address Identification**

Approved building numbers, letters or approved building identification must be accompanied by a building address. These numbers and letters shall contrast with their background. Address numbers shall be Arabic numbers or alphabetical letters. Numbers shall be a minimum of 6-inches high with a minimum stroke width of 0.75- inches.

Address identification will be located on the west side of the building directly visible from Quebec Parkway.
**Key Boxes**

Key boxes, also referred to by the product name “Knox Box®,” are required for the building. Locations shall be coordinated with the fire department.

*Key boxes will be installed at the front entrance to the building and at the fire entry room.*

**Fire Service Elevator Keys**

Standardized fire service elevator keys shall comply with all of the following:

- All fire service elevator keys within the jurisdiction shall be uniform and specific for the jurisdiction. Keys shall be cut to a uniform key code.
- Fire service elevator keys shall be a patent protected design to prevent unauthorized duplication.
- Fire service elevator keys shall be factory restricted by the manufacturer to prevent the unauthorized distribution of key blanks. No uncut key blanks shall be permitted to leave the factory.
- Fire service elevator keys subject to these rules shall be engraved with the words “DO NOT DUPLICATE.”

Access to standardized fire service elevator keys shall be restricted to the following:

- Elevator owners or their authorized agents
- Elevator contractors
- Elevator Inspectors of the jurisdiction
- Fire Code Officials of the jurisdiction.
- The fire department and other emergency response agencies designated by the Fire Code Official

**Fire Flow, Fire Hydrants and Firefighting Service Connections**

**Fire Flow**

*Appendix B of the 2006 IFC* contains the hydrant flow requirements for buildings. These tables are based on the type of construction and area of the building. For a Type II-B building, and having a total building area of 292,358 sq. ft (this is also considered the *fire flow calculation area*), the required fire flow is 8,000 GPM for 4 hours. The Fire Code official is allowed to increase or decrease the fire flow for the building.

This project has taken a 50% reduction in fire flow requirements. This is allowed per Section B105.1 of the Fire Code, and was allowed per the local AHJ and Department of Fire Prevention and Control. Therefore, the total minimum fire flow for the building is 4,000 GPM for 4 hours, giving a required water supply of at least 960,000 gallons. The municipal water supply is adequate enough to supply the required pressure and flow to the building. More information on this can be found later in the report.
**Fire Hydrants**

IFC Appendix C contains the requirements for fire hydrant locations and distributions. Fire hydrants are required to have a 20 psi residual pressure at their required fire flow and have a 3-foot clear circumference area around the fire hydrant. For a required fire flow of 4,000 GPM, Table C105.1 indicates a minimum of four fire hydrants are required for this building. To be considered, existing hydrants must provide a minimum of 1,500 gallons per minute at 20 pounds per square inch (residual pressure). There are no existing fire hydrants on the property lot.

The project will be required to have at least 4 fire hydrants installed on the site. The hydrant spacing is required to be a maximum of 350 feet between hydrants, and the furthest point from a hydrant to any point on the street is 210 feet. It appears that the project site is compliant in this regard.

**Fire Protection Water Supply**

IFC Section 508 requires that the water supply for the Project building be capable and adequate of supplying the required fire flow to the premise. Only one supply is required for this building.

From review of the civil plans, it appears that the building is served by one fire main connecting to the city water supply on Quebec Street.

**Fire Sprinkler and Standpipe Fire Department Connections**

Fire department connections are required to supplement building fire sprinkler and standpipe systems. Section 905.3.4 Stages requires that standpipes are installed where the stage is greater than 1,000 sq. ft. This standpipe system shall be a Class III wet system with 1.5” and 2.5” connection on each side of the stage. No other locations in the building are required to have a standpipe connection.

The stage area in the building is 2,263 sq ft, and will have a single 2.5” hose connection with 1.5” reducing cap installed on each side of the stage. The Fire Department Connection will be installed outside of the fire entry room, with an appropriate audio/visual notification device above the FDC.
BUILDING EGRESS AND LIFE SAFETY FEATURES

Occupancy Classification and Separation

Occupancy Classification

The IBC indicates the following occupancy classifications for areas in the building:

<table>
<thead>
<tr>
<th>USE OF THE SPACE/AREA</th>
<th>OCCUPANCY CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational</td>
<td>E</td>
</tr>
<tr>
<td>Offices / Admin</td>
<td>B</td>
</tr>
<tr>
<td>Theatre / stage</td>
<td>A-1</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>A-2</td>
</tr>
<tr>
<td>Fitness / gym / pool areas</td>
<td>A-4</td>
</tr>
<tr>
<td>Storage Areas</td>
<td>S-2</td>
</tr>
<tr>
<td>Mechanical / Electrical Equipment Rooms</td>
<td>Incidental Use Areas, See Table 508.2</td>
</tr>
<tr>
<td>Small Storage Rooms/Closets</td>
<td>Incidental Use Areas, See Table 508.2</td>
</tr>
</tbody>
</table>

Occupancy Separations

This building is designed according to the non-separated occupancy provisions. The building does not need to comply with occupancy separations in IBC Table 508.4, but will comply with IBC section 508.3.

508.3 Non-separated occupancies. Buildings or portions of buildings that comply with the provisions of this section shall be considered as non-separated occupancies.

508.3.1 Occupancy Classification. Non-separated occupancies shall be individually classified in accordance with section 302.1. The requirements of this code shall apply to each portion of the building based on the occupancy classification of that space except that the most restrictive applicable provisions of section 403 and Chapter 9 shall apply to the building or portion thereof in which the non-separated occupancies are located.

508.3.2 Allowable building area and height. The allowable building area and height of the building or portion thereof shall be based upon the most restrictive allowances for the occupancy groups under consideration for the type of construction of the building in accordance with section 503.1.

508.3.3 Separation. No separation is required between non-separated occupancies.

The primary occupancy types of E, B, A is limited in the available number of stories and allowable areas. Further in the report these stories and allowable area limitations are discussed.
Incidental Use Areas:

Areas that are incidental to the main area shall be classified according to the main occupancy. Separation of these incidental areas shall be by means of a fire (rated) barrier according to IBC Table 508.2. Other special separation requirements exist in other code sections, such as for fire command centers and generator rooms. Where IBC Table 508.2 permits protection by an automatic fire-extinguishing system without fire barriers, the walls enclosing the incidental use area must simply resist the passage of smoke (i.e., a non-rated, smoke partition). Separation requirements of IBC Table 508.2 are:

<table>
<thead>
<tr>
<th>ROOM OR AREA</th>
<th>SEPARATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace room where any piece of equipment is over 400,000 Btu per hour input</td>
<td>1-hour fire barrier or provide automatic fire-extinguishing system</td>
</tr>
<tr>
<td>Rooms with any boiler over 15 psi and 10 horsepower</td>
<td>1-hour fire barrier or provide automatic fire-extinguishing system</td>
</tr>
<tr>
<td>Refrigerant machinery rooms</td>
<td>1-hour fire barrier or provide automatic fire-extinguishing system</td>
</tr>
<tr>
<td>Waste and linen collection rooms over 100 square feet</td>
<td>1-hour fire barrier or provide automatic fire-extinguishing system</td>
</tr>
<tr>
<td>Laboratories and vocational shops, not classified as Group H</td>
<td>1 hour fire barrier or provide automatic fire-extinguishing system</td>
</tr>
</tbody>
</table>

Since the building will have a fire sprinkler system, the IBC would require the following fire resistive separation for the following incidental use areas/rooms in this project:

- Non-rated smoke partitions for electrical and mechanical rooms
- Non-rated smoke partitions for waste and recycling collection rooms

There are other fire-resistive separations required, based upon special uses, rooms or hazards. Such areas that will exist in this building are as follows:

- Per IBC section 410.5.2, rooms directly adjacent to the stage shall be separated from each other by fire barriers with not less than a 1-hour fire-resistance rating.

Special Occupancies

IBC Chapter 4 provides special detailed requirements for certain occupancies or conditions. Special topics specific to this building include:

- Stages and Platforms – Section 410

Detailed requirements for these special occupancies are included later in this report.
Building Heights, Areas and Construction Type

Building Height and Area

The IBC provides requirements for building heights and allowable areas in Chapter 5. These requirements are based on the occupancy classification and construction type. The Adams 14 High School is a mixed-use occupancy. IBC Table 503 designates the building height and allowable area per floor based on the occupancy type present and the required type of construction.

IBC Table 503 allows buildings of Type II-B construction to have an allowable area limitation of 23,500 square feet per “building area” and a height of 2 stories.

Type II construction described as a type of construction in which the building elements listed in the IBC Table 601 are of noncombustible materials, except as permitted in IBC section 603 and elsewhere in the code. These requirements are described further in the report.

IBC section 506 allows for area modifications to increase the allowable area for the building. These increases are used in the Project building and are described below:

The increase is given by the Equation 5-1:

\[ A_a = \left( A_t + \left[ A_t \times I_f \right] + \left[ A_t \times I_s \right] \right) \]

Where:  
\( A_a = \) Allowable area per story  
\( A_t = \) Tabular area per story in accordance with Table 503  
\( I_f = \) Area increase factor due to frontage as calculated in accordance with Section 506.2.  
\( I_s = \) Area increase factor due to sprinkler protection as calculated in accordance with Section 506.3.

IBC section 506.2 allows for Frontage increases when the building has more than 25 percent of its perimeter on a public way or open space having a minimum width of 20 feet. This increase shall be determined by the following:

\[ I_f = \frac{[F/P - 0.25]W}{30} \]

Where:  
\( I_f = \) Area increase due to frontage  
\( F = \) Building perimeter that fronts on a public way or open space having 20 feet open minimum width.  
\( P = \) Perimeter of entire building.  
\( W = \) Width of public way or open space in accordance with Section 506.2.1.

Since the Project building is built on an undeveloped site, with no existing structures on the land, or remotely close, this factor can be calculated out to 0.75 for each area.

IBC section 506.3 allows for Automatic sprinkler increases when the building is equipped throughout by an approved automatic sprinkler system installed in accordance with Section 903.3.1.1. This Project building meets this requirement, and those systems and their requirements are discussed further in this report. The sprinkler increase, \( I_s \), is permitted to be 2 (200%) for buildings with more than one story above grade.
Each area of the building can now be calculated with these increases:

**Area 1 – Main Gym area – Group A-4 Assembly Occupancy**
Allowable area: 9,500 sq ft.
Allowable area: $9,500 + [9,500 \times 0.75] + [9,500 \times 2] = 35,625$ square feet
Actual area: 15,770 square feet

**Area 2 – Locker, wrestling, etc. – Group E Educational Occupancy**
Allowable area: 14,500 sq ft.
Allowable area: $14,500 + [14,500 \times 0.75] + [14,500 \times 2] = 54,375$ square feet
Actual area: 27,910 square feet

**Area 3 – Auxiliary Gym / Pool – Group A-4 Assembly Occupancy**
Allowable area: 9,500 sq ft.
Allowable area: $9,500 + [9,500 \times 0.75] + [9,500 \times 2] = 35,625$ square feet
Actual area: 26,422 square feet

**Area 4 – Admin. / Media/Cafeteria Area – Group B, E, A-4 Occupancy**
Allowable area: 9,500 sq ft.
Allowable area: $9,500 + [9,500 \times 0.75] + [9,500 \times 2] = 35,625$ square feet
Actual area: 15,770 square feet

**Area 5 – North Classrooms – Group E Educational Occupancy**
Allowable area: 14,500 sq ft.
Allowable area: $14,500 + [14,500 \times 0.75] + [14,500 \times 2] = 54,375$ square feet
Actual area: 15,770 square feet

**Area 6 – South Classrooms – Group E Educational Occupancy**
Allowable area: 14,500 sq ft.
Allowable area: $14,500 + [14,500 \times 0.75] + [14,500 \times 2] = 54,375$ square feet
Actual area: 15,770 square feet

**Area 7 – Career / Technical Education – Group E Assembly Occupancy**
Allowable area: 14,500 sq ft.
Allowable area: $14,500 + [14,500 \times 0.75] + [14,500 \times 2] = 54,375$ square feet
Actual area: 15,770 square feet

**Construction Type and Fire Resistance Requirements**

*IBC section 601* gives the required fire resistance rating for building elements. These requirements are outlined in the table below. Type II construction is defined as “Type I and II construction are those types of construction in which the building elements listed in Table 601 are of noncombustible materials, except those permitted in Section 603 and elsewhere in this code.”

*IBC Table 601* provides the required fire resistance ratings for the structure. The following table summarizes the requirements for this building.
### Table 4 - Structural Element Ratings

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary structural frame</td>
<td>0-hours</td>
</tr>
<tr>
<td>Columns supporting floors</td>
<td>0-hours</td>
</tr>
<tr>
<td>All other</td>
<td></td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>0-hours</td>
</tr>
<tr>
<td>Interior</td>
<td>0-hours</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0-hour</td>
</tr>
<tr>
<td>Floor construction and secondary members</td>
<td>0-hours</td>
</tr>
<tr>
<td>Roof construction and secondary members</td>
<td>0-hour*</td>
</tr>
</tbody>
</table>

*Note: Fire protection of structural members, framing and decking for the roof hall shall not be required where the roof construction is 20-feet or more above any floor immediately below.

### Use of Combustible Material in Type II Construction

Section 603.1 outlines the materials that are permitted to be used in Type II construction. An overview of these materials is outlined below:

- Thermal and acoustical insulation, other than foam plastics, having a flame spread index of not more than 25.
  - Exceptions:
    - Insulation placed between two layers of noncombustible materials without an intervening airspace shall be allowed to have a flame spread index of not more than 100.
    - Insulation installed between a finished floor and solid decking without intervening airspace shall be allowed to have a flame spread index of not more than 200.
- Foam plastics in accordance with *IBC Chapter 26*.
- Roof coverings that have an A, B or C classification.
- Interior floor finish and floor covering materials installed in accordance with *IBC section 804*.
- Millwork such as doors, door frames, window sashes and frames.
- Interior wall and ceiling finishes installed in accordance with *IBC sections 801 and 803*.
- Trim installed in accordance with *IBC section 806*.
- Where not installed over 15 feet (4572 mm) above grade, show windows, nailing or furring strips and wooden bulkheads below show windows, including their frames, aprons and show cases.
- Finish flooring installed in accordance with *IBC section 805*.
- Partitions dividing portions of stores, offices or similar places occupied by one tenant only and that do 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 up to 6 feet (1829 mm) in height.
- Stages and platforms constructed in accordance with *IBC sections 410.3 and 410.4*, respectively.
- Combustible exterior wall coverings, balconies and similar projections and bay or oriel windows in accordance with *IBC Chapter 14*.
- Blocking such as for handrails, millwork, cabinets and window and door frames.
• Light-transmitting plastics as permitted by *IBC Chapter 26*.
• Mastics and caulking materials applied to provide flexible seals between components of *exterior wall construction*.
• Exterior plastic veneer installed in accordance with *IBC section 2605.2*.
• Nailing or furring strips as permitted by *IBC section 803.4*.
• Heavy timber as permitted by Note c to *IBC Table 601 and sections 602.4.7 and 1406.3*.
• Aggregates, component materials and admixtures as permitted by *IBC section 703.2.2*.
• Sprayed fire-resistant materials and intumescent and mastic fire-resistant coatings, determined on the basis of fire-resistance tests in accordance with *IBC section 703.2* and installed in accordance with *sections 1704.12 and 1704.13*, respectively.
• Materials used to protect penetrations in fire-resistance-rated assemblies in accordance with *IBC section 713*.
• Materials used to protect joints in fire-resistance-rated assemblies in accordance with *IBC section 714*.
• Materials permitted in the concealed spaces of buildings of Types I & II construction in accordance with *IBC section 717.5*.
• Materials exposed within plenums complying with *section 602 of the International Mechanical Code*.

  • **Fire-retardant-treated wood** shall be permitted in:
    - Nonbearing partitions where the required fire resistance rating is 2-hours or less.
    - Nonbearing exterior walls where no fire rating is required.
    - Roof construction, including girders, trusses, framing and decking.
      • Exception: In buildings of Type IA construction exceeding two stories above grade plan, fire-retardant-treated wood is not permitted in roof construction when the vertical distance from the upper floor to the roof is less than 20-feet.
• Also, non-metallic ducts (according to the *IMC*), combustible piping (according to the *IPC*), and wiring methods using combustible wiring, raceways, etc. (according to the *NEC*) are permitted.

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**Fire Resistive Construction**

**General Fire Resistive Construction**

*Chapter 7 of the IBC* has the requirements for fire resistive construction and different types of fire-rated walls and assemblies including:

- Exterior Walls
- Fire walls
- Fire barriers
- Shaft Enclosures
- Fire partitions
- Smoke Barriers
- Smoke Partitions
- Horizontal (floor, ceiling and roof) assemblies
- Penetrations of fire-resistive-rated (FRR) assemblies
- Joints between FRR assemblies
• FRR requirements of structural members
• Opening protection
• Duct and air transfer openings
• Concealed spaces

Many of these requirements will not apply to the Project building, but are listed here to give supplemental information or code justification regarding the construction type of the building. Items that pertain to the project building will be explained; items that are not included within the project building are not explained in depth in this report. Due to the building being of Type II non-rated construction, these items are particularly important for stopping or slowing the transfer of fire and smoke; therefore these components are highly detailed in the following sections.

Fire Resistance for Structural Members

The fire-resistance-rating (FRR) of structural members is based on two things; the type of construction requirements (IBC Table 601) and the FRR of the assemblies supported. The FRR shall not be less than the ratings required for the FRR assemblies supported by the structural members except for fire barriers, fire partitions, smoke barriers and horizontal assemblies that follow IBC sections 707.5, 709.4, 710.4, and 712.4 respectively.

IBC section 704.2 states that, where columns are required to be fire-resistance rated, they shall be individually encased with protection on all sides, including connections to other structural members. Columns require a FRR along the entire column length including its connections to beams and girders. This protection needs to be continuous from the top of the floor through the ceiling space to the top of the column.

**Figure 1 - IBC 704.2 Column Protection**

*IBC section 704.3 requires individual encasement, and not membrane protection when a primary structural frame member (other than columns) required having a FRR supports:*

- More than two floors;
- One floor and a roof;
- A load-bearing wall; or
- A non-load bearing wall more than two stories high.

*IBC section 704.4 pertains to secondary structural members.* These can be protected by individual encasement protection, by the FRR horizontal membrane, or a combination of both.
The required thickness and construction of FRR assemblies enclosing trusses shall be based on tests or approved calculations showing the assembly has the required FFR.

The edges of lugs, brackets, rivets and bolt heads attached to structural members are permitted to extend within 1 inch of the surface of the fire protection. Pipes, wires, conduits, ducts, or other service facilities shall not be embedded in the required fire protective covering of a structural member that is required to be individually encased.

Where the fire protective covering of a structural member is subject to impact damage (vehicle, moving merchandise, etc.), the protective covering needs to be protected by a corner guard or a substantial jacket of metal or other non-combustible material to a minimum of 5 feet above the finished floor (IBC section 704.9).

Load-bearing structural elements located within the exterior wall or outside a building or structure need to be have the highest FRR according to:

- Table 601 for the type of building element based on the type of construction;
- Table 601 for exterior bearing walls based on the type of construction; or
- Table 602 for exterior walls based on the fire separation distance.

Where sprayed fire resistant materials (SFRM) are used to meet fire resistance rating requirements, they shall be installed in accordance with IBC section 704.13 and in strict conformance with the manufacturer’s installation instructions.

**Fire Resistive Components**

**Exterior Walls – Fire Resistance Rating**

Section 704 of the IBC has the requirements for exterior walls. The location of exterior walls in relationship to site property lines and other buildings on the site determine the fire resistive rating requirements for exterior walls. IBC section 702 defines the fire separation distance (FSD) as the distance measured from the building face to one of the following:

- Closest interior lot line
- Centerline of a street, alley or public way
• Imaginary line between two buildings on the property. The exception to section 704.3 allows buildings on the same lot to be considered one building (and omit exterior wall ratings) if the aggregate area of the buildings is within the limits of Table/Chapter 5 requirements. Where buildings contain separate occupancies or different types of construction, the area will be based on the most restrictive occupancy or type of construction.

The $FSD$ is measured at right angles from the face of the exterior wall. The following diagrams show examples of the three types of fire separation distances from the IBC Commentary:

![Figure from the IBC Commentary:](image)

*Figure 3 - 702.1(6) Fire Separation Distance Measured to an Interior Lot Line*

![Figure from the IBC Commentary:](image)

*Figure 4 - 703.1(7) Fire Separation Distance Measured to the Centerline of a Street*
Figure 5 - 702.1(8) Fire Separation Distance Measured to an Imaginary Line Between Two Buildings on the Same Lot

*FSD: FIRE SEPARATION DISTANCE

**Figure 5 - 702.1(8) Fire Separation Distance Measured to an Imaginary Line Between Two Buildings on the Same Lot**

*IBC Table 602* provides the requirements for exterior wall fire-resistant ratings based on the FSD of the exterior wall. Based on the Type II-B construction and Group E occupancy of this building, the exterior wall ratings based on the fire separation distances will be as follows:

- FSD < 5 feet: 1-hour fire-resistant rated
- 5 feet ≤ FSD < 10 feet: 1-hour fire-resistant rated
- 10 feet ≤ FSD < 30 feet: 0-hour fire-resistant rated
- FSD ≥ 30 feet: 0-hour fire-resistant rated

Note: Load-bearing exterior walls must be rated based on the maximum rating of *IBC Table 601 and 602*.

Since this project is constructed as a single building on the lot, the exterior walls of the building facing each other may be non-rated. Exterior walls facing the streets or lot lines must comply with this section. Based upon a review of the building site plan, the fire separation distance will exceed 30-feet on all sides of the building. According to *IBC Table 602*, the exterior walls will not require a fire resistance rating.

Cornices, eave overhangs, exterior balconies and similar cantilevered or wall hung projections extending beyond the floor area shall conform to the requirements of. Exterior egress balconies and exterior exit *stairways* shall also comply with sections 1014.5 and 1023.1, respectively. The distance from exterior edges of projections to the closest interior lot line or to an imaginary line between two buildings on the property shall not be less than four feet. *Projections from walls of Type I or II construction shall be of noncombustible materials or combustible materials as allowed by Sections 1406.3 and 1406.4.*

*IBC section 1406.3* lists the requirements for balconies and other similar projections of combustible construction. Other than fire-retardant-treated wood, combustible construction needs to afford the same *FRR* required by *Table 601* for floor construction or comply with Type IV construction. The aggregate length of the projections/balconies cannot exceed 50% of the building perimeter on each floor. The exceptions to these requirements are:
1. Fire-retardant-treated wood is permitted for balconies, porches, decks and exterior stairways that are not used as required exits for Type I and II construction that are 3 stories or less in height.
2. Un-treated wood is permitted for pickets and rails, or similar guardrail devices that are limited to 42 inches in height.
3. Where sprinkler protection is extended to the balcony areas, the aggregate length of the balcony on each floor shall not be limited.

*IBC section 704.8* and the corresponding table give the maximum area of unprotected (non-rated) and protected (rated) exterior wall openings in exterior walls that may or may not be required to be fire-resistive rated based on the FSD. Equation 7-2 gives the total area of openings where both unprotected and protected openings are present:

\[
\frac{A}{a} + \frac{Au}{au} \leq 1.0
\]

*IBC section 704.9* allows (other than Group H-1/H-2/H-3) buildings equipped throughout with a NFPA 13 fire sprinkler system to have unprotected (non-rated) openings based on the percentage listed in *IBC Table 704.8* for the greater percentage of protected (rated) openings. *IBC section 704.10* allows (other than Group H) buildings to have unlimited, unprotected openings of the 1st story of exterior walls facing a street having a FSD > 15 feet, or facing an unoccupied space (on the same lot or dedicated for public use) not less than 30 feet in width and accessed from a street by a posted fire lane. The FSD for this building is greater than 30-feet, therefore opening protection is not required and unprotected openings are not limited.

*IBC section 705.8.5* does not require vertical separation of openings if one of the following is true:

- Buildings that are 3 stories or less in height.
- Buildings equipped with a NFPA 13 fire sprinkler system.

Since this building is less than 3 stories and will have a NFPA 13 fire sprinkler system, vertical separation of openings is not required.

*Section 704.10* requires vertical exposure protection for buildings on the same lot, for every opening that is less than 15 feet vertically above the roof of an adjoining building or adjacent structure that is within a horizontal FSD of 15 feet of the wall in which the opening is located. This lot will contain only a single building; therefore these provisions do not apply.

*IBC section 704.11* gives the parapet requirements for exterior walls. Parapets are rarely required. There are 6 exceptions to allow the omission of parapets:

1. Exterior walls not required to be fire-resistive rated *(FRR)* according to *Table 602* because of fire separation distances (i.e., non-rated exterior walls).
2. The building has an area of not more than 1,000 square feet on any floor.
3. Walls that terminate at roofs of not less than 2-hour fire-resistance-rated construction or where the roof, including the deck and supporting construction, is constructed entirely of non-combustible materials.
4. One-hour *(FRR)* exterior walls that terminate at the underside of roof sheathing, deck or slab (there are four conditions listed in the IBC).
5. Group R-2 and R-3 occupancies with a Class C roof covering (there are two conditions listed in the 2006 IBC).

6. Where the wall is permitted to have at least 25% of the exterior wall areas containing unprotected openings based on FSD in section 704.8 (FSD > 15 feet for a non-sprinklered building and FSD > 5 feet for a sprinklered building, section 704.8.1).

Section 1406 of the IBC lists the requirements for the use of limited amounts of combustible materials on the exterior sides of exterior walls. Based on the FSD of the wall to the property line:

- FSD ≤ 5 feet: Combustible exterior wall coverings cannot exhibit “sustained flaming” according to NFPA 268.
- FSD > 5 feet: Table 1406.2.1.2 lists the tolerable level of incident radiant heat flux that a wall covering may be exposed to without any sustained flaming according to NFPA 268.

Architectural trim that uses combustible materials is limited by IBC section 1406.2.2 to buildings with Type I, II, III and IV construction up to 3 stories or 40 feet in height above the grade plane. Fire-retardant-treated wood shall not exceed 10% of an exterior wall surface where the FSD is less than 5 feet or less. Architectural trim that exceeds 40 feet above grade plane needs to be non-combustible and secured by non-combustible means.

**Fire barriers**

Fire barriers are used for the following separations (horizontal & vertical):

- Shafts, mechanical and egress (section 707.4)
- Exit enclosures (section 1020.1)
- Exit passageways (section 1021.1)
- Horizontal exits (section 1022.1)
- Atriums (section 404.5)
- Incidental use areas (Table 508.2)
- Occupancy separations (Table 508.3.3)
- Separation of different, single-use fire areas (according to Table 706.3.9)

It is important to recognize that when an area requires fire barrier separation, that the separation occurs around the vertical (floor/ceiling) and horizontal (wall) assemblies separating the area from other uses.

IBC section 706.5 pertaining to continuity of fire barriers requires fire barrier walls to extend from the top of the floor/ceiling assembly below to the underside of the floor of roof slab/deck above and be securely attached. Fire barriers must be continuous through concealed spaces (e.g., spaces above suspended ceilings). Horizontal fire barriers (floors, ceilings and roofs) need to comply with IBC section 711. These will be described further later in the horizontal assembly section.

The Project Building will have fire-barriers used as separation walls. The attached floorplans show the location of the fire-barriers.

Figure from the IBC Commentary:
Supporting construction (e.g., structural frame, etc.) for fire barrier walls shall be protected to afford the same protection as the FRR of the fire barrier supported. Hollow vertical spaces within fire barriers need to be fire-stopped at every floor level.

IBC section 706.6 does not allow the maximum aggregate width of openings at any floor level to exceed 25% of the length of the wall, or exceed 156 square feet maximum area of a single opening in a fire barrier. Openings in fire barriers need to comply with IBC section 715 and openings into exit enclosures need to comply with IBC section 1020.1.1 and 1021.4. The five exceptions are:

1. When the building or adjoining fire areas are equipped throughout with NFPA 13 fire sprinkler systems, openings are not limited to 156 square feet.
2. The opening is not limited to 156 square feet or 25% aggregate width when the opening protection is a fire door into an exit enclosure.
3. Openings are not limited to 156 square feet or an aggregate width of 25% of the length of the wall, where the opening protective assembly has been tested with ASTM E 119 or UL 263 and has a FRR not less than the fire barrier wall.
4. Fire windows permitted in atrium separation walls shall not be limited to a maximum aggregate width of 25% of the length of the wall.
5. Openings are not limited to 156 square feet or 25% aggregate width when the opening protective is a fire door assembly separating an exit enclosure from an exit passageway.

Penetrations into exit enclosures or exit passageways are allowed only when permitted by IBC section 1020.1.2 or 1021.5 respectively, and only those required for exit doors, equipment & ductwork necessary for independent pressurization, sprinkler & standpipe piping and electrical raceways for fire department communication and electrical raceway serving the exit passageway and terminating at a steel box (maximum 16 square inches). Duct penetrations must be properly protected as required by IBC 716.

Shaft Enclosures

IBC section 707 applies to shaft enclosures. Shaft enclosures are constructed with fire barriers as described above. IBC section 707.4 requires shaft enclosures to have a FRR of at least:

- 2-hours where connecting 4 or more stories
• 1-hour where connecting 3 or less stories

Figure from the IBC Commentary:

*Figure 7 - 707.4 Vertical Shafts - Fire Resistance Rating*

The number of stories connected by the shaft shall include basements, but not mezzanines. Shaft enclosures need to be constructed as fire barriers. Shaft enclosures need to have a FRR of not less than the FRR floor/ceiling assembly they penetrate, but not more than 2-hours. The Project building will only have a “shaft” at the sole elevator serving the basement, first and second floors. This shaft will be of 1-hour fire-resistant construction, due to the connection of only 3 stories. Shafts that connect 4 or more stories are required to have a FRR of 2-hrs.

There are multiple exceptions to the requirements for shaft enclosures. The common exceptions that may apply to this project are:

1. A shaft enclosure is not required in a building equipped throughout with an automatic sprinkler system in accordance with IFC section 903.3.1.1 for an escalator opening or stairway that is not a portion of the means of egress protected according to Item 1.1 or 1.2.
   1.1. Where the area of the floor opening between stories does not exceed twice the horizontal projected area of the escalator or stairway and the opening is protected by a draft curtain and closely spaced sprinklers in accordance with NFPA 13. In other than Groups B and M, this application is limited to openings that do not connect more than four stories.
   1.2. Where the opening is protected by approved power-operated automatic shutters at every penetrated floor. The shutters shall be of noncombustible construction and have a fire-resistance rating of not less than 1.5 hours. The shutter shall be so constructed as to close immediately upon the actuation of a smoke detector installed in accordance with IFC section 907.11 and shall completely shut off the well opening. Escalators shall cease operation when the shutter begins to close. The shutter shall operate at a speed of not more than 30 feet per minute (152.4 mm/s) and shall be equipped with a sensitive leading edge to arrest its progress where in contact with any obstacle, and to continue its progress on release there from.

2. A shaft enclosure is not required for penetrations by pipe, tube, conduit, wire, cable and vents protected in accordance with IBC section 712.4.
3. A shaft enclosure is not required for penetrations by ducts protected in accordance with IBC section 712.4. Grease ducts shall be protected in accordance with the International Mechanical Code.

4. In other than Group H occupancies, a shaft enclosure is not required for floor openings complying with the provisions for atriums in IBC section 404.

5. In other than Groups I-2 and I-3, a shaft enclosure is not required for a floor opening or an air transfer opening that complies with the following:
   - Does not connect more than two stories.
   - Is not part of the required means of egress system.
   - Is not concealed within the construction of a wall or a floor/ceiling assembly.
   - Is not open to a corridor in Group I and R occupancies.
   - Is not open to a corridor on non-sprinklered floors in any occupancy.
   - Is separated from floor openings and air transfer openings serving other floors by construction conforming to required shaft enclosures.
   - Is limited to the same smoke compartment.

6. A shaft enclosure shall not be required for floor openings created by unenclosed stairs or ramps in accordance with Exception 3 or 4 in section 1016.1.

7. Where permitted by other sections of this code.

IBC section 707.5 pertaining to continuity of shaft enclosures, requires shaft enclosure walls to extend from the top of the floor/ceiling assembly below to the underside of the floor of roof slab/deck above and be securely attached. Shaft enclosures must be continuous through concealed spaces (e.g., spaces above suspended ceilings). Supporting construction (e.g., structural frame, etc.) for shaft enclosure walls shall be protected to afford the same protection as the FRR of the fire barrier supported. Hollow vertical spaces within fire barriers need to be fire-stopped at every floor level.

IBC section 707.6 for exterior walls of shaft enclosures allows exterior walls of shafts to be FRR according to exterior wall requirements and based on fire separation distances (FSD). It is possible to have a non-rated, exterior wall on a shaft. An important exception to this allowance would be for exterior ramps and stairways in IBC section 1023.6.

Openings into the shaft shall be protected according to IBC section 715 (outlined below in the opening protection section) and shall be self-closing or automatic-closing by smoke detection.

Shafts that do not extend to the bottom of the building need to comply with IBC section 707.11. Shafts that do not extend to the underside of the roof need to be enclosed at the top with construction with the same FRR as the top-most floor, but not less than the FRR required for the shaft enclosure.
Figures from the IBC Commentary:

**Figure 8 - 707.11(1) Vertical Shafts - Bottom Enclosures**

**Figure 9 - 707.11(2) Bottom Enclosure Room**

**Figure 10 - 707.11(3) Vertical Shafts - Bottom Enclosure with Draft-Stopping**

**Figure 11 - 707.11(4) Vertical Shafts - Bottom Enclosure with Sprinklers**
Elevator and dumbwaiter shafts shall comply with *IBC section 707 and Chapter 30*.

**Fire partitions**

*Fire partitions* are regulated by *IBC section 708*. *Fire partitions* might be used for the following separations (horizontal & vertical) applicable to this building.

- Fire resistive rated corridors as required by *IBC section 1017.1*.
- Elevator lobby separation as required by *IBC section 707.14.1*.

It is important to realize that when an area requires *fire partition* separation, that the separation occurs around the *vertical (floor/ceiling)* and horizontal (wall) assemblies separating the area from other uses. *IBC section 708.4*, pertaining to continuity of *fire partitions*, requires *fire partition* walls to extend from the top of the floor/ceiling assembly below to the underside of the floor of roof slab/deck above or the *FRR* floor/ceiling or roof/ceiling assembly above and be securely attached. If the *fire partitions* are not continuous to the deck, and where constructed with combustible construction, the space between the ceiling and the deck above shall be fire-blocked or draft-stopped according to *IBC sections 717.2 and 717.3*. The supporting construction must also be protected to afford the required fire-resistance rating of the wall supported.
There are 6 exceptions to the fire partition continuity requirements, which can be found in IBC section 708.4; however none of the exceptions are required for the Project building.

This building does not require FRR corridors per IBC section 1017, and elevator lobbies may utilize smoke partitions as described above, therefore the design of this building does not contain any fire partitions.

Smoke Partitions

IBC section 710 pertains to smoke partitions. These walls are utilized at the following locations:

- Science areas, storage over 100 sq. ft.
- Incidental use separation where IBC 508.2.5 permits automatic fire sprinklers in lieu of fire resistive separation.

IBC section 710.3 states smoke partitions are not required to have a FRR unless required to somewhere else in the IBC.

IBC section 710.4 requires continuity of smoke partitions to form an effective membrane, continuous from floor-to-underside-of-floor/roof-deck above or to the underside-of-the-ceiling above (where the ceiling membrane is constructed to limit the transfer of smoke).

IBC section 710.5 requires window openings to be sealed to resist the free passage of smoke or be automatic-closing upon detection of smoke. Door openings in smoke partitions must comply with the following:

- Louvers are not allowed in smoke partition doors.
- Where required elsewhere in the IBC, smoke partition doors shall be tested according to UL 1784 with an artificial bottom seal installed across the full width of the bottom of the door assembly. The air leakage rate shall not exceed 3.0 CFM per square foot of door opening at 0.10 inches of water column for the ambient air test.
- Where required elsewhere in the IBC, smoke partition doors shall be self-closing or automatic-closing according to IBC section 715.4.7.3.

Penetrations and joints in smoke partitions need to resist the free passage of smoke. Air transfer openings in smoke partitions need to have a smoke damper according to IBC section 716.3.2 (except where an alteration is needed for an approved smoke control system).

This building will have smoke partitions in the following locations:

- Storage rooms
- Science / chemistry rooms
- Photo lab
- Mechanical / electrical equipment rooms.
- Armory in basement

Horizontal (floor, ceiling and roof) assemblies

Horizontal assemblies (floor/ceiling or roof/ceiling) are regulated by IBC section 711. They must have a FRR as required for one of the following:

- The type of construction of the building;
• Occupancy separation requirements; or
• Fire area separations (*fire barriers*).

**The type of construction for the Project building will not require any horizontal barriers to be implemented.**

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**Openings and Penetrations of Fire-Resistance-Rated (FRR) Assemblies**

**Penetrations**

*IBC section 712* of the IBC applies to through-penetrations and membrane-penetrations. Penetrations into or through fire resistance rated assemblies must comply with this section. Where sleeves are used to protect penetrations, they shall be securely fastened and protected according to *IBC section 712.2*.

Penetrations into or through *fire walls, fire barriers, smoke barriers and fire partitions* shall comply with one of the following:

- The penetrations are installed as tested in an approved *FRR* assembly.
- Through-penetrations are protected by an approved penetration fire-stop system, installed as tested according to ASTM E 814 or UL 1479, with a minimum positive pressure differential of 0.01 inch of water column and an F-rating of not less than the *FRR* required for the wall penetrated.

Exceptions to these two through-penetration requirements are for steel, ferrous or copper pipes of steel conduits, with the annular space between the penetrating item and the *FRR* wall protected by one of the following methods:

- In concrete or masonry walls where the penetrating items are a maximum 6-inch nominal diameter and the opening is a maximum 144 square inches, concrete, grout or mortar is permitted where installed the full thickness of the wall or a thickness required to maintain a *FRR*; or
- The material used to fill the annular space needs to prevent the passage of flame and hot gases sufficient to ignite cotton waste where subject to ASTM E 119 fire conditions under a minimum positive pressure differential of 0.01 inch of water column pressure at the location of the penetration for the *FRR* rating time period of the construction being penetrated.

*Figure from the IBC Commentary:*
Membrane-penetrations need to also comply with the requirements for through-penetration requirements listed above. Where walls and partitions are required to have a minimum of 1-hour FRR construction, recessed fixtures need to be installed in a manner that does not reduce the required FRR.

Figure from the IBC Commentary:
The exceptions to membrane-penetration requirements are:

1. Membrane penetrations of 2-hour maximum fire-resistance-rated walls and partitions by steel electrical boxes that do not exceed 16 square inches in area provided the aggregate area of the openings through the membrane does not exceed 100 square inches in any 100 square feet of wall area. The annular space between the wall membrane and the box shall not exceed 1/8 inch. Such boxes on opposite sides of the wall or partition shall be separated by one of the following:

   a. By a horizontal distance of not less than 24 inches where the wall or partition is constructed with individual non-communicating stud cavities;
   b. By a horizontal distance of not less than the depth of the wall cavity where the wall cavity is filled with cellulose loose-fill, Rockwool or slag mineral wool insulation;
   c. By solid fire blocking in accordance with section 717.2.1;
   d. By protecting both outlet boxes with listed putty pads; or
   e. By other listed materials and methods.
2. **Membrane penetrations by listed** electrical boxes of any material provided such boxes have been tested for use in fire-resistance-rated assemblies and are installed in accordance with the instructions included in the listing. The *annular space* between the wall membrane and the box shall not exceed 1/8 inch unless listed otherwise.
   a. Such boxes on opposite sides of the wall or partition shall be separated by one of the following:
      b. By the horizontal distance specified in the listing of the electrical boxes;
      c. By solid fire blocking in accordance with section 717.2.1;
      d. By protecting both boxes with listed putty pads; or
      e. By other listed materials and methods.

3. Membrane penetrations by electrical boxes of any size or type, which have been listed as part of a wall opening protective material system for use in fire-resistance-rated assemblies and are installed in accordance with the instructions included in the listing.

4. Membrane penetrations by boxes other than electrical boxes, provided such penetrating items and the annular space between the wall membrane and the box, are protected by an approved membrane penetration fire-stop system installed as tested in accordance with ASTM E 814 or UL 1479, with a minimum positive pressure differential of 0.01 inch (2.49 Pa) of water, and shall have an F and T rating of not less than the required fire-resistance rating of the wall penetrated and be installed in accordance with their listing.

5. The *annular space* created by the penetration of an automatic sprinkler, provided it is covered by a metal escutcheon plate.

Figure from the IBC Commentary:

![Figure 20 - 712.3.2(2) Exception to Annular Space Protection](image)

Duct and air transfer openings without fire dampers need to comply with the requirements above. Non-combustible penetrating items cannot be connected to combustible items beyond the point of fire-stopping, unless it can be demonstrated the FRR integrity of the wall will be maintained.
Penetrations of a floor, floor/ceiling assembly, or the ceiling membrane of a roof/ceiling assembly need to comply with one of the following:

- The penetrations are installed as tested in an approved FRR horizontal assembly.
- Through-penetrations are protected by an approved penetration fire-stop system installed as tested according to ASTM E 814 or UL 1479, with a minimum positive pressure differential of 0.01 inch of water column and an F-rating and T-rating of not less than 1-hour, but not less than the FRR required for the floor penetrated. (Exception: Floor penetrations contained and located within the cavity of a wall do not require a T-rating.)

Exceptions to these two through-penetration requirements are for the FRR horizontal assembly to be protected by one of the three following methods:

- Penetrations by steel, ferrous or copper conduits, pipes, tubes, vents, or concrete or masonry items through a single FRR floor assembly where the annular space is protected with materials that prevent the passage of flame and hot gases sufficient to ignite cotton waste where subject to ASTM E 119 or UL 263 fire conditions under a minimum positive pressure differential of 0.01 inch of water column pressure at the location of the penetration for the FRR rating time period of the construction being penetrated. Penetration items with a maximum 6-inch nominal diameter are not limited to the penetration of a single FRR floor assembly if the area of the penetration does not exceed 144 square inches in any 100 square feet of floor area.

- Penetrations in a single concrete floor by steel, ferrous or copper conduits, pipes, tubes and vents with a maximum 6-inch nominal diameter provided concrete, grout or mortar is installed the full thickness of the floor or the thickness required to maintain the FRR. The penetrating item with a maximum 6-inch nominal diameter shall not be limited to the penetration of a single concrete floor provided that the area of the penetration does not exceed 144 square inches.

- Electrical outlet boxes of any material are allowed provided they are tested for use in FRR assemblies and installed according with the tested assembly.

Figure from the IBC Commentary:

*Figure 21 - 714.4.1(1) Noncombustible Penetration of a Fire-Resistance-Rated Floor/Ceiling Assembly*
Figure 22 - 712.4.1(2) Examples of Annular Space Protection with Sleeves

Penetrations of a membrane, that are part of a horizontal assembly, need to also comply with the requirements for through-penetration requirements listed above. Where floor/ceiling assemblies are required to have FRR construction, recessed fixtures shall be installed in a manner that does not reduce the required FRR.

The five exceptions to membrane penetration requirements are:

1. **Membrane penetrations** by steel, ferrous or copper conduits, pipes, tubes or vents, or concrete or masonry items where the annular space is protected either in accordance with section 712.4.1.1 or to prevent the free passage of flame and the products of combustion. The aggregate area of the openings through the membrane shall not exceed 100 square inches in any 100 square feet of ceiling area in assemblies tested without penetrations.

2. Ceiling membrane penetrations of maximum 2-hour horizontal assemblies by steel electrical boxes that do not exceed 16 square inches in area, provided the aggregate area of such penetrations does not exceed 100 square inches in any 100 square feet of ceiling area, and the annular space between the ceiling membrane and the box does not exceed 1/8 inch.

3. **Membrane penetrations** by electrical boxes of any size or type, which have been listed as part of an opening protective material system for use in horizontal assemblies and are installed in accordance with the instructions included in the listing.

4. **Membrane penetrations** by listed electrical boxes of any material provided such boxes have been tested for use in fire-resistance-rated assemblies and are installed in accordance with the instructions included in the listing. The annular space between the ceiling membrane and the box shall not exceed 1/8-inch unless listed otherwise.
5. The *annular space* created by the penetration of a fire sprinkler, provided it is covered by a metal escutcheon plate.

Figures from the IBC Commentary:

*Figure 23 - 712.4.1.2(1) Protection of Penetrations Through Ceiling Membrane of Fire-Resistance-Rated Assembly*

*Figure 24 - 712.4.1.2(2) Noncombustible Penetrations of Ceiling Membrane of a Fire-Resistance-Rated Floor/Ceiling Assembly*

Non-fire-resistance-rated horizontal assemblies require penetrations to be rated as follows:

- Non-combustible penetrating items that connect not more than 3 stories are permitted provided the annular space is filled with an approved non-combustible material to resist the free passage of flame and the products of combustion.

Figure from the IBC Commentary:
Figure 25 - 712.4.2.1 Noncombustible Pipe Penetrations of Non-Fire-Resistance-Rated Assemblies

- Penetrating items that connect not more than 2 stories are permitted provided the annular space is filled with an approved non-combustible material to resist the free passage of flame and the products of combustion.

- Penetrations of horizontal assemblies by ducts and air transfer openings that are not required to have dampers shall comply with section 712. Duct and air transfer openings that are protected with dampers shall comply with section 716.

- Non-combustible penetrating items cannot be connected to combustible items beyond the point of fire-stopping, unless it can be demonstrated the FRR integrity of the horizontal assembly will be maintained.

- Floor fire doors used to protect openings in FRR floors shall be tested in the horizontal position according to ASTM E 119 and be rated not less than the assembly being penetrated and labeled by an approved agency.

**Joints between FRR Assemblies**

Joints installed between fire-resistive rated (FRR) walls, floor or floor/ceiling assemblies, and roofs or roof/ceiling assemblies shall be protected by an approved fire-resistant joint system designed to resist the passage of fire for the time period not less than the required FRR of the wall, floor or roof.

Figure from the IBC Commentary:
Fire-resistant joint systems are not required for the joints at the following locations applicable to this project:

- Floors where the joint is protected by a shaft enclosure (IBC section 707).
- Walls that are permitted to have unprotected openings.
- Roofs where openings are permitted.
- Control joints not exceeding a maximum width of 0.625 (5/8) inch and tested according to ASTM E 119.

Fire-resistant joint systems shall be tested according to ASTM E 1966 or UL 2079 with additional requirements for non-symmetrical walls in IBC section 713.3. Exterior curtain wall/floor intersections are covered in IBC section 713.4. Where FRR floor/ceiling assemblies are required, voids at the intersection with exterior curtain walls need to be sealed to prevent interior fire spread. The joint material/system needs to prevent the passage of flames and hot gasses sufficient to ignite cotton waste when subject to ASTM E 119 conditions with a minimum positive pressure differential of 0.01 inch of water column for the FRR time period of the floor assembly. Height and FRR requirements of curtain wall spandrels need to comply with IBC section 704.9.

**Opening Protection**

IBC Section 715 has the requirements for opening protectives. General requirements for fire doors & shutters are given in IBC Table 715.4 based on the type of FRR assembly as follows:

**Table 5 - Opening Protection**

<table>
<thead>
<tr>
<th>TYPE OF ASSEMBLY</th>
<th>REQUIRED ASSEMBLY RATING (Hours)</th>
<th>MINIMUM FIRE DOOR OR SHUTTER ASSEMBLY RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Fire walls &amp; fire barriers</em> having a required fire-resistance rating greater than 1-hour</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1-1/2</td>
</tr>
<tr>
<td></td>
<td>1-1/2</td>
<td>1-1/2</td>
</tr>
</tbody>
</table>
**Fire barriers** having a required fire-resistance rating of 1-hour for **Shaft Exit enclosures** and **Exit Passageway Walls**

<table>
<thead>
<tr>
<th></th>
<th>REQUIRED ASSEMBLY RATING (Hours)</th>
<th>MINIMUM FIRE WINDOW ASSEMBLY RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire barriers</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other fire barriers</td>
<td>1</td>
<td>3/4</td>
</tr>
</tbody>
</table>

**Fire partitions**

<table>
<thead>
<tr>
<th></th>
<th>REQUIRED ASSEMBLY RATING (Hours)</th>
<th>MINIMUM FIRE WINDOW ASSEMBLY RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor Walls</td>
<td>1</td>
<td>1/3</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1/3</td>
</tr>
<tr>
<td>Other Fire partitions</td>
<td>1</td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1/3</td>
</tr>
</tbody>
</table>

**Exterior Walls**

<table>
<thead>
<tr>
<th></th>
<th>REQUIRED ASSEMBLY RATING (Hours)</th>
<th>MINIMUM FIRE WINDOW ASSEMBLY RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>1-1/2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1-1/2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3/4</td>
</tr>
</tbody>
</table>

**Smoke Barriers**

<table>
<thead>
<tr>
<th></th>
<th>REQUIRED ASSEMBLY RATING (Hours)</th>
<th>MINIMUM FIRE WINDOW ASSEMBLY RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1/3</td>
</tr>
</tbody>
</table>

*IBC section 715.4* has testing and other requirements for doors. Fire doors and shutters shall also comply with NFPA 80.

*IBC section 715.4.7.3* has the requirements for smoke-activated doors. Automatic-closing fire doors installed in the following locations shall be automatically-closing by the actuation of smoke detectors installed according to *IFC section 907.10* or by loss of power to the smoke detector or the door hold-open device. The door must start closing within 10 seconds of smoke detector activation. These doors include:

- Doors installed across a corridor.
- Doors that protect openings in exits or corridors required to be of fire-resistance-rated construction.
- Doors that protect openings in walls that are capable of resisting the passage of smoke in accordance with *IBC section 508.2.2.1*.
- Doors installed in smoke barriers in accordance with *IBC section 709.5*.
- Doors installed in fire partitions in accordance with *IBC section 708.6*.
- Doors installed in a fire wall in accordance with *IBC section 705.8*.
- Doors installed in shaft enclosures in accordance with *IBC section 707.7*.
- Doors installed in smoke partitions in accordance with *IBC section 710.5.3*.

*IBC section 715.5* gives the requirements for fire windows and fire protection rated glazing, including specifications and testing requirements. **Fire rated glazing must also comply with NFPA 80.** *IBC Table 715.5* gives the fire-resistance-rating based on the type of FRR assembly as follows:

<table>
<thead>
<tr>
<th>TYPE OF ASSEMBLY</th>
<th>REQUIRED ASSEMBLY RATING (Hours)</th>
<th>MINIMUM FIRE WINDOW ASSEMBLY RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior Walls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire walls</td>
<td>All</td>
<td>Not permitted^a</td>
</tr>
<tr>
<td>Fire barriers</td>
<td>&gt; 1</td>
<td>Not permitted^a</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3/4</td>
</tr>
<tr>
<td>Fire partitions</td>
<td>1</td>
<td>3/4</td>
</tr>
</tbody>
</table>
Non-rated exterior walls can have non-rated openings. Where exterior walls are rated, the exception to *IBC section 705.8* for the protected (rated) openings allows for unprotected (non-rated) openings when the opening assembly is protected by an approved water curtain using approved sprinklers and the building has a fire sprinkler system throughout according to NFPA 13.

**Duct and Air Transfer Openings**

*IBC section 716* has the requirements for duct and air transfer openings. Fire and/or smoke dampers are required in different locations by the *IBC*. Fire dampers need to comply with UL 555 requirements. Smoke dampers need to comply with UL 555S requirements. Combination fire/smoke dampers need to comply with UL 555 and UL 555S requirements. Ceiling radiation dampers need to comply with UL 555C.

Fire dampers need to have the following FRR according to *IBC Table 716.3.1* for fire damper ratings:

<table>
<thead>
<tr>
<th>TYPE OF PENETRATION</th>
<th>MINIMUM DAMPER RATING (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 3-hour fire-resistance rated assemblies</td>
<td>1-1/2</td>
</tr>
<tr>
<td>3-hour or greater fire-resistance rated assemblies</td>
<td>3</td>
</tr>
</tbody>
</table>

*IBC section 716.3.1.1* gives the fire damper actuation temperatures:

- 50°F above the normal operating temperature in the duct system but not less than 160°F,
- Not more than 286°F in *smoke control systems* complying with Section 909.

Where combination fire/smoke dampers are used, the damper shall have the minimum fire protection rating specified by *IBC Table 716.3.1* for the type of penetration plus a minimum Class II leakage rating and minimum elevated temperature rating of 250°F.

The following table provides a basic summary of the areas where *fire dampers, smoke dampers, and combination fire/smoke dampers* are required.

<table>
<thead>
<tr>
<th>Location</th>
<th>Fire Damper</th>
<th>Smoke Damper</th>
<th>Combination Fire/Smoke</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Walls</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire walls</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal exits</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Fire barriers</td>
<td>X</td>
<td>Exceptions 716.5.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>---</td>
<td>--------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaft Enclosures</td>
<td>X</td>
<td>Exceptions 716.5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fire partitions</strong></td>
<td>X</td>
<td>Exceptions 716.5.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRR Corridors</td>
<td>X</td>
<td>Exceptions 716.5.4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke Barriers</td>
<td>X</td>
<td>Exceptions 716.5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke Partitions</td>
<td>X</td>
<td>Exceptions 716.5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal Assemblies</td>
<td>X</td>
<td>Exceptions 716.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 27 - 716.5 Fire Dampers in Rated Wall**

**Figure 28 - 716.5.3.1(1) - Fire Dampers - Exception 1**
Figures from the IBC Commentary:

*Figure 29 - 716.5.4(1) Fire Dampers - Exception 1*

*Figure 30 - 716.5.4(2) Fire Dampers - Exception 2*

**IBC section 716.3.2.1** gives the required *smoke damper* actuation methods.

- Where a *smoke damper* is installed within a duct, a smoke detector shall be installed in the duct within 5 feet of the *damper* with no air outlets or inlets between the detector and the *damper*. The detector shall be *listed* for the air velocity, temperature and humidity anticipated at the point where it is installed. Other than in mechanical smoke control systems, *dampers* shall be closed upon fan shutdown where local smoke detectors require a minimum velocity to operate.
• Where a smoke damper is installed above smoke barrier doors in a smoke barrier, a spot-type detector listed for releasing service shall be installed on either side of the smoke barrier door opening.
• Where a smoke damper is installed within an air transfer opening in a wall, a spot-type detector listed for releasing service shall be installed within 5 feet horizontally of the damper.
• Where a smoke damper is installed in a corridor wall or ceiling, the damper shall be permitted to be controlled by a smoke detection system installed in the corridor.
• Where a total-coverage smoke detector system is provided within areas served by a heating, ventilation and air-conditioning (HVAC) system, smoke dampers shall be permitted to be controlled by the smoke detection system.

**IBC section 716.4** requires fire and smoke dampers to have a means of access large enough to permit inspection and maintenance. These access points must be permanently labeled with at least ½-inch letters reading “SMOKE DAMPER”, “FIRE/SMOKE DAMPER” or “FIRE DAMPER” as appropriate.

**IBC section 716.6** requires penetrations by ducts and air transfer openings of horizontal assemblies to be protected as shaft openings according to **IBC section 707** or by methods in **IBC section 716.6**.

**Through penetrations of Horizontal Assemblies:** For occupancies (other than Groups I-2 and I-3), section 716.6.1 allows a duct and air transfer opening system constructed according to the IMC and penetrating a FRR floor/ceiling assembly that connects not more than 2 stories, to be constructed without shaft enclosure protection provided a fire damper is installed at the floor line.

There is an exception to this section that allows a duct to penetrate 3 floors (or less) without a fire damper at each floor if five conditions are met (26-gauge, open into only one dwelling unit & continuous from the unit to the exterior of the building, use of a ceiling radiant damper, etc.).

Figures from the IBC Commentary:

*Figure 31 - 716.6.1(1) Air Duct Penetration of a Fire-Resistance-Rated Floor/Ceiling Assembly*
Membrane penetrations of Horizontal Assemblies: Ceiling radiation dampers are allowed to be installed at the ceiling line when a duct or transfer grill penetrates the ceiling of a floor/ceiling or roof/ceiling assembly. Ceiling radiation dampers need to be listed according to UL 555C. There is an exception at the end of IBC section 716.6.2 for exhaust ducts complying with IBC section 712.4.1.2.

Non-fire-resistance rated assemblies: IBC section 716.6.3 allows a duct system constructed according to the IMC, penetrating a non-fire-resistance-rated assembly and connecting not more than 2 stories, to be constructed without shaft enclosure protection provided the annular space between the assembly and the penetrating duct is filled with an approved non-combustible material to resist free passage of flame and smoke.

A duct system constructed according to the IMC, penetrating a non-fire-resistance-rated assemblies and connecting not more than 3 stories, can be constructed without shaft enclosure protection provided the annular space between the assembly and the penetrating duct is filled with an approved non-combustible material to resist free passage of flame and smoke, and a fire damper is installed at each floor level.

Figures from the IBC Commentary:
Flexible ducts and air connectors are not allowed to pass through any FRR assemblies (horizontal floor/ceiling or walls).

**Concealed Spaces**

*IBC section 717* pertains to concealed spaces. Most of the requirements discuss combustible concealed spaces. This building is of Type II-B construction; therefore combustible concealed spaces are not permitted.
IBC section 717.5 applies to combustible material in concealed spaces in Type I or II (non-combustible) construction. Generally, combustible material is not permitted in concealed spaces of Type I or II constructed buildings, with the following exceptions:

1. Combustible materials in accordance with IBC section 603 (allowable combustible materials in Type 1 & 2 construction).
2. Combustible materials exposed within plenums complying with section 602 of the International Mechanical Code.
3. Class A interior finish materials classified in accordance with section 803.
4. Combustible piping within partitions or shaft enclosures installed in accordance with the provisions of this code.
5. Combustible piping within concealed ceiling spaces installed in accordance with the International Mechanical Code and the International Plumbing Code.
6. Combustible insulation and covering on pipe and tubing, installed in concealed spaces other than plenums, complying with section 719.7.

Interior Finish

Interior finishes need to comply with Chapter 8 of the IBC. IBC Table 803.5 gives interior wall and ceiling flame spread finish requirements by occupancy type for the room or area. As a general rule, the installation of a fire sprinkler system usually allows for a one “class” reduction for the IBC Table 803.5 requirements.

Interior finishes are classified according to the ASTM E 84 standard according to three classes for ASTM E 84 flame spread and smoke developed indices:

- **Class A**: flame spread 0-25, smoke developed 0-450.
- **Class B**: flame spread 26-75, smoke developed 0-450.
- **Class C**: flame spread 76-200, smoke developed 0-450.

IBC section 803.2 allows for materials (other than textiles) to be tested according NFPA 286 as an alternate to the ASTM E 84 listed criteria.

Materials having a thickness less than 0.036-inch applied directly to the surface of walls or ceilings do not have to be tested.

IBC section 803.3 requires interior finish material to be securely fastened so the material will not become detached when subject to room temperatures of 200°F (93°C) for 30 minutes or less.

Section 803.4 requires interior finish materials applied to fire-resistive rated (FRR) assemblies (walls/ceilings) or non-combustible construction to be directly attached to such construction or with furring strips not exceeding 1.75-inches applied directly against such surfaces. The intervening spaces between the furring strips shall be filled with inorganic or non-combustible materials; filled with Class-A materials, or be fire blocked at not more than 8-foot intervals in both directions.

Figure from the IBC Commentary:
If walls are set-out or ceilings are dropped more than the 1.75-inches listed above, *IBC section 803.4.2* requires the use of Class A finish materials or other alternatives. An **interior wall or ceiling finish material that is not more than ¼-inch thick** is required to be applied directly against non-combustible backing, except for Class A materials or material subjected to qualifying tests. Thin (less than ¼-inch) interior finish material can delaminate from its backing material and develop a much faster flame spread speed than indicated by a flame spread rating for a thicker sample.

All *Smoke Developed Index* ratings must be between 0 and 450 according to ASTM E 84. The determination of *Flame Spread Index* ratings from *Table 803.5* depends on:

- Group/Occupancy classification of the area from Chapter 3.
- Whether or not the area is protected by a NFPA 13 or 13R fire sprinkler system.
- What the area is used for:

  1. Vertical exits & exit passageways (most restrictive).
  2. Exit access corridors & other exit ways.
  3. Rooms & enclosed spaces
An excerpt from IBC Table 803.5 showing the applicable criteria for this Project is shown below:

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Exit enclosures and exit passageways (a)</th>
<th>Corridors</th>
<th>Rooms and enclosed spaces (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 &amp; A-2</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>A-4</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>B &amp; E</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

Notes: (a) Class C interior finish materials shall be permitted for wainscoting or paneling of not more than 1,000 SF of applied surface area in the grade lobby where applied directly to a noncombustible base or over furring strips applied to a noncombustible base and fire blocked as required by section 803.11.1.

(c) Requirements for rooms and enclosed spaces shall be based upon spaces enclosed by partitions. Where a fire-resistance rating is required for structural elements, the enclosing partitions shall extend from the floor to the ceiling. Partitions that do not comply with this shall be considered enclosing spaces and the rooms or spaces on both sides shall be considered one. In determining the applicable requirement for rooms and enclosed spaces, the specific occupancy thereof shall be the governing factor regardless of the group classification of the building.

(l) Applies when spaces are protection by an automatic fire sprinkler system installed in accordance with NFPA 13.

IBC section 803.6 has requirements for textiles including materials having woven or non-woven, napped, tufted, looped or similar surfaces. Textiles (including carpeting) on walls or ceilings need to have a Class A flame spread rating and be protected by a NFPA 13 or 13R fire sprinkler system. Expanded vinyl wall covering shall also comply with this section.

Thermal and acoustical insulation needs to comply with section 719. Exposed insulation materials are required to have a Class-A flame spread index rating (0-25) and a smoke developed index rating of 0-450.

Acoustical ceiling systems need to comply with IBC section 803 and comply with the manufacturer’s installation requirements and ASTM C 635 or ASTM C 636.

IBC section 804 has the requirements for interior floor finishes. Interior floor finishes are classified as Class I or Class II according to NFPA 253 test criteria. Class I materials are tested with a higher heat exposure than Class II materials. Class II floor finish materials may be used in exit enclosures, exit passageways and corridors for Group A, B, E, and S occupancies. Since the building is sprinklered, these areas could also utilize other, non-classified materials that comply with the DOC FF-1 “pill test” (CPSC 16 CFR, Part 1630).

Decorative materials (IBC section 806) such as curtains, draperies, hangings and other decorative materials suspended from walls or ceilings need to be non-combustible or flame resistant according to IBC section 806.1 or NFPA 701, with the limitations:

- Non-combustible decorative material is not limited.
• Flame-resistant decorative material cannot exceed 10% of the aggregate area of walls or ceilings (except, 50% for Group A auditoriums with an entire building NFPA 13 fire sprinkler system).

Foam plastics used as interior trim need to comply with IBC section 2604.2. Pyroxylin plastics are prohibited in Group A occupancies. Section 806.5 requires interior trim material to have a Class C flame spread index rating and not exceed 10% of the aggregate wall or ceiling area where it is located.

**Means of Egress**

**General Means of Egress Requirements**

There are some general egress concepts to keep in mind that apply to most buildings and there are some specific egress requirements that apply to this project:

A means of egress system is comprised of three basic components.

• **Exit access**: Exit access is the portion of the egress system that leads from any occupied portion of a building to an exit. This includes all the unprotected spaces of the building where an occupant would be exposed to fire or smoke in the event of a fire. The concept of “travel distance” only applies to travel through the unprotected exit access area before the occupant reaches a protected exit enclosure.

Figure from the IBC Commentary:

![Figure 36 - 1002.1(3) Exit Access](image)

- **Exit**: The portion of the means of egress which is separated from other interior spaces (exit access) of the building by fire-resistance rated (FRR) construction and opening protection, or by an exterior wall (exterior exit) to provide a protected (from smoke/fire) path of egress travel between the exit access and the exit discharge.

Figure from the IBC Commentary:
Figure 37 - 1002.1(2) Exit

- **Exit discharge**: The portion of the means of egress which is between the termination of the (protected) exit and the public way (outside area, street).

Figure from the IBC Commentary:

![Exit discharge diagram]

Figure 38 - 1002.1(4) Exit Discharge

The means of egress system for the building needs to be evaluated for all three components. Means of egress systems must be continuous (uninterrupted) to the public way and the required width of a means of egress system cannot be diminished along the path of egress travel.

Changes in elevation of less than 12-inches generally require the use of sloped surfaces. Where the slope is greater than 1:20 (5%), a ramp complying with IBC section 1010 is required. Where the elevation difference is 6-inches or less, the ramp can have either handrails or floor finish materials that contrast with adjacent floor finish materials. Walking surfaces of the means of egress must have a slip resistant surface and be securely attached.

**Occupant Loads**
IBC Table 1004.1.1 gives the maximum floor area per occupant, which can also be referred to as the occupant load factor (OLF). The square footage of a room or area is divided by the OLF to determine the calculated occupant load (OL) of the area. The table lists OLF’s in terms of “gross” or “net” Floor Area. These terms are defined as:

- **Floor Area, Gross**: The floor area within the inside perimeter of the exterior walls. This area excludes vents shafts (with no openings) and (interior) courts. This area includes corridors, stairways, closets or any other interior feature. Buildings without exterior walls have a gross floor area equal to the area under horizontal projections of the roof or floor above. Gross area calculations typically apply to Business and Storage use areas.

- **Floor Area, Net**: The actual occupied area of the building excluding unoccupied accessory spaces (corridors, stairways, toilet rooms, mechanical rooms and closets). Net floor area calculations generally apply to spaces with Assembly use areas.

The OLF applied to an area relies on the actual use of the area and not on the occupancy group classification (IBC Chapter 3) of the overall area or building. The following occupant load factors are utilized the Adams 14 building.

<table>
<thead>
<tr>
<th>FUNCTION OF SPACE</th>
<th>FLOOR AREA (SF) PER OCCUPANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly with fixed seats</td>
<td>Use actual seat count or 18” of seating length per person for benches without dividing arms.</td>
</tr>
<tr>
<td>Assembly – Concentrated (chairs only, not fixed)</td>
<td>7 net</td>
</tr>
<tr>
<td>Assembly – Un-concentrated (tables and chairs)</td>
<td>15 net</td>
</tr>
<tr>
<td>Assembly – Standing Space</td>
<td>5 net</td>
</tr>
<tr>
<td>Business Areas</td>
<td>100 gross</td>
</tr>
<tr>
<td>Educational – Classroom Area</td>
<td>20 net</td>
</tr>
<tr>
<td>Educational – Shops and Vocational Areas</td>
<td>50 net</td>
</tr>
<tr>
<td>Exercise Rooms / Locker rooms</td>
<td>50 gross</td>
</tr>
<tr>
<td>Kitchen</td>
<td>200 gross</td>
</tr>
<tr>
<td>Accessory storage, mechanical and electrical</td>
<td>300 gross</td>
</tr>
</tbody>
</table>

The assembly areas of this project are designed with the circulation areas, restrooms and shafts not included in the area for occupant loading as appropriate for a “net” OLF. The reason for this is that occupants in circulation areas are accounted for in other occupied areas. The concept is commonly referred to as “non-simultaneous use”, which means that occupants will either be in the occupied space, or the circulation space, but not both at the same time.

Every room or space used, as an assembly space, needs to have an occupancy load sign posted in a conspicuous location near the main exit or exit access doorways.

Where exits (stairs, exterior exit discharge doors, etc.) serve more than one floor level, only the occupant load of the floor with the greatest population needs to be considered to establish the required exit capacity/width. Egress convergence (adding the populations from different floors) generally must only be considered for the basement and second floor levels when sizing exterior exit discharge doors from stairways. The condition in Figure 1004.5(1) occurs in this building. The capacity of the first floor discharge for stairways for this building must consider the convergence of occupants from the basement and second floor.
Figures from the IBC Commentary:

**Figure 39** - 1004.5(1) Egress Convergence at 1st Story

**Figure 40** - 1004.5(2) Egress Convergence at Intermediate Level
Figure 41 - 1004.5(3) No Egress Convergence

The occupant load of a room or area with fixed seating is based on one of the following:

- The actual number of fixed seats with dividing arms.
- 18 inches of bench width (no dividing arms).
- 24 inches of booth seating width measured at the backrest of the booth seating.

Outdoor areas (yards, patios, courts, etc.) accessible to building occupants require means of egress. If the outdoor area can be used by other people in addition to the occupants of the building, then the means of egress components for the building must be sized to accommodate both occupant loads.

Table 11 - Basement Occupant Loads

<table>
<thead>
<tr>
<th>Basement Occupant Loads (Occupancy)</th>
<th>FLOOR AREA (SF) PER OCCUPANT</th>
<th>Occupant Load Factor</th>
<th>Occupant Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>2,519</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>E</td>
<td>5,359</td>
<td>20</td>
<td>268</td>
</tr>
<tr>
<td>S-2</td>
<td>846</td>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>ACC</td>
<td>5,242</td>
<td>300</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>13,996</td>
<td></td>
<td>341</td>
</tr>
</tbody>
</table>

Table 12 - First Floor Occupant Loads

<table>
<thead>
<tr>
<th>1st Floor Occupant Loads (Occupancy)</th>
<th>FLOOR AREA (SF) PER OCCUPANT</th>
<th>Occupant Load Factor</th>
<th>Occupant Load</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>57,750</td>
<td>20</td>
<td>2,888</td>
<td>Classrooms</td>
</tr>
<tr>
<td>E</td>
<td>60,368</td>
<td>50</td>
<td>1,208</td>
<td>Shop/Vocational</td>
</tr>
<tr>
<td>E</td>
<td>3,859</td>
<td>200</td>
<td>20</td>
<td>Kitchen</td>
</tr>
<tr>
<td>S-2</td>
<td>3,396</td>
<td>300</td>
<td>12</td>
<td>Storage</td>
</tr>
<tr>
<td>A-1</td>
<td>1,772</td>
<td>5N</td>
<td>355</td>
<td>Lobby</td>
</tr>
<tr>
<td>A-1</td>
<td>5,155</td>
<td>50</td>
<td>104</td>
<td>Theatre</td>
</tr>
<tr>
<td>A-1</td>
<td>225’-10”</td>
<td>18”</td>
<td>151</td>
<td>Theatre Seats</td>
</tr>
<tr>
<td>A-1</td>
<td>2,263</td>
<td>15</td>
<td>151</td>
<td>Stage</td>
</tr>
<tr>
<td>B</td>
<td>23,627</td>
<td>100</td>
<td>237</td>
<td>Offices / Admin</td>
</tr>
<tr>
<td>A-2</td>
<td>7,126</td>
<td>15N</td>
<td>476</td>
<td>Cafeteria</td>
</tr>
</tbody>
</table>
Table 13 - Second Floor Occupant Loads

<table>
<thead>
<tr>
<th>2nd Floor Occupant Loads (Occupancy)</th>
<th>FLOOR AREA (SF) PER OCCUPANT</th>
<th>Occupant Load Factor</th>
<th>Occupant Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>46,001</td>
<td>20</td>
<td>2,300</td>
</tr>
<tr>
<td>B</td>
<td>9,398</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>S-2</td>
<td>350</td>
<td>300</td>
<td>2</td>
</tr>
<tr>
<td>ACC</td>
<td>249</td>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>55,998</td>
<td></td>
<td><strong>2,397</strong></td>
</tr>
</tbody>
</table>

Occupant loads are detailed for each individual area on the life safety sheets. Each individual area (i.e., each sheet) for the first floor has each occupant load and required egress component detailed on the sheet. The basement and second floor have the individual areas and the total occupant loading for each floor also detailed on their respective sheets. The occupant loads shown above are for the entire floor area of each level of the building.
**Egress Width and Other Dimensions**

The width (capacity) of egress components is based on the occupant load of the area calculated and width factors given in *IBC section 1005*. When more than one exit is required, the sizing of each exit available is based on the requirement that the loss of a single exit will not reduce the available capacity to less than 50% of the required capacity.

The minimum width is determined using the following factors.

- **Stairways**: 0.3 inches per occupant multiplied by the total number of occupants served.
- **Other Components**: 0.2 inches per occupant multiplied by the total number of occupants served.

Note that these egress components are for the 2009 Edition of the International Building Code. The 2006 IBC, which would be the applicable Project Codes that this building was built under, utilized egress components of 0.2 inches per occupant for stairways and 0.15 inches per occupant for other egress systems. The Project building egress component factors have been selected on the basis of the 2009 due to the nature of the occupants. This takes into account a Performance based egress analysis and timed evacuation, which will be discussed further on in the report.

The capacity required from any story of a building shall be maintained to the termination of the means of egress.

Generally, the *means of egress* must have a minimum ceiling height of 7 feet 6 inches. Protruding objects are permitted to extend below the minimum ceiling height to a minimum clearance of 80-inches or 6-feet, 8-inches. Door closures and stops need to have a minimum headroom clearance of 78-inches or 6-feet, 6-inches.

Horizontal projections into the egress way are generally limited to a maximum of 4-inches when they are between the heights of 27 and 80-inches. However, handrails serving stairs may project up to 4.5 inches. The minimum clear widths for accessible routes required in *IBC section 1104* may not be reduced by projections.

Doors opening into the path of egress travel cannot reduce the required width to less than one-half (1/2) the required width during the course of the swing. When fully opened, the door cannot project more than 7-inches into the required width.

Figure from the IBC Commentary:
Occupant loading, required egress widths and actual egress widths are detailed on the Life Safety drawings.

Means of egress Illumination

Section 1006 outlines that the means of egress (including the exit discharge) needs to be illuminated at all times. The illumination level needs to be at least 1 foot-candle (11 lux) at the floor level.

Means of egress illumination needs to be supplied by the building’s electrical supply. In the event of a power failure, an emergency power system shall automatically illuminate the following areas for at least 90-minutes:

1. Aisles and unenclosed egress stairways in rooms and spaces that require two or more means of egress.
2. Corridors, exit enclosures and exit passageways in buildings required to have two or more exits.
3. Exterior egress components at other than their levels of exit discharge until exit discharge is accomplished for buildings required to have two or more exits.
4. Interior exit discharge elements, as permitted in IBC section 1024.1, in buildings required to have two or more exits.
5. Exterior landings as required by IBC section 1008.1.6 for exit discharge doorways in buildings required to have two or more exits.

Emergency lighting systems need to provide an average of 1 foot-candle and a minimum of 0.1 foot-candle along the path of egress travel along the floor. Lighting levels are permitted to decline to an average of 0.6 foot-candle (6 lux) and a minimum of 0.06 foot-candle (0.6 lux) at the end of the 90-minute time duration). A maximum to minimum illumination uniformity ratio of 40 to 1 shall not be exceeded.

Exit Signs

Exit sign requirements are in IBC section 1011. Exit and exit access doors need to be marked by an approved exit sign readily visible from any direction of travel. The path of egress travel to exits and within exits shall be marked by readily visible exit signs to clearly indicate the direction of egress travel in cases where the path of travel is not immediately visible to the occupants. Intervening means of egress doors within exits shall also be marked with exit signs. The maximum distance between exit signs cannot exceed 100 feet (or the listed visibility distance for the sign if less than 100 feet).

Exit signs are not required in the following locations applicable to this project:

- Rooms or areas that require only one exit.
- Main exterior exit doors that are obviously and clearly identifiable as exits (where approved by the building official).

Illuminated exit signs must be illuminated at all times and provided with an emergency power source with a duration of at least 90 minutes from storage batteries or a generator.
ICC A117.1 tactile signs (both raised lettering and Braille, but not illuminated) stating EXIT are required adjacent to each door to an:

- Egress stairway
- Exit passageway
- Exit discharge doors
- Area of refuge

Exit signs applicable to the Project building are outlined on the attached floorplans sheets. These exit signs are only shown on the exterior egress doors, and are not shown on any interior circulation portions of the building. This is done to show the exit capacity of the doors is adequate for the occupant loading of the building.

**Egress System Components**

**Doors, Gates and Turnstiles**

*Means of egress* doors shall meet the requirements of *IBC section 1008*. *Means of egress* doors shall be readily distinguishable from the adjacent construction and finishes such that the doors are easily recognizable as doors. Doors cannot be concealed by curtains, drapes, decorations, mirrors of other similar materials.

Some door size requirements (with exceptions in *IBC section 1008.1.2*) are:

- Clear openings of doorways are measured between the face of the door and the stop with the door opened at 90 degrees. The minimum clear opening door width is 32 inches (including a door opening with two door leaves, with no mullion).
- The maximum width of swing door leaf is 48-inches.
- The minimum height of doors is 80-inches (6-feet, 8-inches).

Projections are not allowed into the clear opening width for a door lower than 34 inches above the floor. Projections between 34-inches and 80-inches above the floor cannot exceed 4-inches into the clear door opening width. This provision allows for the door hardware to be in the clear opening width.

Figures from the IBC Commentary:
Doors generally have to be side-hinged swinging. There are exceptions to this requirement, but none of them apply to this project. Doors must swing in the direction of egress travel where serving an occupant load of 50 or more persons.

Door opening force requirements (applied to the latch side) are:

- The opening force for the interior-side of swing doors without closures cannot exceed 5 pounds.
- For other side-swinging, sliding and folding door, the door latch must release when subject to a 15-pound force.
- The door shall be set in motion when subject to a 30-pound force.
- The door shall swing to a full-open position when subject to a 15-pound force.

**IBC section 1008.1.3** has requirements for special doors including:

- Revolving doors (*IBC section 1008.1.3.1*), limited to a maximum 50-person capacity.
- Power-operated doors (*IBC section 1008.1.3.2*).
- Horizontal sliding doors (*IBC section 1008.1.3.3*).

A floor or landing shall be provided on each side of a door at equal elevations (maximum variation of ½-inch due to differences in finish materials). Interior landings need to be level and exterior landings can have up to a 2% slope.

**Landings at doors** have the following requirements:

- Must have a **width** not less than the stairway or door (whichever is greater) they serve.
- Doors in the fully opened position cannot reduce the landing width by more than 7 inches.
• When a landing serves an occupant load of 50 or more, doors in any position cannot reduce the landing to less than one-half (½) its required width.
• Landing **length** is measured in the direction of travel and cannot be less than **44 inches**.

Section 1008.1.6 requires **door thresholds** to:
• Not exceed 0.5-inch in height for swinging egress doors
• Be beveled for raised thresholds and floor level changes greater than 0.25-inch at doorways, with a maximum 50% slope (1 unit rise to 2 unit run).

Spacing between two doors in series (as is commonly found in entry vestibules) must be 48-inches plus the width of the door swinging into the space. For a common 36-inch door, this would require 84-inches or 7-feet between the doorways. Since all the main egress doors for the Project building will serve more than 50 occupants, both sets of doors shall swing outward in the direction of egress travel.

Doors must be readily open-able from the egress side without the use of a key or special knowledge or effort. **Accessible door hardware** (handles, pulls, latches, locks, other operating devices) if required in Chapter 11, cannot require tight grasping/pinching or twisting of the wrist to operate. **Door hardware mounting heights** (handles, pulls, latches, locks, other operating devices) shall be between 34 inches and 48 inches above the finished floor. Locks used for only security purposes (and not normal operation) are permitted at any height. The unlatching of any door shall not required more than one operation.

Generally, egress doorways cannot be locked from the egress side. All exit doors shall allow free passage from the egress side. The chapter contains several sections pertaining to special locking arrangements that could be used. For the Project building, there are no access controlled doors that would qualify. The only doors that are access controlled are to permit faculty and staff after-hours entry into the building for administrative or building maintenance services.

**Panic and fire exit hardware** is required (when a latch or locking device is provided) for each door in a *means of egress* from a *Group A and E occupancy* having an occupant load of **50 or more**. Panic hardware is also required in electrical rooms with equipment rated 1,200 amperes or more and over 6-feet wide that contains overcurrent devices, switching devices or control devices. These doors shall swing in the direction of egress travel. The panic/fire hardware requirements are:

• The actuating portion of the releasing device needs to extend at least one-half (½) of the door leaf width.
• The maximum unlatching force allowed is **15 pounds**.
• Panic hardware shall be listed in accordance with UL 305.
• Fire exit hardware (required on fire-rated egress doors) shall also be listed in accordance with UL 10C.

**Gates** serving as a *means of egress* must comply with section 1008.2.

**Turnstiles** are generally not allowed along a *means of egress* path, but are allowed via a detailed exception and limited to a 50-person egress capacity.

**Stairways**
**IBC section 1009** has the requirements of **stairways**. The **width of stairways** relies on the **occupant load** calculated from IBC Table 1004.1, but there is a minimum width of 44-inches. **Stairways** serving an **occupant load of 50 or less** can have a minimum 36-inch width. Other exceptions apply to **spiral stairs** (section 1009.8), and **aisle stairs** (section 1023). It is important to remember, enclosed **stairways** that are considered as **accessible means of egress** (**IBC section 1007.3**) must have a minimum of 48-inches between handrails.

**Stairway headroom clearance** must be a minimum of 80-inches (6-feet, 8-inches) measured vertically at the edge of the stair nosing (continuous above the stairway to the point where the line intersects the landing below, one tread depth beyond the bottom riser), for the full width of the **stairway** and landing. Spiral stairs (**IBC section 1009.8**) are permitted to have a 78-inch headroom clearance.

![Figure 45 - 1009.2 Stairway Headroom Requirements](image)

**Stair treads and risers** have dimension requirements of:

- **Risers**: 4 inches minimum and 7 inches maximum (riser height measured vertically between the leading edges of adjacent treads), with a 0.375-inch (3/8-inch) maximum variation between the tallest and shortest riser heights.

- **Tread depths**: 11 inches minimum (tread depth measured horizontally between the vertical planes of the foremost projection of adjacent treads & at right angles to the treads leading edge), with a 0.375-inch (3/8-inch) maximum variation between the longest and shortest tread depths.

![Figure from the IBC Commentary:](image)
IBC section 1009.3.2 has further detailed requirements on the dimensional uniformity of stairs.

The profile of stairs must be as follows:

- The radius of curvature at the leading edge of the tread cannot be greater than 1/2-inch.
- Beveling of nosings cannot exceed 1/2-inch.
- Risers must be solid and vertical or sloped from the underside of the leading edge of the tread above at an angle not exceeding 30 degrees from vertical.
  - **Exception** - Stairways that are not required to be accessible (IBC section 1007.3) may have open risers that do not permit the passage of a 4-inch diameter sphere.
- The leading edge (nosing's) of treads cannot project more than 1-1/4-inches beyond the tread below and all projections of the leading edges must be a uniform size, including the leading edge of the floor at the top of a flight of stairs.

Figures from the IBC Commentary:

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For SI: 1 inch = 25.4 mm.

**Figure 46 - 1009.3.1 Tread/Riser Dimensions**

**Figure 47 - 1009.3.3(1) Tread/Riser Profile**
There must be a **floor or a stairway landing** at the top and bottom of each **stairway**. The **width of landings** must be at least the **width of the stairway**. The **landing length** (measured in the direction of travel) must equal the width of the stair, but does not have to exceed 48 inches for straight-run **stairways**. (Except Aisle stairs complying with section 1025)

Figure from the IBC Commentary:

![Figure 48 - 1009.4(1) Typical Landing Dimensions Straight-Run Stair](image)

A landing may be any other shape (not square/rectangular), as long as the radial arc of the landing is as wide as the **stairway** (i.e., a 70-inch wide **stairway** could have a round landing with a radius of 70 inches).

The maximum distance between floors without the use of an intermediate landing is **12-feet**. A flight of stairs cannot have a vertical run of stairs greater than **12-feet** without reaching a landing at a floor level or having intermediate landings.

Doors opening into a landing cannot reduce the landing to less than one-half (½) the required width of the stairs. When fully open, the door cannot project more than 7-inches into the landing. Where wheelchair spaces are required on the **stairway** landing in accordance with **IBC 1007.6.1**, the wheelchair space shall not be located in the required width of the landing and doors cannot swing into the wheelchair space.

Figure from the IBC Commentary:

![Figure 49 - 1009.4(4) Door Clearance Requirements in Stairs](image)
**Stairway construction** must comply with the type of construction for the building *(Type II buildings must have non-combustible stairways)*, except wood handrails are permitted for all types of construction. The walking surface of treads and landings shall not slope greater than 1:48 (2%) in any direction and they shall have a solid, securely attached surface. There are other sloping and conditions for outdoor stairs in *IBC section 1009.6.2*.

The walls and soffits within enclosed useable spaces under enclosed and unenclosed *stairways* shall be protected by 1-hour fire resistance rated construction, or the rating of the *stairway* enclosure, whichever is greater. Access to the enclosed shall not be directly from within the stair enclosure.

**Handrails** are generally required on both sides of a *stairway*. It is important to remember the definition of a “*stair*” is one or more risers. A “*stairway*” is one or more flights of stairs with landings. Handrails can be required for single-riser stairs and for *ramps* according to *IBC section 1010.8*. Handrail requirements are discussed further in a later section in this report.

A *stairway* to the roof is required for buildings four or more stories in height above grade. For this Project building, due to the 2 story height, does not require a stairway to the roof. Roof hatches are provided for access to mechanical equipment and have already been discussed in this report.

**Ramps**

*IBC section 1010* has the requirements for *ramps*. A summary of the requirements for *ramps* is:

- **Slope** of *ramps* used as a *means of egress* cannot be greater than a 1:12 pitch (8%). Slope of *ramps* not used as a *means of egress* cannot be greater than a 1:8 pitch (12.5%).

- **Cross-slope** (measured perpendicular to the direction of travel) cannot be steeper than a 1:48 pitch (2%).

- The **maximum rise** for any *ramp* run (between landings) cannot exceed 30-inches.

- The **minimum width** of a *means of egress* *ramp* generally cannot be less than 44-inches (specific requirements are in *IBC section 72 for corridors*). The minimum clear width or the *ramp* and distance between handrails must be at least 36 inches.

- The **minimum headroom clearance** of a *means of egress* *ramp* is 80-inches (6-feet, 8-inches).

- **Projections** into the required *ramp* and landing width are prohibited. Door openings onto a *ramp* landing cannot reduce the clear width to less than 42-inches.

Figure from the IBC Commentary:
Figure 50 - 1010.2 Typical Means of Egress Ramp

- **Ramps** need to have **landings** at the bottom and top of each **ramp**, points of turning, entrances and exits and at doors.

- **Landing slopes** cannot be steeper than a 1:48 pitch (2%).

- **Landing widths** must be as wide as the widest **ramp**. **Landing lengths** must be at least 60-inches.

- Where changes in direction of travel occur at landings between **ramp** runs, the landing needs to be a minimum of 60” x 60”.

- Where doorways are located adjacent to a **ramp** landing, maneuvering clearances required by **ICC A117.1** are permitted to overlap the required landing area.

Figure from the IBC Commentary:
• **Ramp** construction needs to comply with the type of construction of the building (non-combustible for Type I and II construction), although wood handrails are permitted for all types of construction. The surface of ramps must be slip-resistant. Outdoor ramps must not allow water to accumulate on walking surfaces.

• **Handrails** are required on ramps with a rise greater than 6 inches on both sides.

Figure from the IBC Commentary:

![Figure 52 - 1010.8(1) Ramp with Handrail at Wall]

• **Edge protection** must be provided for ramps. This is accomplished either by a barrier (curb, rail, or wall) or extended floor surface.
  - **Curbs** must be a minimum of 4-inches in height.
  - **Barriers** must be constructed to prevent the passage of a 4-inch diameter sphere, for any portion of the ramp within 4 inches of the floor or ground surface.
  - Extended floor surfaces shall extend 12-inches minimum beyond the inside face of a handrail.

Figure from the IBC Commentary:

![Figure 53 - 1010.9.1 Edge Protection]
• Guards are required where required by IBC section 1013 (generally when the ramp/landing surface is greater than 30-inches above the floor or grade surface.

**Handrails**

Handrails are regulated by IBC section 1012. Handrails are required for stairways and ramps.

Handrail heights (measured above stair tread nosings, or finish surface of the ramp slope) must be a minimum of 34-inches and a maximum of 38-inches. **Handrail extensions** must return to a wall, guard or walking surface, or be continuous to the handrail of an adjacent stair flight. Handrails that are not continuous between flights shall extend at least 12-inches beyond the top riser and continue to slope for the depth of one tread beyond the bottom riser.

*Figure 54 - 1012.7(1) Typical Handrail Arrangement*

Figure from the IBC Commentary:
Handrails have requirements for **graspability**

- **Type I handrails** require an outside diameter circular cross-section between 1-1/4 to 2 inches, or a non-circular perimeter dimension between 4 to 6-1/4 inches. The maximum cross-sectional dimension of 2-1/4 inches. Edges must have at least a minimum 0.01-inch radius.
- **Type II handrails** with a perimeter greater than 6-1/4-inches must have a graspable finger recess area on both sides of the profile. Details for such handrails and the finger recess are contained in IBC section 1012.3.2.

Handrail-gripping surfaces must be **continuous** without interruption by newel posts or other obstructions. Handrails cannot rotate within their fittings. **Handrail clearances from the wall** (or outer surface, free from any sharp or abrasive elements) must at least 1-1/2 inches. **Handrail projections into the stairway** cannot exceed 4-1/2 inches.

Per **IBC section 1012.8**, **intermediate handrails** are required for wide **stairways**. Intermediate handrails shall be located in such a manner that all portions of the **stairway** width required for egress capacity are within 30-inches of a handrail. On **monumental stairs**, handrails shall be located along the most direct path of egress travel.

**Guards**

**IBC section 1013** has the requirements for guards. **Guards** are required along open-sided walking surfaces that are located more than 30-inches above the floor or grade below, at any point within 36-inches horizontally to the edge of the open side. Such surfaces include:

- Mezzanines
- Equipment platforms
- Stairs
- Ramps
• Landings
• Glazed sides (not complying with IBC section 1607.7) of stairways/ramps/landings.

Guards are not required at the following locations:
• On the audience side of stages and raised platforms, including steps leading up to the stage and raised platform.
• On raised stage and platform areas, such as runways, ramps and side stages used for entertainment or presentations.
• At vertical openings in the performance area of stages and platforms.
• At elevated walking surfaces appurtenant to stages and platforms for access to and utilization of special lighting or equipment.

There are other exceptions listed, however they are not applicable to the Project building.

Guard heights need to be at least 42-inches, measured vertically above the leading edge of the tread, adjacent walking surface or adjacent seat board. This means stairways must have a separate handrail at a 34-38 inch height that projects from a 42-inch high guard along the open-side of the stairway. The height in assembly seating areas shall be in accordance with Section 1025.14.

Figure from the IBC Commentary:

![Figure 56 - 1013.1 Open-sided Walking Area](image)

Opening limitations for guards require balusters or ornamental patterns to be provided to prevent the passage of a 4-inch sphere between any openings in the guard to the required guard height. There are exceptions to this rule as follows:
• The triangular openings at the open side of a stair, formed by the riser, tread and bottom rail, shall not allow passage of a 6-inch sphere.
• For elevated walkways for access to electrical, mechanical and plumbing equipment, alternating tread devices and Group S areas not open to the public; guards shall not have openings that allow passage of a 21-inch sphere.
• In assembly seating areas, for guard heights up to a height of 26 inches, a 4-inch sphere cannot pass through. For guards in height from 26 inches to 42 inches above the adjacent surface walkway, an 8-inch sphere cannot pass through.

Per IBC 10013.5, guards shall be provided where appliances, equipment, fans, roof hatch openings or other components that require service are located within 10-feet of a roof edge or open side of a walking surface located more than 30-inches above the floor, roof or grade below. The guard shall be constructed to prevent the passage of a 21-inch sphere and shall extend not less than 30-inches beyond each end of such equipment.

**Exit Access**

**General Exit Access**
The requirements for exit access are in IBC section 1014. The first part of a means of egress system is the exit access portion. Exit access is the portion of the egress system that leads from any occupied portion of a building to an exit. This includes all the unprotected spaces of the building where an occupant would be exposed to fire or smoke in the event of a fire. The concept of “travel distance” only applies to travel through the unprotected exit access area before the occupant reaches a protected (rated) exit enclosure.

The IBC allows egress through intervening spaces (or rooms) that are “accessory” to the area served. The IBC does not define that term “accessory”, but the adjoining rooms should serve a use that is similar or supportive of the space that is exiting through it. For example, an exhibit space (assembly) in a museum can exit through an adjoining exhibit space or spaces (assuming the egress path is clearly marked with exit signage). There is no limit to the number of accessory spaces an occupant may egress through (other than limitations of maximum travel distance or common path of travel). Spaces that cannot serve as accessory or intervening spaces in an egress path include:

- Kitchen
- Storage rooms
- Closets
- Toilet Rooms
- A room that can be locked to prevent egress (i.e., accessory spaces must remain unlocked at all times)

**Common path of travel** is the distance that must be traveled before two separate and distinct paths of travel to two exits are available. Common path of travel is included within the permitted travel distance. Although travel distances are much greater than the common path of travel, you must have the choice between two separate exit paths within the common path of travel limitation. The maximum common paths of travel are:

- **75 feet**, for most occupancies (other than Group H-1/H-2/H-3). This will apply to the educational and non-fixed seating portions of the building.
- **30 feet** for assembly areas with fixed seating, in accordance with Section 1025.8. This will apply to the theater and gym/池 area portions of the Project building.
Details about the exit access for the project and compliance with the code requirements are identified on the floorplans submitted with this Project report. The common path of travel for all areas within the building are in compliance with the aforementioned requirements.

**Exit and Exit Access Doorways**

*IBC section 1015* has the requirements for *exit* and *exit access* doorways. Generally, two or more exits are required from any space when any of the following conditions exist:

- The occupant load of the space exceeds the values in *IBC Table 1015.1*.

<table>
<thead>
<tr>
<th>OCCUPANCY</th>
<th>MAXIMUM OCCUPANT LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, E, F, M and U</td>
<td>49</td>
</tr>
<tr>
<td>H-1, H-2 and H-3</td>
<td>3</td>
</tr>
<tr>
<td>H-4, H-5, I-1, I-3, I-4 and R</td>
<td>10</td>
</tr>
<tr>
<td>S</td>
<td>29</td>
</tr>
</tbody>
</table>

- The *common path of egress* travel exceeds a general length of 75 or 30-feet, as applicable to the occupancy group of the space.
- Where required for mechanical spaces in *IBC sections 1015.3, 1015.4 and 1015.5* as detailed in this section of the report.

When **two exits are required** from a space, they must be located “remotely” from each other based on the length of the maximum overall diagonal dimension of the building or area served. The remote distance between the *exit* doors or *exit access* doorways is measured in a straight line between the centers of the doorway openings (on the centerline across the opening doorway). Limits are as follows:

- General areas: 1/2 the maximum overall diagonal dimension of building or area served.
- Where the building is provided with an automatic sprinkler system: 1/3 the maximum overall diagonal dimension of the building or area served.

Figure from the IBC Commentary:
Figure 58 - 1015.2.1(1) Examples of Remoteness Between Exits or Exit Access Doors From a Room or Building

It is important to remember to properly assess the remoteness of exits appropriately when using exiting through an adjoining (intervening) space as shown below.

Figure from the IBC Commentary:

Figure 59 - 1015.2.1(4) Remote Location of Exit Access Doors (Adjoining Rooms)
When three or more exits/exit-access-doorways are required from a space, at least two exit (access) doors must be located “remotely” from each other as described above. Additional exits or exit access doorways shall be arranged a “reasonable distance” (not defined) apart so that if one becomes blocked, the other will be available.

The special requirements for mechanical spaces in IBC sections 1015.3, 1015.4 and 1015.6 are as follows:

- Two exit access doorways are required in boiler, incinerator and furnace rooms where the area is over 500 square feet and any fuel-fired equipment exceeds 400,000 Btu input capacity. Where two exit access doorways are required, one doorway is permitted to be a fixed ladder or an alternating tread device (see IBC section 1009.9). Exit access doorways shall be separated (remoteness) by a horizontal distance equal to at least one-half (½) the maximum horizontal distance of the room.

- Two exit access doorways are required in refrigeration machinery rooms where the area is over 1,000 square feet. Where two exit access doorways are required, one doorway is permitted to be a fixed ladder or an alternating tread device (ATD, see section 1009.9). Exit access doorways shall be separated (remoteness) by a horizontal distance equal to at least one-half (½) the maximum horizontal distance of the room. All portions of the refrigeration machinery rooms shall be within 150 feet of an exit or exit access door. This may be increased according to IBC Table 1016.1 (e.g., 250 feet for Group F-1 occupancy with a fire sprinkler system). Doors shall swing in the direction of egress travel, regardless of the occupant load served. Doors shall be tight fitting and self-closing.

- Where two means of egress are required for stages, they shall be provided on each side of the stage, in accordance with Section 410.5.3. This has been previously discussed in this report.

**Exit Access Travel Distance**

IBC section 1016 has the requirements for exit access travel distance. The concept of travel distance only applies to travel through the unprotected exit access area before the occupant reaches a protected (rated) exit enclosure. Where the path of exit access includes unenclosed stairways or ramps (as permitted by section 1019.1), the distance of travel down the stairs (or ramps) needs to be included in the travel distance measurement (measured on a plane and tangent to the stair tread nosing’s in the center of the stairway).

Travel distances must be measured along the path of egress natural, unobstructed travel. Normal travel distances cannot be measured along the shorter diagonal path across a room (a.k.a. “as the crow flies”) since this path is usually obstructed by furniture, walls and other obstructions. Pathway measurements typically utilize a rectilinear approach.

IBC Table 1016.1 gives the travel distances for buildings based on the occupancy group:

<table>
<thead>
<tr>
<th>OCCUPANCY</th>
<th>WITHOUT SPRINKLER SYSTEM (Feet)</th>
<th>WITH SPRINKLER SYSTEM (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, E</td>
<td>200</td>
<td>250a</td>
</tr>
<tr>
<td>B</td>
<td>200</td>
<td>300b</td>
</tr>
<tr>
<td>S-2</td>
<td>300</td>
<td>400b</td>
</tr>
</tbody>
</table>

Footnotes:

a. See the following sections for modifications to exit access travel distance requirements:
Section 1025.7: For increased limitation in assembly seating.  
b. Buildings with NFPA 13 fire sprinkler systems.

The travel distance modification listed in footnote ‘a’ for assembly seating is described below: Essentially, the requirements for the travel distance are the same as Table 1016.1, requiring that travel distance be no more than 250’ in sprinklered buildings. The exceptions noted in 1025.7 are for smoke-protected assembly seating (SPAS) and for open air seating, both of which this Project building has.

**Corridors**

*IBC section 1017* has the requirements for *corridors*. *Table 1017.1* has the requirements for the *fire-resistance-rating (FRR) of corridors*. The *corridor* walls constructed as *fire partitions* in accordance with *IBC section 709* if a rating is required. According to *Table 1017.1*, since the building is equipped throughout with an NFPA 13 fire sprinkler system, *corridors* would not require a fire rating for the occupancy groups in the building.

The minimum *corridor* width is generally 44-inches or a greater width based on the occupancy load calculations of *IBC section 1005.1*. *This width required width cannot be obstructed*. The exceptions to these widths are:

- **24-inches**: For access to and utilization of electrical, mechanical or plumbing systems and equipment.
- **36-inches**: For occupant loads of 50 or less.
- **72-inches**: For Group E occupancies with a corridor having a required capacity of 100 or more.

Where more than one exit or *exit access* doorway is required, the *exit access* shall be arranged so no *dead ends* in *corridors* more than 20-feet are created. *This 20-foot dead end requirement will apply to most areas of the building*. The exceptions to this requirement are:

- **Dead end corridors** shall not exceed 50-feet for Group B occupancies equipped with an NFPA 13 fire sprinkler system. *This 50-foot limit will apply to the B occupancy area of the building.*
- **Dead end corridor** lengths shall not be limited so long as the length of the dead end is less than 2.5 times the width of the dead end.

Since *exit access corridors* are critical *means of egress* components, the potential for the spread of smoke and fire (*air movement*) in *corridors* must be minimized. Therefore, *exit access corridors* generally cannot serve as *supply, return, exhaust, relief or ventilation air ducts or plenums*. The exceptions to this requirement are:

- Use of a *corridor* as a source of makeup air for exhaust systems in rooms that open directly onto the *corridor* (e.g., toilet rooms, bathrooms, dressing rooms, smoking lounges and janitor closets), shall be permitted provided that each *corridor* is directly supplied with outdoor air at a rate greater than the rate of makeup air taken from the *corridor*.
- Within tenant spaces of 1,000 square feet or less, utilization of *corridors* for conveying return air is permitted.

Use of the space between the *corridor ceiling* and the floor/roof structure above as a return air plenum is permitted for one or more of the following conditions:
• The corridor is not required to be FRR.
• The corridor is separated from the plenum by FRR construction.
• The air-handling system serving the corridor is shut down upon activation of air-handling unit smoke detectors required by the IMC.
• The air-handling system serving the corridor is shut down upon detection of sprinkler waterflow when the building has a fire sprinkler system.
• The space between the corridor ceiling and the floor/roof structure above the corridor is used a component of an approved smoke control system.

Corridors must be continuous from the point of entry to an exit, and not interrupted by intervening rooms. Foyers, lobbies or reception rooms constructed as required for corridors (1-hour FRR fire partitions with 20-minute doors) are not construed as intervening rooms.

**Exits**

**General Exit Requirements**

The exit is the portion of the means of egress which is separated from other interior spaces (exit access) of the building by FRR construction and opening protection, or by an exterior wall (exterior exit) to provide a protected (from smoke/fire) path of egress travel between the exit access and the exit discharge.

Key concepts of exits, IBC section 1018, are:

• An exit cannot be used for any purpose that interferes with its function as a means of egress.
• Once a given level of exit protection is achieved (i.e., once you enter a protected, fire-resistance-rated exit enclosure), such level of protection shall not be reduced until arrival at the exit discharge (i.e., the exit may not discharge back into an unprotected, inside area of the building).
• All buildings must have at least one exterior exit door leading directly to an exit discharge or the public way.

**Number of Exits & Continuity**

IBC section 1019 has the requirements for the number of exits and exit continuity. Table 1019.1 provides the minimum number of exits that are required from an area:

<table>
<thead>
<tr>
<th>OCCUPANT LOAD</th>
<th>MINIMUM NUMBER OF EXITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 500</td>
<td>2</td>
</tr>
<tr>
<td>501 – 1,000</td>
<td>3</td>
</tr>
<tr>
<td>1,001 or more</td>
<td>4</td>
</tr>
</tbody>
</table>

The required number of exits from any story must be maintained until arrival at grade or the public way. IBC section 1019.2 also gives cases where a story may have a single exit. A summary of requirements from the table that are applicable to this project is below:

<table>
<thead>
<tr>
<th>STORIES WITH ONE EXIT</th>
<th>OCCUPANCY</th>
<th>MAXIMUM OCCUPANTS PER FLOOR AND TRAVEL DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Story or Basement</td>
<td>A, E, S</td>
<td>49 occupants and 100-ft* travel distance</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Second Story</td>
<td>B,</td>
<td>29 occupants and 75-feet of travel distance</td>
</tr>
</tbody>
</table>

* travel distance increased due to NFPA 13 fire sprinkler system.

This project will not qualify for these criteria; therefore a minimum of two exits is required for each story.

Exits must be continuous from the point of entry into the exit to the exit discharge. This would include, but not be limited to, the fire-resistance rating of the exit enclosure walls and opening protection rating of the doors. The code provides no exceptions for this requirement.

**Exit enclosures**

**IBC section 1020** has the requirements for exit enclosures, including interior exit stairways and interior exit ramps. Such enclosures shall be enclosed with fire barriers. Exit enclosures may not be used for any other purposes other than means of egress. The FRR of the exit enclosure is dependent upon the number of stories connected; however the rating shall not be less than the FRR of the floor assembly penetrated, up to a maximum of 2-hour fire resistance. The FRR of the exit enclosures needs to be:

- 2-hours: For exit enclosures 4 or more stories, or for exit enclosure that penetrate 2-hour FRR floor assemblies (section 706.4).
- 1-hour: For exit enclosures 3 stories or less.
- The number of stories penetrated includes basement levels, but does not include mezzanine levels.

The exit enclosures in this building do not penetrate more than 4 stories and do not penetrate a rated floor/ceiling assembly, therefore are only required to be of 1-hour fire-resistive construction.

Exit enclosures must terminate at an exit discharge, exit passageway or a public way. Where an exit passageway is used to extend the exit enclosure, the enclosure shall be separated from the passageway by a fire barrier or horizontal assembly with a FRR equal to that required for the exit enclosure. A fire door assembly shall be installed in the fire barrier to provide a means of egress from the exit enclosure to the exit passageway. The “Exit Discharge” section of this report provides more detail about exit enclosure termination.

Openings into an exit enclosure, other than unprotected exterior openings, shall be limited to those necessary for exit access to the enclosure from normally occupied spaces and for egress from the enclosure. This means that areas such as storage rooms, equipment rooms, restrooms and other similar spaces cannot open directly into the exit enclosure. Permitted openings must be properly protected with opening protectives in accordance with IBC section 715. Since the exit enclosures in the building require a 1-hour FRR, the openings shall have 1-hour (60-minute) fire-rated door assemblies.

Per IBC section 1020.1.2, penetrations into and openings through an exit enclosure are prohibited except for the following materials/items protected in accordance with IBC section 712:

- Required exit doors;
• Equipment and ductwork necessary for independent ventilation or pressurization;
• Fire sprinkler piping;
• Standpipes;
• Electrical raceway for fire department communication systems and electrical raceway serving the exit enclosure and terminating at a steel box not exceeding 16-square inches.

There shall be no penetrations or communication openings, whether protected or not, between adjacent exit enclosures.

Per IBC section 1020.1.3, equipment and ductwork for exit enclosure ventilation, as permitted by IBC section 1022.4, shall comply with one of the following arrangements:

• Equipment and ductwork shall be on the exterior of the building and be directly connected to the exit enclosure by ductwork enclosed in construction as required for shafts.
• When equipment is located within the enclosure, the intake and exhaust air shall be taken directly from the outdoors or the air shall be conveyed through ducts enclosed in construction as required for shafts.
• Where located within the building, the equipment and ductwork shall be separated from the remainder of the building, including other mechanical equipment, with construction as required for shafts.

In each case, openings into the FRR construction shall be limited to those needed for maintained and operation and shall be properly protected by opening protective’s for shaft enclosures.

**Exit passageways**

IBC section 1021 has the requirements for exit passageways. An exit passageway is an “exit” component that is separated from the rest of the building by FRR construction. It is the horizontal equivalent of a FRR vertical stairway enclosure. Exit passageways are useful for providing a FRR enclosure for FRR stair enclosures that terminate in the middle of a building. Since the IBC does not allow egress from the terminus of a FRR stair enclosure to pass through a non-rated portion of the building, an exit passageway can be designed to provide a protected path to an exit discharge. Exit passageways may also be used for very large floor areas where travel distance limitations cannot be met. Other options for handling the terminus of a stair enclosure using a lobby can be found in IBC section 1024 or the section below on “Exit Discharge.”

The width of an exit passageway must comply with widths calculated by IBC Table 1005.1 that are based on the occupant load served. The minimum width allowed is generally 44 inches, but may be as low as 36 inches if the occupant load served is less than 50. The required width must be unobstructed, but the obstructions allowed for doors and handrails are:

• Doors when fully opened and handrails cannot project more than 7 inches.
• Door swings may not reduce the width by more than one-half the required width.
• Non-structural projections (trim, decorative material, etc.) are permitted but cannot project 1-1/2 inches.

Exit passageways must be constructed with FRR fire barriers (section 706, for walls, floors, ceilings) that are at least 1-hour fire rated or not less than the connecting exit enclosure (usually a stair enclosure), whichever is greater. For example, if the connecting stair enclosure is 2-hour FRR, the
exit passageway must be 2-hour FRR. Exit passageway opening protective’s (e.g., doors) must be according to section 715:

- 1-hour rated doors, for 1-hour FRR exit passageways.
- 1-1/2 hour rated doors, for 2-hour FRR exit passageways.

This Project building does not utilize any exit passageways.

*Exit passageways may not open into un-occupied spaces* (janitor closets, mechanical rooms, electrical or telecom rooms, storage areas, etc.

As with vertical *exit enclosures*, **penetrations into and openings through an exit passageway** are prohibited except for the following materials/items protected in accordance with IBC section 715:

- Required exit doors;
- Equipment and ductwork necessary for independent ventilation or pressurization;
- Fire sprinkler piping;
- Standpipes;
- Electrical raceway for fire department communication systems and electrical raceway serving the *exit enclosure* and terminating at a steel box not exceeding 16-square inches.

There shall be no penetrations or communication openings, whether protected or not, between adjacent *exit enclosures*.

**Horizontal exits**

*IBC section 1022* has the requirements for *horizontal exits*. *Horizontal exits* are used to provide an exit from one area of the building to another area without the use of *exit enclosures* (typically a stair). A *horizontal exit* cannot serve as the only exit from a portion of the building (i.e., another exit must be available) and cannot provide more than one-half of the total number of exits or exit width.

The building design currently does not utilize *horizontal exits*.

**Exit Discharge**

*IBC section 1024* has the requirements for *exit discharge* egress elements. *FRR exit enclosures* are generally required to lead to “*exit discharge*” doors opening to the exterior at grade or provide direct access to grade. The *exit discharge* cannot re-enter the building. The three exceptions to this requirement are:

- A maximum of 50% (number & capacity) of the *exit enclosures* are permitted to egress through **areas on the level of discharge** provided all the following apply.
  - Egress from the *exit enclosure(s)* through the level of discharge to the exterior of the building is *readily visible and identifiable* from the terminus of the *exit enclosure*.
  - The entire area of the level of discharge is *separated from areas below by the same FRR as the exit enclosure*.
  - The egress path from the *exit enclosure* on the level of discharge is protected by a fire sprinkler system. All portions of the level of discharge with access to the egress path
need to be protected by a NFPA 13 or 13R fire sprinkler system or separated from the egress path according to the FRR of the exit enclosure.

Figure from the IBC Commentary:

![Figure 60 - 1024.1(1) Protection of Lobby with an Exit Discharge]

- A maximum of 50% (number & capacity) of the exit enclosures are permitted to egress through a vestibule provided all the following apply:
  - The entire area of the vestibule is separated from areas below by the same FRR as the exit enclosure.
  - The vestibule depth from the exterior of the building is not greater than 10 feet and the vestibule length is not greater than 30 feet.
  - The area is separated from the remainder of the level of exit discharge by construction providing protection at least equivalent of approved wired glass in steel frames.
  - The vestibule area is used only for means of egress and exits directly to the outside.

Figures from the IBC Commentary:

![Figure 61 - 1024.1(2) Vestibule with Exit Discharge]
All of the exits in this Project building discharge to grade level, and because of the type of construction for the building, this portion of the code is not required, however is provided for informational purposes.

Other requirements for exit discharge components are:

- The **capacity** of the exit discharge needs to be not less than the **required discharge capacity** of the exits being served.
- **Exterior** balconies/stairways/ramps need to be located at least 10 feet from adjacent lot lines & other buildings on the same lot (unless the exterior walls are **FRR** and protected according to section 704 based on fire separation distance).
- **Exit discharge** components must be sufficiently open to the exterior to minimize the accumulation of smoke.
- The exit discharge needs to provide a **direct and unobstructed access** to a public way. A **safe dispersal area (SDA)** may be provided in lieu of this requirement where all the following apply:
  - The SDA is sized to provide at least 5 square feet for each person served.
  - The SDA is located on the same property and at least 50 feet away from the building served.
  - The SDA needs to be permanently maintained and identified as a SDA.
  - The SDA is provided a safe and unobstructed path of travel from the building.

**Assembly Egress Requirements**

*IBC section 1025* contains requirements for exit access in Group A occupancies that contain seats and tables. More specifically, this section describes when aisles serve as a portion of the exit access in the means of egress system. *IBC section 1017* also contains specific requirements for aisles. These requirements will apply to the cafeteria seating area, gym, pool and theater portion of the building.

Every occupied portion of a Group A occupancy that contains seats and tables shall have aisles leading to exits or exit access doors. The following summarizes the assembly egress requirements.
- **Aisles** are the main circulation routes through the seating area.
- **Aisle Access** refers to the space between the tables and chairs within the seating area.
- The minimum clear aisle width is 36-inches or the width calculated from *IBC Table 1005.1* for the seating area served by the aisle.
- The minimum clear aisle access width is 12-inches, plus 1/2-inch for each additional foot of aisle access length (or portion of) beyond 12-feet. There is no minimum width for aisle access lengths of 6-feet or less that serve four or less people.
- The actual seating space occupied by a person at a table is 19-inches. When spacing tables in a seating area, this space must be taken into account. For example, if an aisle accessway serves two tables with seating along the table edges on both sides of the aisle accessway, then the distance between the two table edges would need to be at least 50-inches (19" + 12" (min for aisle accessway) + 19") for an aisle Accessway up to 12-feet long. If there was only seating on one side of the aisle accessway, then this number would be 19-inches less. This number would be 1/2-inch more for each foot (or portion of) beyond a 12-foot aisle access distance. Another example, if two tables were put beside each other and there were only two seats along the table edges on both sides of the (short-less than 6 feet) aisle accessway, then space between the tables would only need to be 38-inches. Also, if any seating were provided along a main aisle, then the aisle would have to be 19-inches bigger than the minimum (36” or 28” for less than 50 people) allowed or the width calculated by *IBC Table 1005.1*.

Figure from the IBC Commentary:

**Figure 63 - 1014.4.3 Aisle Measurement with Seating & Tables**

- The Aisle Access Travel Distance cannot exceed 30 feet, before a person has a choice of 2 or more paths of travel to separate exits.

Figure from the IBC Commentary:
Figure 64 - 1014.4.3.1 Access for Tables and Seating

Accessible Means of Egress

Accessible spaces need to be provided with at least one accessible means of egress. Where more than one means of egress is required by IBC section 1015.1 or 1019.1, not less than two accessible means of egress need to be provided.

Each required accessible means of egress must be continuous to the public way. The path shall consist of the following components:

- Accessible routes complying with IBC section 1104.
- Interior exit stairways complying with IBC sections 1007.3 and 1020.
- Exterior exit stairways complying with IBC sections 1007.3 and 1023.
- Elevators complying with IBC section 1007.4.
- Platform lifts complying with IBC section 1007.5.
- Horizontal exits complying with IBC section 1022.
- Ramps complying with IBC section 1010.
- Areas of refuge complying with IBC section 1007.6.

Due to the limited number of stories in the Project building, and the number of exits provided in the building, it would appear that all exits are accessible and compliant with Code.

Accessibility Requirements

Chapter 11 in the IBC contains the accessibility requirements. Chapter 11 requirements and the requirements in the ICC/ANSI 117.1-1998 companion document provide a code or design basis for
building compliance with ADA and FHA accessibility requirements. Appendix E in the IBC has non-building related accessibility requirements that relate to miscellaneous items provided with the building design. It is not the intent of this report to provide a review of accessibility requirements, which must be verified under a separate review.

Fire Classification of Roof Assemblies

Section 1505 of the IBC has the requirements for roof covering classifications. IBC Table 1505.1 gives the minimum roof covering classifications based on the construction type.

Table 18 - Minimum Roof Covering Classification

<table>
<thead>
<tr>
<th>I-A</th>
<th>I-B</th>
<th>II-A</th>
<th>II-B</th>
<th>III-A</th>
<th>III-B</th>
<th>IV</th>
<th>V-A</th>
<th>V-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>B</td>
<td>B</td>
<td>Cc</td>
<td>B</td>
<td>Cc</td>
<td>B</td>
<td>B</td>
<td>Cc</td>
</tr>
</tbody>
</table>

The Project building, per Table 601, is of Type II-B construction; therefore the roof covering must meet Class C roof assembly requirements. According to IBC Section 1505.4, Class C roof assemblies are those that are effective against light fire-test exposure. The assembly must be listed and identified as Class C by an approved testing agency.

Elevator and Conveying Systems

IBC Chapter 30 has the requirements for elevators and other conveying systems in buildings. The elevator hoistways must be constructed as shaft enclosures in accordance with IBC 708. Where four or more elevator cars serve the same portion of a building, the elevators shall be located in at least two separate hoistways. Not more than four elevator cars shall be located in any single hoistway enclosure. Elevators shall not be in a common shaft with a stairway.

Hoistway enclosure opening protectives shall be in accordance with Chapter 7. The elevator for this Project building is required to be on emergency power, and therefore must comply with Section 3003. Venting of the hoistway is not required.

The elevator installed in the Project building is what is termed as a MRL, “machine-room less” type system, in which all of the traction devices are installed on the top of the elevator cab assembly. As such, access to this must provided by means of gaining accessibility to the top of the elevator for maintenance functions.

This Project building will not be used as a fire-service elevator, and therefore those provisions do not apply.

This Project building elevator shaft will be constructed in a 2-hour fire-resistive rated assembly. Details on the construction of the shaft have already been detailed in this report.
Special Detailed Requirements Based Upon Use and Occupancy

Stages and Platforms

The IBC Section 410 outlines the special requirements for the Project building based on use and occupancy. For this Project building, there are some highlights that need to be addressed:

- 410.3.1 – Stages shall be constructed from materials as required for floors for the type of construction of the building in which such stages are located. Since this is a Type II-B building, the stage construction must meet the same material requirements.
- 410.3.7 – The stage in the Project building is over 1,000 sq. ft., and therefore will require emergency ventilation. The ventilation shall comply with subsequent sections, which state that either roof vents or smoke control shall be used.
- 410.5.1 – The stage shall be separated from dressing rooms, scene docks, property rooms, workshops, storerooms and compartments appurtenant to the stage and other parts of the building by a fire barrier with not less than 2-hour fire-resistance rating with approved opening protective’s. For the Project building, this is outlined on the attached floorplans. Refer to floorplans for more detail and extent of wall.
- 410.5.2 – All rooms that are accessory use to the stage, such as dressing rooms, scene docks, storerooms, etc., shall be separated from each other by fire barriers with not less than a 1-hour fire-resistance rating. For the Project building, this is outlined on the attached floorplans. Refer to floorplans for more detail and extent of barriers.
- 410.5.3 – At least on approved means of egress shall be provided from each side of the stage and from each side of the space under the stage. For the Project building, these exits are shown on the floorplans. Refer to floorplans for more information.
- 410.7 – Standpipes are required to be installed in accordance with Section 905. For stages over 1,000 sq. ft., a Class III wet standpipe system shall be installed with 1.5” & 2.5” hose connections on each side of the stage. However, since this building is equipped with an approved NFPA 13 sprinkler system, this can be reduced down to 1.5” Class II or Class III connection on each side of the stage.
FIRE PROTECTION AND FIRE ALARM SYSTEMS

Fire Suppression Systems

Automatic Fire Sprinkler, Standpipe and Fire Pump Systems

Fire Sprinkler System

*IFC section 903* contains the requirements for automatic fire sprinkler systems. An automatic fire sprinkler system will be required in this building according to:

- **IFC section 903.2.1.3, Group A-2:** An automatic sprinkler system is required for A-2 occupancies where the fire area exceeds 5,000-square feet or the fire area has an occupant load greater than 100 and where an A-2 occupancy is on a level other than the level of exit discharge.
- **IFC section 903.2.1.4, Group A-4:** An automatic sprinkler system is required for A-4 occupancies where the fire area exceeds 12,000-square feet or the fire area has an occupant load greater than 300 and where an A-2 occupancy is on a level other than the level of exit discharge.
- **IFC section 903.2.1.3, Group E:** An automatic sprinkler system is required for E occupancies where the fire area exceeds 20,000-square where an E occupancy is on a level other than the level of exit discharge.

Note, the Group A-1 occupancies within the project building is not a large enough fire area to, by itself, require the installation of an automatic sprinkler system. However, the Adams County High School 14 will have an automatic fire sprinkler system installed throughout. The system shall be designed and installed in accordance with *NFPA 13 – Installation of Fire Sprinkler Systems*. Design densities for the sprinkler system are based upon the relative fire hazard or fuel load. Hazard classifications are described in *NFPA 13 – section 5.1*.

- **Light hazard occupancies** are defined as occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.
- **Ordinary hazard (Group 1) occupancies** are defined as occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft (2.4 m), and fires with moderate rates of heat release are expected.
- **Ordinary hazard (Group 2) occupancies** shall be defined as occupancies or portions of other occupancies where the quantity and combustibility of contents are moderate to high, where stockpiles of contents with moderate rates of heat release do not exceed 12 ft (3.66 m) and stockpiles of contents with high rates of heat release do not exceed 8 ft (2.4 m).
The applicable sprinkler criteria for this building are summarized in the following table:

<table>
<thead>
<tr>
<th>Hazard Classification</th>
<th>Basement</th>
<th>1st Floor</th>
<th>2nd Floor</th>
<th>Design Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Hazard</td>
<td>ROTC Center, corridor &amp; bathroom group</td>
<td>Bistro, Music, Classrooms, Admin</td>
<td>Classrooms</td>
<td>0.10 GPM / 1,500 Sq. Ft.</td>
</tr>
<tr>
<td>Ordinary Hazard Group I</td>
<td>Armory, Rifle Range, Mechanical Room, Pool Equip</td>
<td>Fire Entry, Storage, Mechanical / Electrical, Gym, Sports, Main Kitchen(s), Wrestling, Auditorium</td>
<td>Prep Rooms (Flammable Liquid Storage), Storage</td>
<td>0.15 GPM / 1,500 Sq. Ft.</td>
</tr>
<tr>
<td>Ordinary Hazard Group II</td>
<td>Stage, Construction Trades, Library</td>
<td></td>
<td></td>
<td>0.20 GPM / 1,500 Sq. Ft.</td>
</tr>
</tbody>
</table>

This building does not contain high hazard classifications or high-piled storage.

The Department of Fire Prevention and Control requires hydraulic calculations shall be based on water supply information minus a 10% deduction at minimum to a maximum of 10 psi from the static and residual pressure. Shop drawings shall indicate the actual flow and the reduced parameters as used in the hydraulic calculations. Water supply information used for hydraulic calculations shall be less than a year old.

Based on information provided, the water supply at the site is 85 PSI static, and 20 PSI residual with 4,000 GPM flowing. This capacity is adequate enough for the system to cover the most demanding remote area of the sprinkler system.

Quick-response (QR) fire sprinklers are required by IFC section 903.3.2 for all light hazard areas. Section 11.2.3.2.3.1 of NFPA 13 also allows QR sprinkler use in ordinary hazard areas, with the appropriate design area reduction according to the ceiling height.

With few exceptions, fire sprinklers will be required throughout the building. When sprinklers are omitted, IFC section 903.1.1.1 requires an approved automatic fire detection system in the room. Sprinklers cannot be omitted from any room merely because it is damp, of fire-resistance rated construction, or contains electrical equipment. The only areas in this building that may have fire sprinklers omitted according to the IFC and NFPA 13 are:

1. Any room where the application of water, or flame and water, constitute a serious life or fire hazard.
2. Any room or space where sprinklers are considered undesirable because of the nature of the contents, only with the approval of the Fire Code Official.
3. Certain concealed spaces (see NFPA 13 – section 8.15.1).
4. Non-combustible mechanical shafts
5. Certain exterior roofs, canopies and porte-cochere’s (See NFPA 13 – section 8.15.7).
**Wet-pipe** sprinkler systems are generally required and provided in most area with a temperature above 40°F and not subject to freezing. Areas subject to freezing may be protected with a **dry-pipe or antifreeze** sprinkler system. **Pre-action** sprinkler systems may be used in areas with high-value equipment, such as computer rooms.

The entire project building will be protected with a wet pipe sprinkler system. A few pictures of the fire service entry are shown below:
**Elevator shafts** require fire sprinklers in different locations based on design features. A sidewall spray sprinkler will be required at the bottom of elevator shafts, located not more than 2 feet above the floor of the pit. If a sprinkler is located at the top of the elevator shaft, a smoke detector is required to shunt-trip the power to the elevator before the sprinkler activates. *Per NFPA 13, hoistways and machine rooms/spaces shall be protected by 286 degree F sprinklers located in accordance with subsections of NFPA 13.* Coverage shall be designed for *ordinary hazard, group one.* Sprinklers shall be supplied from a separate, independent branch line with a readily accessible indicating shut-off valve located outside the hoistway or room. Valves shall have identification signs.

The project utilizes “machine room less” (MRL) elevators; therefore sprinkler cannot be omitted from the hoistway as allowed otherwise by exceptions. The hoistways will require both fire sprinkler and fire detection equipment designed in accordance with the requisite building and fire codes.

The area covered by a single sprinkler zone is generally 52,000-square feet (for a wet sprinkler system). Sprinkler systems also need to be **zoned separately for each floor level.** Each sprinkler zone must be equipped with an electrically monitored control valve and water flow switch. The control valve will be monitored with a supervisory signal and the flow switch will be monitored with an alarm signal. These signals and devices need to be monitored by the fire alarm system.

**Where smoke control systems are provided** in an area (e.g., an atrium), the area needs to be served as a separate sprinkler zone to allow the water flow switch to activate the smoke control system.

The project building is large enough to require, at a minimum, 5 sprinkler zones based on the area of the first floor. The second floor and the basement may be fed off of a combination riser, provided that the areas are monitored in accordance with NFPA 13 and NFPA 72. The second floor will require 2 separate zones.

**Project Specific Sprinkler System Information**

The risers for the fire sprinkler system are located within Room H112 [Fire Entry Room]. This is also designated at the ‘Fire Command Center’, which will be discussed later in the report. This room houses the primary sprinkler system components, including the backflow prevention assembly, risers, monitoring equipment, main drain, etc.

The project building is expected to have concealed style sprinkler heads located in all public areas where there is a drop ceiling (pendant heads). Areas do not have ceilings, or areas that are back of house, will utilize upright sprinkler heads. Viking Microfast sprinkler heads are the sprinkler of choice for the project building; these heads come in upright, pendant and sidewall styles with differing K factors. Typically, a white finish for both the frame of the sprinkler head and the cover plate are expected.

As mentioned prior, there is varying design densities located throughout the building. For the project building, the most demanding area would be the construction trades area, with the highest density and farthest location from the riser room. A remote area has been calculated for this portion of the school utilizing the computer based program *Autosprink VR8.* The construction trades area is designated as Ordinary Hazard Group II, and based on the calculations from the
computer program; give a total hydraulic demand of 333.73 GPM @ 57.692 PSI. This, along with the municipal supply, is charted below on N1.85 paper to prove that the municipal system is adequate for the sprinkler demand:

![Figure 65 - Water Supply Graph N1.85](image)

With hose demand factored in, it is shown above that the system is well within the acceptable range of the municipal supply. The municipal system was designed to the code minimum 20 PSI with a flow of 4,000 GPM.

**Standpipe System**

As outlined previously in the report, standpipe systems are required for special occupancy areas. For this project building, a standpipe system, with connections, is required at the stage area. Refer to previous section on requirements for standpipe system.

**Fire Department Connection**

Section 912 of the 2006 IFC requires that a fire department connection be installed to supplement the fire sprinkler system or to add system flow and pressure to the standpipe system.

The fire department will use a **fire department connection (FDC)** to connect the hoses from the fire engines to pressurize water and pump it into the fire sprinkler and standpipe systems. This project building will require only one FDC. The location of the FDC is on the northeast corner of the building, located in Area ‘H’. This is the location of the fire entry room.
The locations must be fully visible and recognizable from the street and also located such that fire apparatus and hose connected to the system will not obstruct access to the buildings for other fire apparatus. Immediate access to the connections must be provided and kept without obstruction by fences, bushes, trees, walls or any other fixed or movable object. A working space of not less than 36-inches shall be provided around the fire department connections. **A fire hydrant must be located within 100 feet to the FDC location.**

An electronic horn/strobe device is mounted on the wall directly above the FDC to provide an audible and visible signal to the approaching fire engine.

The FDC shall be a minimum of one 2-1.2” x 2-1/2” x 4” Siamese as approved by the Fire Code Official. The number of 2.5-inch inlets provided shall not be less than one for each 250 gallons per minute of system demand or major fraction thereof, to a maximum of six 2.5-inch inlets. The standpipe system design flow is 500 gallons per minute; therefore two 2-1/2” connections will be required at the FDC locations. Each 2.5-inch inlet shall be equipped with a clapper valve to allow each hose to be connected and charged before the addition of more hoses.

Signs shall be provided to identify the FDC. The signage shall be metal with raised letters at least 1-inch in size. The sign shall read “AUTOMATIC SPRINKLER AND STANDPIPE CONNECTION” or other similar message approved by the fire department. The Fire Code Official is authorized to require locking caps on fire department connections.

Pictures of the fire department connection are shown below:

![Picture 5 - Fire Department Connections Side View](image)
Fire Pump

The fire sprinkler system demand, for the project building, is less than the available municipal water supply. **Therefore, no fire pump is required for the building.**

Alternative Automatic Fire Extinguishing Systems

Commercial Cooking Hood Suppression System

The Adams County High School contains both a cafeteria and commercial kitchen area on the first level. Both areas have equipment that requires a Type I hood and duct system and an automatic extinguishing system.

IMC section 506 contains the requirements for commercial cooking operations including requirements for exhaust equipment and grease ducts. IMC section 507.2 requires a **Type I ventilating hood and duct system** for commercial-type food and heat-processing equipment that produce grease vapors and smoke. Type I kitchen hoods are required to be installed at or above all commercial food heat-processing appliances that produce steam, fumes, odor or heat. Type I kitchen hoods need to be used over solid fuel cooking appliances that discharge to an independent exhaust duct system.

Type I hoods must be equipped with listed grease filters. The inside lower edge of canopy-type commercial cooking hoods shall overhang or extend a horizontal distance of at least 6 inches beyond the edge of the cooking surface covered below, on all open sides of the cooking surface. The maximum vertical distance is 4 feet between the front lower lip of the hood and the cooking surface. IMC section 507.13 lists the capacity of canopy-type cooking hoods. The exhaust outlets
located within the hood can cover a maximum 12-foot section of the hood and need to be located to maximize the capture of particulate matter from the cooking surface.

**IMC section 508** contains the requirements for **make-up air** provided to kitchen exhaust systems. There is a maximum 10°F difference allowed between the make-up air and the air in the conditioned kitchen space. The make-up air provided should be approximately equal to the amount exhausted by the kitchen hood exhaust system. Make-up air can be provided by gravity and/or mechanical means, but is usually provided solely by mechanical means. The make-up air and exhaust systems need to be interconnected electrically to require the make-up air system operation when the kitchen hood exhaust system is operating.

**Type I** kitchen hood exhaust systems are required by **IFC section 609 and IMC section 509** to be protected by an automatic **fire extinguishing system** according to **IFC section 904.11**. The extinguishing systems are required to be **automatically actuated** (usually by fusible links attached to a tensioned cable above the cooking surface that melt and release in the event of a fire) and by a **manual means** (usually a manual pull station near the cooking surface). The manual activation device is required to be near a **means of egress** and located at least 10-feet, but not more than 20-feet from the kitchen hood exhaust system. The manual pull station needs to be located on a wall between 42-inches to 48-inches above the floor level.

**Commercial cooking suppression systems** are typically a pre-engineered automatic dry (NFPA 17) or wet (NFPA 17A) chemical extinguishing system. Systems installed shall meet or exceed **UL 300** requirements, and shall be installed in accordance with the manufacturer’s specifications and instructions. The automatic fire extinguishing system shall protect all cooking surfaces that may produce grease laden vapors, including deep fat fryers, griddles, upright broilers, char-broilers, range tops and grills. Protection shall also be provided for the enclosed plenum space within the hood above filters and exhaust ducts serving the hood.

**Automatic fire extinguishing systems** shall be interconnected to the fuel or current supply for cooking equipment. The interconnection shall be arranged to automatically shut off all cooking equipment and electric receptacles, which are located under the hood, when the system is actuated. The hood ventilation system shall remain operational upon activation of system unless authorized to perform otherwise by the Fire Code Official and the manufacturer. **Activation of an automatic fire extinguishing system shall transmit an alarm to the building fire alarm system.**

The extinguishing system needs to be interlocked with

- Shut-off valves on the gas lines supplying the cooking equipment.
- Shut-offs for electrical power sources.
- Make-up air supply fans.
- Other system equipment necessary to operate the fire extinguishing system, such as a connection to the fire alarm system to monitor the operation of the extinguishing system. Activation of the fire alarm system needs to activate notification devices and send an alarm signal to the monitoring company.

After activation of the extinguishing system, the fuel and electrical power to the cooking equipment is required to be manually reset.

A **“Class K” fire extinguisher** is required within 30 feet of commercial cooking equipment utilizing vegetable or animal oils and fats, according to **IFC section 904.11.5**.
Located behind the roll down fire shutters is the commercial kitchen hood with special suppression system.

**Portable Fire Extinguishers**

*IFC section 906* and NFPA 10 give the requirements for **portable fire extinguishers**.

*Portable fire extinguishers* are required in Group A, B, E, and S occupancies. The fire extinguishers shall be spaced in accordance with NFPA 10. Fire extinguishers are required to be located in conspicuous locations and be readily accessible and immediately available for use. They cannot be obstructed from view. In areas where visual obstruction cannot be completely avoided, means shall be provided to indicate the locations of extinguishers.

Most areas in this building are considered “light (or low) hazard” areas. These areas include assembly, and business areas. Extinguishers are required to have a minimum “2A” rating with up to 3,000 square feet of building area being cover for “each A” (i.e., a 2A-rated extinguisher can cover up to a 6,000 square foot area). The **maximum travel distance** to an extinguisher is 75 feet. The maximum floor area protected by an extinguisher is 11,250 square feet.

“Ordinary (or moderate) hazard” areas include mercantile shops, parking garages and dining areas, which need a “2A” extinguisher every 3,000 square feet and within 75 feet of travel. The maximum floor area protected by an extinguisher is 11,250 square feet.

**Portable extinguishers are also required in the following special locations applicable to this project:**
• Within 30-feet of commercial cooking equipment (Type ‘K’ Extinguisher).
• In areas where flammable or combustible liquids are stored, used, or dispensed.
• On each floor of structures under construction.
• Special-hazard areas, including but not limited to computer rooms, generator rooms, and where required by the Fire Code Official.

Extinguishers must be mounted by a bracket or hangar (or placed in cabinets). The bottom of an extinguisher needs to be a minimum of 4 inches above the floor and the top must be a maximum of 5 feet above the floor.

Portable fire extinguishers will be provided throughout the Adams County High School as required.

Fire Detection, Alarm and Communication Systems

Fire Alarm System

General Fire Alarm System Requirements

*IFC section 907* contains the requirements for automatic fire detection and alarm systems. An automatic fire detection and alarm system will be required in this building according to:

• *IFC section 907.2.1, Group A*: A manual fire alarm system is required in Group A occupations having and occupant load of 300 or more.
  o Activation of the fire alarm in Group A occupancies with an occupant load of 1,000 or more shall initiate a signal using an emergency voice/alarm communication system. This is required in the Gym area.
  o Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system installed in accordance with NFPA 13 and arranged such that the notification appliances will activate throughout the notification zones upon sprinkler waterflow.

• *IFC section 907.2.2, Group E*: A manual fire alarm system shall be installed in Group E occupancies. When automatic sprinkler systems or smoke detectors are installed, such systems shall be connected to the building fire alarm system.
  o Manual fire alarm boxes are not required where all the following apply:
    ▪ Interior corridors are protected by smoke detectors with alarm verification.
    ▪ Auditoriums, cafeterias, gymnasiums and the like are protected with heat detectors or other approved detection devices.
    ▪ Shops and laboratories involving dusts or vapors are protected by heat detectors or other approved devices.
    ▪ Off-premises monitoring is provided.
    ▪ The capability to activate the evacuation signal from a central point is provided.
    ▪ In buildings where normally occupied spaces are provided with a two-way communication system between such spaces and a constantly attended receiving station from where a general evacuation alarm can be sounded, except in locations specifically designated by the fire code official.
  o The building is equipped throughout with an automatic sprinkler system installed in accordance with NFPA 13 and arranged such that the notification appliances will
activate throughout the notification zones upon sprinkler waterflow, and manual activation is provided from a normally occupied location.

The project building does not meet all the exceptions required for the removal of manual pull stations, and therefore the project building will be equipped with pull stations. A photo of an installed manual pull station within the school is shown below:
Picture 8 - Manual Pull Station With Cover
Per **IFC 907.1.2**, systems and their components shall be listed and approved for the purpose for which they are installed. All fire alarm control units and annunciator panels shall be UL 864 listed or equivalent. Installation locations of all control panels and annunciators are subject to field approval by the fire department. Locations should be within 10-feet of the main building entrance, unless specifically approved for an alternate location, and are subject to field approval prior to installation. A fire alarm system shall not be used for any purpose other than fire warning or as specifically approved, e.g. pool alarm, access control release per IBCA, elevator recall and shunt trip, emergency alarms per **IFC section 908**, and mass notification systems as approved by the Fire Code Official. Access to the reset and silence operator interface shall be secured behind a locked door. Access keys to locked fire alarm equipment shall be maintained in an approved location. Fire alarm control units shall not be equipped with a key or special numeric code to access system reset and silence functions.

Main controls for the fire detection, alarm and communication systems will be in the **Fire Command Center**, located in Area ‘H’. Keys for the command center will be provided in an approved key box at the entrance.

The basic fire alarm system required is a manual fire alarm system. This system would include, at a minimum, manual pull stations at exits and notification appliances throughout the building. The fire sprinkler system is also connected to the system for electronic supervision, monitoring and annunciation of waterflow alarms. More advanced features will be required within this project building. These systems include automatic detection and an emergency voice/alarm communication system. An addressable fire alarm detection and alarm system will be provided throughout with emergency voice communications systems required for a school building.

**Manual pull stations** must comply with **IFC section 907.4** as follows:

- Located not more than 5-feet from the entrance to each exit (on each floor level) and be located so the nearest pull station is not more than a 200-foot travel.
- Mounted at a height between 42 to 48-inches vertically above the floor to activating lever/handle. NFPA 72 allows mounting heights between 3-1/2-feet to 4-1/2-feet, but ADA requires mounting heights between 42-inches (3-1/2 feet) to 48-inches (4 feet).
- Red in color.
- Be provided with a protective cover if required by the building or fire departments.
- Be provided with a sign according to **IFC section 907.3.4** if the pull station does not activate an alarm that is monitored and transmitted to the fire department.
- A manual pull station is required is the fire sprinkler system riser room.

The fire detection and alarm system shall have an approved annunciator panel in the **Fire Command Center**. Annunciator panels shall be point-lit graphic or computer graphic or a directory LED point display type as approved by the Fire Code Official. Upon initiation of an alarm, supervisory or trouble condition the panel shall record the status. Alarms shall “lock-in” until the fire alarm system is reset with a dedicated reset switch located at the main fire alarm control panel. Annunciation lights shall be red for “Alarm” and yellow for “Trouble” and “Supervisory” signals. Each signal type shall be distinctly identified.
Drawings showing the intended fire alarm system layouts (i.e., ones developed for this program) are attached at the end of the report. Actual as-built fire alarm shop drawings from the contractor are also attached as the end of this report.

**Project Specific Fire Alarm Systems**

The project building is served with a *protected premise* fire alarm system (which also falls under a proprietary supervising stations alarm system). Signals from the fire alarm control panel are transmitted to the County’s main station before being transmitted out to the responding fire department.

The project building is equipped with a Simplex 4100U (Model #4100-9111), located in room Fire Entry Room H112 and a supplemental panel located in the SRO Room E105. A remote annunciator (Model #4603-9101) is located in the vestibule entrance to the facility. Smoke detectors (Model #409-9792), heat detectors (Model #4098-9401), manual pull stations (Model #4099-9003), and duct detectors (Model #409-9756) are all wired and addressed back the main fire alarm panel.

*Picture 9 - Fire Alarm Control Panel and Graphic Map*

While not specifically required for a fully sprinklered building, additional fire alarm devices have been added to the building based on AHJ requirements and Owner requirements.

The location of the initiation devices on a per floor basis are outlined below:
## Table 20 - Fire Alarm Initiation Device Location

<table>
<thead>
<tr>
<th>Initiation Devices</th>
<th>Basement</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Floor</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke Detectors</td>
<td>Electrical room, storage, pool &amp; main mechanical rooms</td>
<td>Fire Service Entry, storage, top of stairways, Electrical / IDF / Mech rooms, classrooms, drama &amp; costume areas, photo lab</td>
<td>Top of Stairs, janitors, IDF, storage, Elev. Mach room, electrical rooms, classrooms</td>
</tr>
<tr>
<td>Heat Detectors</td>
<td>Restrooms, acid/chlorine storage, bottom of elevator shaft</td>
<td>Restrooms, elevator machine rooms, elevator, bottom of elevator shaft</td>
<td>Top of elevator shaft, elevator machine room, restrooms</td>
</tr>
<tr>
<td>Duct Detectors</td>
<td>N/A</td>
<td>RA ducts of RTU 9, 10, 11, 13A &amp; 13B, 14, 15, 16, 17, 18</td>
<td>RA ducts of RTU 1, 2, 3, 4, 5, 6, 7</td>
</tr>
<tr>
<td>Manual Pull Stations</td>
<td>Within 5’ of all exit doors or exitways</td>
<td>Within 5’ of all exit doors or exitways</td>
<td>Within 5’ of all exit doors or exitways</td>
</tr>
</tbody>
</table>

All duct detectors for the project building are required to have remote light indicators, and testing switches, located near the detector, within a readily available area.

Notification devices are required in the project building, and shall be laid out per applicable codes and NFPA 72. Refer to fire alarm sheets for locations of all devices and components.
Emergency Communication Systems

Emergency Voice/Alarm Communication System

An emergency voice/alarm communication system is not required for the project building per prescriptive codes. However, this was added at the owner’s request, and was installed and designed per the IFC. The operation of any automatic fire detector, sprinkler water-flow or manual pull station shall automatically sound an alert tone followed by voice instructions giving approved information and directions of a general or selective (floor/area) basis to the building, based on the recorded message. Speakers, in combination with the fire alarm system, are provided throughout the project building to accomplish this.

A manual override for emergency voice communication shall be provided for all paging zones. The emergency voice/alarm communication system shall also have the capability to broadcast live voice messages through paging zones on a selective and all-call basis. The emergency voice/alarm communication system shall be allowed to be used for other announcements, provided the fire alarm system takes precedence over any other use.

The emergency voice/alarm communication system shall be designed and installed according to NFPA 72. The emergency voice/alarm communication system must be audible and intelligible throughout the building. The system shall also be provided with an approved emergency power source. The system shall have the capability to provide:

- Fire alarm notification
- Weather threat notification (severe weather warning, tornado)
- Inside threat condition
• Outside threat condition
• Live messaging from Fire Department

The emergency voice/alarm communication system shall utilize one of the design methods below. Communication risers shall be installed in metallic conduit and shall comply with NFPA 70 and NFPA 72.

• Separate "A" and "B" risers with alternating floor speakers, designed such that no more than ½ the speakers on a floor shall be affected by loss of any one amplifier, pre-amplifier or cable within the floor or communication zone.
• Class A wiring configuration for risers and floor distribution wiring with alternating speakers such that system survivability is maintained in the event of a failure of any distributed or banked amplifier to limit the failure to no more than ½ the notification appliances on the floor plate. Internally backed-up amplifier modules are acceptable.

Class A wiring configuration for risers and class B floor distribution wiring with alternating speakers such that system survivability is maintained in the event of a failure of any distributed or banked amplifier to limit the failure to no more than ½ the notification appliances on the floor plate. Internally backed-up amplifier modules are acceptable.
EMERGENCY PLANNING AND PREPAREDNESS

Fire Safety and Evacuation Plans

2009 IFC Chapter 4 requires Fire Safety and Evacuation Plans for Group E occupancies. This building will require fire safety and evacuation plans. Details of the fire safety and evacuation plans are attached in Appendix ‘J’.

Fire Safety Plans

Per IFC 404.3.2, Fire Safety Plans shall contain the following:

1. The procedure for reporting a fire or other emergency.
2. The life safety strategy and procedures for notifying, relocating or evacuating occupants including those with disabilities.
3. Site plans indicating the following:
   3.1 The occupancy assembly point.
   3.2 The locations of fire hydrants.
   3.3 The normal routes of fire department vehicle access.
4. Floor plans identifying the locations of the following:
   4.1 Exits.
   4.2 Primary evacuation routes.
   4.3 Secondary evacuation routes.
   4.4 Accessible egress routes.
   4.5 Areas of refuge.
   4.6 Manual fire alarm boxes.
   4.7 Portable fire extinguishers.
   4.8 Occupant-use hose stations.
   4.9 Fire alarm annunciators and controls.

   These requirements are shown on the life safety sheets for the project building. Refer to sheets A4.01 – A4.24.

5. A list of major fire hazards associated with the normal use and occupancy of the premises, including maintenance and housekeeping procedures.
6. Identification and assignment of personnel responsible for maintenance of systems and equipment installed to prevent or control fires.
7. Identification and assignment of personnel responsible for maintenance, housekeeping and controlling fuel hazard sources.

The requirements listed above shall be required for this project. Specific information regarding the above are outlined in Appendix ‘J’ Fire Safety and Evacuation Plans.

Fire Evacuation Plans
Per *IFC section 404.3*, Fire evacuation plans shall contain the following:

1. Emergency egress or escape routes and whether evacuation of the building is to be complete or, where approved, by selected floors or areas only.
2. Procedures for employees who must remain to operate critical equipment before evacuating.
3. Procedures for accounting for employees and occupants after evacuation have been completed.
4. Identification and assignment of personnel responsible for rescue or emergency medical aid.
5. The preferred and any alternative means of notifying occupants of a fire or emergency.
6. The preferred and any alternative means of reporting fires and other emergencies to the fire department or designated emergency response organization.
7. Identification and assignment of personnel who can be contacted for further information or explanation of duties under the plan.
8. A description of the emergency voice/alarm communication system alert tone and preprogrammed voice messages, where provided.

The requirements listed above shall be required for this project. Specific information regarding the above are outlined in Appendix ‘J’ Fire Safety and Evacuation Plans.

**Emergency Evacuation Drills**

*Emergency evacuation drills*, complying with *IFC section 405* are required for this facility. Drills are required for the occupancies in the building at the intervals specified in the table below.

<table>
<thead>
<tr>
<th>GROUP OR OCCUPANCY</th>
<th>FREQUENCY</th>
<th>PARTICIPATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Quarterly</td>
<td>Employees</td>
</tr>
<tr>
<td>Group B</td>
<td>Annually</td>
<td>Employees</td>
</tr>
<tr>
<td>Group E</td>
<td>Monthly*</td>
<td>All Occupants</td>
</tr>
</tbody>
</table>

*Footnote A states that this frequency shall be allowed to be modified in accordance with Section 408.3.2.

Section 408.3 gives specific requirements based on use and occupancy of the building. More specifically, Section 408.3.1 First emergency evacuation drill requires that the Project building have the first emergency evacuation drill of each school year be conducted within 10 days of the beginning of classes.

Leadership, timing, procedure and record keeping for drills shall be in accordance with *IFC section 405*. Drills shall be designed in cooperation with the local authorities. Complete evacuation for the building of all persons required to participate is required. It is unlawful to refuse to participate or to interfere with fire department personnel conducting an emergency drill.
Hazard Communication

Hazardous materials may be present on the site. An example of such material would be the fuel storage for the emergency generator. Such materials must be properly identified.

Material Safety Data Sheets (MSDS) for all hazardous materials shall be either readily available on the premises as a paper copy, or where approved, shall be permitted to be readily retrievable by electronic access. Individual containers of hazardous materials, cartons or packages shall be marked or labeled in accordance with applicable federal regulations. Buildings, rooms and spaces containing hazardous materials shall be identified by hazard warning signs in accordance with IFC section 2703.5.
FIRE SAFETY DURING CONSTRUCTION

IFC Chapter 14 contains requirements for fire safety during construction. The following requirements will apply to this project.

Access for Fire Fighting

Approved vehicle access for firefighting shall be provided to all construction or demolition sites. Vehicle access shall be provided to within 100 feet of temporary or permanent fire department connections. Vehicle access shall be provided by either temporary or permanent roads, capable of supporting vehicle loading under all weather conditions. Vehicle access shall be maintained until permanent fire apparatus access roads are available.

There are no existing roads on the site for firefighting access. The general contractor will be responsible for providing access that is capable of providing support of fire department equipment under all weather conditions. Entry points shall be coordinated with the fire department.

Means of Egress

Where a building has been constructed to a building height of 50-feet (15 240 mm) or four stories, at least one temporary lighted stairway shall be provided unless one or more of the permanent stairways are erected as the construction progresses. Required means of egress shall be maintained during construction and demolition, remodeling or alterations and additions to any building. The Adams 14 Project building will not need to meet this requirement during construction due to its limited height.

Water Supply for Fire Fighting

An approved water supply for fire protection, either temporary or permanent, shall be made available as soon as combustible material arrives on the site. There are no existing fire hydrants on site, therefore the general contractor shall provide either temporary hydrants for fire department use or shall provide adequate means of water supply for the fire department.

Standpipes

The Project building will not require a temporary standpipe during construction. The building is not tall enough to meet the requirements set forth in Section 1413.1.

Portable Fire Extinguishers

Portable fire extinguishers are required during construction. Fire extinguishers need to be provided at the following locations:

1. Each stairway, on all floor levels where combustible materials accumulate.
2. Every storage and construction shed.
3. Where specific hazards exist (e.g., storage & use of flammable/combustible liquids).
PERFORMANCE BASED CRITERIA

The 2009 Life Safety Code – NFPA 101 outlines the criteria that must be met for the ‘performance-based option’. Chapter 5 of the LSC outlines these requirements; they are also outlined in the SFPE Guide to Performance-Based Fire Protection. A conceptual design procedure is shown below:

**Figure 66 – NFPA 3.11.1 Steps in Performance-Based Fire Protection Design**

As previously outlined, there are numerous prescriptive based requirements that must be met for the project building. Those have already been discussed in detail; the following performance-based outline will serve as an outline for intended criteria, objectives and analysis for the building.

**Project Scope**

As it pertains to the project building, the scope of this section of the document is to ensure the life safety and property protection of the project building. Prescriptive requirements and
building characteristics have been previously outlined and identified, along with the use and occupancy of the project building. Since the building has been operational for several years, the ownership and investors have identified several areas of the building as ‘high-risk’. The focus of this report is the Theatre area and the Gym area. The ownership and investors include the faculty, students, fire department and Department of Education. These ‘high-risk’ areas will be explained in more detail further in the report, along with the performance criteria that is associated with them.

Project Goals

There are several goals for each individual project that must be achieved. For this project building, the main goal is to provide for a safe environment for the students. However, there are also fundamental stakeholder goals that must also be met:

1. **Life Safety** – As stated before, this is the fundamental goal for the project building. After all the building systems are in place, and the staff / employees are trained for fire safety and emergencies, the life safety of the students is the main priority.

2. **Property Protection** – It is the intent of this report, after analyzing the design fire(s) to provide the owners and insurers with some level of property protection after a fire event. Minimal damage to the building and surrounding areas are highly important and must be achieved.

3. **Continuity of Operations** – The ability of the project building to resume normal day-to-day activities after a fire event.

4. **Environmental Protection** – While the survival of the occupants is the foremost design goal, the impact to the surrounding area is also important. The project building was built on a small portion of the remains of the Rocky Mountain Arsenal, which has since been converted to a wildlife refuge. Therefore, any fire event must be mitigated in order to protect the rare one-eyed Maltese falcon.

Other goals that should be considered in the overall design process, but not included within this report:

5. Aesthetically pleasing to the community. The design team would need to ensure that it blends in with the surrounding area in terms of architectural design and environmental continuity.

6. Dual-role ability for the project building to serve as more than one venue. This includes functioning as a school, and serving as a venue for community events.

Design Objectives / Performance Criteria

In following with the goals outlined before, there are several design objectives for the project building that must be met. These design objectives are the limits of the Available Safe Egress Time (ASET). These are described below, and will be used for the reference against the Required Safe Egress Time (RSET):

Trial Designs

The trial design for the performance based design shall include information regarding the following sections:

- Fire Initiation and Development
- Spread Control and Management of Smoke
Pre-movement Behavioral Response and Timed Evacuation

**Occupant Characteristics and Pre-movement Time in Fire Events**

There are several factors that influence the pre-movement times of occupants in buildings when alerted to fire. Audio, visual and physical factors can all influence how fast an occupant will react to a fire. How occupants are first notified has a potential impact on how quick they leave the area and the building. Audio factors would include fire alarm, notification by others (i.e. another occupant telling someone that something is wrong), hearing the fire, etc. Visual factors would include seeing the fire, seeing smoke, or seeing something stemming from the impact of the fire (debris, glass shattering, etc.). Finally, physical factors would include smelling the smoke, feeling the heat from the fire, feeling the building move from fire impact, or feeling an impact from the fire on the building (like water seepage from the fire sprinkler system). These factors are just some that would contribute the pre-movement times.

Bryan’s chapter in the SFPE handbook (Bryan) outlines seven psychological and physical processes that are also related to pre-movement time. Below is a brief description of each:

- **Recognition** – This is the beginning of the occupant’s awareness of the fire event. They may not always indicate that there is a fire, and the way in which an occupant is notified also has a part to play in this. Again, either visual or audio cues will help the occupant differentiate the event.
- **Validation** – The next part in which the occupant defines if there is an event or not. During this process the occupant may try to obtain more information about the event; the person is aware something is happening, but needs to make sure that the event is life threatening or not.
- **Definition** – This is where the occupant defines the event in relation to themselves. Basically the occupant is processing the event in terms of how large is the fire and how can I get out.
- **Evaluation** – This is the coping portion of the six steps. At this point, the occupant realizes that there is a fire and has come to the conclusion that they need to leave. The occupants brain is now saying, “Okay, there is a fire, I need to leave. Where is the fire, how close am I to it, and how/do can I get out?”
- **Commitment** – This is the commitment to leave the area or stay in place from the occupant. Sometimes, in situations like hospitals (where there is a defend in place strategy) the occupant may not want to leave the area. A high-rise building where the fire is many stories below (this would be if the occupant were even notified) is another case of where the occupant might choose to stay instead of leave.
- **Reassessment** – It is at this time where the occupants stress and anxiety levels are the highest. The greater the magnitude of the event the higher the reassessment process will occur over and over in the occupants mind. The decision of where to go or what to do come to the forefront of the occupants reasoning and take precedence over every other thought.
Based off of these occupant characteristics, there are six building characteristics that can help reduce the pre-movement times of the occupants. Proulx outlines these in the SFPE handbook:

- **Types of warning systems** – Whether it is a fire alarm system or voice evacuation system, the type of warning system will have an impact on the movement time. Studies have shown that live messages are usually the best ways to move occupants from the area or in the building. The audibility and intelligibility (per NFPA) need to be very clear to ensure that the occupants can understand what they need to do and where they need to go.

- **Building layout and Wayfinding** – In buildings where wayfinding signage is inadequate, occupants usually spend more time obtaining information on where to go. It is very important that the building have the adequate signage posted so that the occupant spends less time finding out where to go and actually goes where they need to.

- **Visual Access** – Visual access of the other occupants or the fire alarm signaling is helpful for the occupants in making the decision to leave. Seeing the other occupants fleeing, or remaining in place holds important in the occupants mind. Also, the ability to see clearly to the exits and seeing the exits defined has an impact on the occupant.

- **Training** – This is one of the more important roles in the pre-movement times. Training of the occupants, regardless of the type and use of the building, will greatly help reduce the pre-movement time of the occupants. Regular fire drills and evacuation drills, scheduled or un-scheduled, greatly help the occupant. The brain tends to fall back on “muscle memory”, i.e., doing something over and over again when a certain event happens. If the occupants train over and over again to evacuate a certain way during a fire alarm signal, when the real event happens, the occupants make that decision without knowing it.

- **Frequency of False Alarms** – While training is integral to pre-movement times, false alarms tend to “soothe” or “pacify” occupants into thinking that there is nothing wrong. If the building has a false alarm once a week, then when the real event occurs, the occupants are likely to not respond and think that it is just another false alarm.

For the two scenarios outlined above, it is assumed that the occupants (for both scenarios) are alert and aware; however the Theatre occupants are within a dimly lit room; therefore there is a possibility of a delay in the recognition of movement. Additionally, the occupants in the Theatre are more likely to be parents and grandparents of the students, therefore the mobility speed would possibly be decreased.

**Timed Evacuation**

Emergency movement in building is a critical factor to have an understanding of when designing building. There are many factors to analyze when determining the evacuation times for buildings, which include (but are not limited to): detection time, behavioral response, wayfinding, boundary layers of stairs and movement paths, notification of occupants, walking speed, impediments to progress, etc. These factors and the intentions behind them are further outlined in the SFPE handbook and the NFPA handbooks.

When determining the Required Safe Egress Time (RSET), several factors must be considered.

- Measure from fire ignition
- Time to detection
- Pre-movement Time
- Movement Time

These will all sum to the total time to evacuate the occupants from the area, or the RSET. The RSET and ASET calculations will be explained in each design fire section of the report below.
Evaluation of Trial Designs

The trial design(s) shall be evaluated to determine if the results of each scenario met the aforementioned performance requirements. These trial designs, and the results of each, are outlined below:

THEATRE SCENARIO

As outlined prior, one of the high risk areas within the project building is the Theatre. It is a dimly lit area, with storage rooms located within the area and an increased occupant load with the seating and stage area. Parameters of this scenario are outlined below:

- Fire Initiation and Development – Starts in storage room, renders exit unusable.
- Spread Control and Management of Smoke – Theatre is separated from rest of building via 2-hr FRR construction. There is not a smoke control system installed in the room.
- Fire Detection and Notification – The storage room has smoke detection, as well as the two doors outside for the exit.
- Fire Suppression – Can the sprinkler system respond effectively to the fire? Two differing scenarios are run – full heat release rate, and sprinkler controlled fire (constant HRR).
- Occupant Behavior and Egress – Beginning of play, everyone is seated. No one on stage. Egress will be an issue, with one primary means blocked, and occupants having to transverse seats, sloped ramps and stairs.
- Passive Fire Protection – Assumed that fire is contained within storage room, but scenario is contained within the Theatre.

Shown below are pictures of the theatre to better visualize the area for the scenario:
Below is a picture of the blocked exit, on the west side of the theatre (this is the vomitorium):

![Picture 11 - Theatre Seating](image)

![Picture 12 - Theatre Vomitorium](image)
Below is a picture showing the tall height of the theatre:

![Picture 13 - Theatre Height](image)

**Design Fire**

As outlined prior, the Life Safety Code describes design fire scenarios that are used to evaluate project buildings:

5.5.3.2 Design Fire Scenario 2:

(1) It is an ultrafast-developing fire, in the primary means of egress, with interior doors open at the start of the fire.

(2) It addresses the concern regarding a reduction in the number of available means of egress.

5.5.3.3 Design Fire Scenario 3:

(1) It is a fire that starts in a normally unoccupied room, potentially endangering a large number of occupants in a large room or other area.

(2) It addresses the concern regarding a fire starting in a normally unoccupied room and migrating into the space that potentially holds the greatest number of occupants in the building.

For this scenario, the theater area has two vomitories that serve as the primary means of ingress/egress to the area, located on the west side of the area. There are two additional exits, each located on the north and south side of the building. On the west side of the room, the south egress path is located adjacent to a storage area. For this scenario, it is assumed that a fire starts in the storage area, and that the door to the storage area is propped open. As outlined above, Design Fire #2 states that it is an ultra-fast developing fire. While the fuel package in this case is not ultra-fast in nature, it does address number
(2), effectively rendering one of the main egress components unusable. Design Fire #3 address that the fire would start in a normally unoccupied room, and could endanger a large number of occupants in the adjoining room. While not fitting the exact definition of each design fire scenario outlined by NFPA 101, this scenario does address concerns of both scenarios.

A floorplan of the area showing the exits, egress path, seating arrangement, and room of origin for the fire are shown below. The total expected occupant load for the area is 255 seated occupants.

![Figure 67 - Theatre Floorplan](image)

**Fuel Package**

To define the fuel package for the scenario, the storage room must be outlined to see what the expected use would be. For the Theatre area, it is assumed that this is where they store extra chairs for plays and similar events.

The SFPE Handbook, 3rd Edition, outlines heat release rates for stackable chairs. Figure 3-1.15 shows the HRR curves for stacked chairs, polypropylene with steel frames and no padding on the seats, and the commentary outlines that when stacked together for storage, these types of chairs represent a significant fuel load.

For this scenario, it is assumed that there are 6 chairs in 1 stack, located within the storage room. There are four (4) stacks of chairs within the storage room. From the chart below, it is found that each stack gives a HRR of approximately 1,800kW at a time of 700 seconds. There is a significant
delay in the ramp of the HRR, with almost no heat until roughly a time of 300 seconds. After this, it would assume a growth rate of ‘medium’. It is assumed for this scenario, that these are the only items within the storage room at the time of the fire. It is also assumed that one stack of chairs ignites, and the other three may or may not ignite depending on the radiant heat flux from the first stack to the others when the sprinkler system activates. Also, this fire occurs during the initial setup of the play on the stage, and there are no occupants yet on the stage area. Therefore, the only affected occupants are the 255 seated occupants as outlined previously.

Figure 68 - SFPE 3-1.15 Stackable Chairs, Polypropylene with Steel Frame, No Padding

For the FDS modeling, explained further in the report, the following parameters were inserted into the file based on the fuel package. The SFPE Handbook, 3rd Edition outlines CO and soot yields, and as well heat of combustion, for polypropylene (PP). This is shown below:

![Figure 3-1.15. Stackable chairs, polypropylene with steel frame, no padding.](image)

**Table 22 - Yields of Polypropylene**

<table>
<thead>
<tr>
<th>Material</th>
<th>( \Delta H_f ) (kJ/g)</th>
<th>( Y_{CO} )</th>
<th>( Y_{CO} )</th>
<th>( Y_{H} )</th>
<th>( Y_{S} )</th>
<th>( \Delta H_{\text{CO}} )</th>
<th>( \Delta H_{\text{H}} )</th>
<th>( \Delta H_{\text{S}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMMA</td>
<td>52.2</td>
<td>2.12</td>
<td>0.010</td>
<td>0.001</td>
<td>0.002</td>
<td>34.2</td>
<td>16.0</td>
<td>7.6</td>
</tr>
<tr>
<td>PE</td>
<td>43.6</td>
<td>2.78</td>
<td>0.224</td>
<td>0.007</td>
<td>0.006</td>
<td>38.4</td>
<td>21.3</td>
<td>3.6</td>
</tr>
<tr>
<td>PP</td>
<td>43.4</td>
<td>2.79</td>
<td>0.234</td>
<td>0.006</td>
<td>0.003</td>
<td>38.3</td>
<td>22.0</td>
<td>0.2</td>
</tr>
<tr>
<td>PS</td>
<td>36.2</td>
<td>2.83</td>
<td>0.260</td>
<td>0.014</td>
<td>0.016</td>
<td>32.2</td>
<td>11.2</td>
<td>4.6</td>
</tr>
</tbody>
</table>

ASET / RSET

**ASET**

ASET is defined as *Available Safe Egress Time*. This is defined as the time in which the limits of the desired design objectives occur. These time values should be longer (greater) than...
the Required Safe Egress Time in order to achieve the desired life safety goals. These are outlined in further detail below:

![Figure 69 - Available & Required Safe Egress Time](image)

- Visibility levels in the Theatre shall remain above 10m (30 feet) (Jin). Occupants in the Theatre are assumed to not be familiar with their surroundings. As mentioned previously, expected occupants of the theatre are parents and grandparents of the students. These levels are discussed and outlined in the 3rd Edition and 4th Edition of the SFPE Handbook:

<table>
<thead>
<tr>
<th>Degree of Familiarity with Inside Building</th>
<th>Smoke Density (extinction coefficient)</th>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar</td>
<td>0.15 1/m</td>
<td>13 m</td>
</tr>
<tr>
<td>Familiar</td>
<td>0.5 1/m</td>
<td>4 m</td>
</tr>
</tbody>
</table>

- Tenability levels (CO levels) in this scenario shall remain below 1,400 PPM CO for 30 minutes, or 6,000 PPM for 5 minutes (Purser). This is outlined in the 3rd Edition SFPE Handbook Table 2-6B(a) and 4th Edition SFPE Handbook Table 2-6.B1:

<table>
<thead>
<tr>
<th>Incapacitation</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO 8000-8000 ppm</td>
<td>12,000-16,000 ppm</td>
</tr>
<tr>
<td>HCN 150-200 ppm</td>
<td>250-400 ppm</td>
</tr>
<tr>
<td>Low O₂ 10-13%</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>CO₂ 7-8%</td>
<td>&gt;10%</td>
</tr>
<tr>
<td>Incapacitation</td>
<td>Death</td>
</tr>
<tr>
<td>CO 1400-1700 ppm</td>
<td>2500-4000 ppm</td>
</tr>
<tr>
<td>HCN 90-120 ppm</td>
<td>170-230 ppm</td>
</tr>
<tr>
<td>Low O₂ &lt;12%</td>
<td>5-7%</td>
</tr>
<tr>
<td>CO₂ 6-7%</td>
<td>&gt;9%</td>
</tr>
</tbody>
</table>
Temperature Levels in this scenario shall remain under 120 deg C (248 deg F) for 8 minutes, and under 60 deg C (140 deg F) for 30 minutes (Purser). It is assumed for exposure to convective heat that the occupant is at rest for these temperatures. This criterion is outlined in the 3rd Edition (Figure 2-6.26) and the 4th Edition (Figure 2-6.27) of the SFPE Handbook.

Table 25 - Thermal Tolerances for Humans

The last goal is to prevent flashover within the storage room. In order for this to happen, the temperature of the storage room must stay under 500 deg C.

**RSET**

The Required Safe Egress Time (RSET) is defined as the time from ignition until the time evacuation for all occupants is complete. This includes several time steps along the way within the overall time.
The theatre scenario, as outlined above, has 255 seated occupants in the area when the fire occurs. There are a total of four (4) exits, with two being primary and two being secondary. Shown below is a floor plan of the area, with the exit doors marked with Red Arrows. The seating areas are labeled S1 thru S4. More information about these will be discussed further in the report.

![Theatre Floorplan with Design Fire](image)

**Figure 71 - Theatre Floorplan with Design Fire**

In addition the exits, the storage rooms on either side of the vomitory are equipped with smoke detectors. Additionally, the doors that are used for separation (within the 2-hr FRR wall) have smoke detection on either side of the door, used for auto-closers on the door. The as-built condition of the smoke detectors is shown below:
The NFPA Handbook and SFPE Handbook outline the following criteria for total evacuation time:

\[ RSET = t_d + t_n + t_o + t_i + t_e \]  \hspace{1cm} (1)

where
\[ t_d = \text{time from fire ignition to detection} \]
\[ t_n = \text{time from detection to notification of occupants of a fire emergency} \]
\[ t_o = \text{time from notification until occupants decide to take action} \]
\[ t_i = \text{time from decision to take action until evacuation commences} \]
\[ t_e = \text{time from the start of evacuation until it is completed} \]

The RSET elements \( t_d \) and \( t_n \) may involve hardware, such as fire detection devices and fire alarm equipment, and

For this scenario, based on the smoke detection within the storage room, it was found that the time from ignition to detection is 183 seconds. [This was found from the output file from the FDS model.]

The time from detection to notification is assumed to be no more than 5 seconds, which takes into account the smoke detector going into alarm, sending a signal to the fire alarm control panel, and then the fire alarm control panel outputting the signal on the SLC to the notification devices.

The time from notification to the occupants starting to egress is assumed to be 45 seconds. This time was chosen due to the nature of the occupants. Being older, and cognizant of what a fire alarm signal means, this would seem like a reasonable amount of time to assign to the occupants to start egressing.
From this point, all further evacuation times are calculated per the methods outlined in NFPA and SFPE handbooks. Both of these references follow similar methods of calculating how long it will take to move the occupants from their seats to the exit doors. The first item is to find the limiting factor of the flow through the primary and secondary exits.

For this scenario, two different calculations were run. The first was to determine the amount of time that was needed to evacuate the area with all exits and no fire scenario; the second was to determine the impact of losing a primary means of egress and a fire event. For the first scenario, it is assumed that all occupants use the exits equally; for the second scenario, it is assumed that the occupants will split the remaining three doors. Furthermore, all the calculated time are based on the farthest travel distance, i.e., an occupant using the door farthest away. This will give a conservative value, due to the fact that in all reality the occupant would use a closer exit. This will be illustrated further in the report.

In order to determine the evacuation time, the speed of the occupants walking and moving up or down the stairs must be determined. Table 4.2.4 of the NFPA Handbook outlines boundary layers for exit route elements:

**Table 26 - Boundary Layer Widths**

<table>
<thead>
<tr>
<th>Exit Route Element</th>
<th>Boundary Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>in.</strong></td>
</tr>
<tr>
<td>Starways—walls or side of tread</td>
<td>6.0</td>
</tr>
<tr>
<td>Railings, handrails*</td>
<td>3.5</td>
</tr>
<tr>
<td>Theater chairs, stadium benches</td>
<td>0.0</td>
</tr>
<tr>
<td>Corridor, ramp walls</td>
<td>8.0</td>
</tr>
<tr>
<td>Obstacles</td>
<td>4.0</td>
</tr>
<tr>
<td>Wide concourses, passageways</td>
<td>Up to 18</td>
</tr>
<tr>
<td>Door, archways</td>
<td>6.0</td>
</tr>
</tbody>
</table>

*Where handrails are present, use the value if it results in a lesser effective width.

It is important to note that there is no boundary layer width for theatre chairs; the exit route is composed of the space in between the front of the seat, and the back of the seat of the next row down. First, the speed at which the occupants will move needs to be determined. In order to this, the density of the occupants in each seating area needs to be found. From the Life Safety drawings, the occupant load and area of each seating area is shown below (these were outline prior):

**Table 27 - Theatre Seat Area Densities**

<table>
<thead>
<tr>
<th>Seat Area</th>
<th>Occupants</th>
<th>Area</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38</td>
<td>293</td>
<td>0.130</td>
</tr>
<tr>
<td>2</td>
<td>76</td>
<td>556</td>
<td>0.137</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>293</td>
<td>0.130</td>
</tr>
<tr>
<td>4</td>
<td>104</td>
<td>1569</td>
<td>0.066</td>
</tr>
</tbody>
</table>

As shown above, the highest density seating area is Seating Area #2. This corresponds to the seating area in the middle of the room, on the upper side of the floor level. Now the speed at which the occupants can move can be calculated:
Table 28 - Constants for Egress Equations

Using the above equation, with the constants outlined in Table 4.2.5, the travel speed is calculated as 147.4 ft/min (for vertical travel). Taking into account the conversion factor outlined in Table 4.2.6, the stair treads will convert the vertical distance to a horizontal distance:

The longest section of stairs were measured on the floor plans as being 14 feet (horizontally), multiplied by 2.22, which gives a total distance of 31 feet. Regardless of the exit being blocked or not, this gives a total vertical travel time of **13 seconds**.

First, the NFPA handbook outlines the horizontal travel speed that occurs in a theatre (where density was a factor), as shown in Table 4.2.3:
The longest travel distance for an occupant was measured out to be 78 feet (all exits in use) and 122 feet (one exit blocked). This gives time for horizontal movement to be either 95 seconds or 149 seconds.

As outlined above, the theatre has 4 exits, with two primary exits that are 72” wide (60” effective width) and two secondary exits that are 36” wide (24” effective width). For the purposes of this analysis, and to give the most conservative time for evacuation, the 36” doors are used to determine the time duration. It is recognized that the wider doors will allow for a faster flow and less time. For the first scenario, the time needed to exit the doors is 80 seconds and for the second scenario the time needed is 106 seconds. In the second scenario, it is assumed that the occupants will use exits further from the source of the fire, and will share each of the remaining three exits equally. Based on the layout of the exits, there would be no queuing at the doors.

For the first scenario, it would be assumed that since the idea is to just find the time needed to evacuate the occupants, there would be no detection time lag. Therefore, the total time to evacuate is 3.96 minutes, or 237 seconds. This calculation is shown below:

<table>
<thead>
<tr>
<th>Exit</th>
<th>Clear width (inches)</th>
<th>Boundary Layer (inches)</th>
<th>Effective Width (inches)</th>
<th>Effective Width (feet)</th>
<th>Max. Spec. Flow Rate for Doors (persons/min)</th>
<th>Max Flow (persons/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>72</td>
<td>12</td>
<td>40</td>
<td>5.00</td>
<td>24</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>72</td>
<td>12</td>
<td>60</td>
<td>5.00</td>
<td>24</td>
<td>120</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>12</td>
<td>24</td>
<td>2.00</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>36</td>
<td>12</td>
<td>24</td>
<td>2.00</td>
<td>24</td>
<td>48</td>
</tr>
</tbody>
</table>

Total Estimated Occupants During Theatre: 64 people

*This number is the 255 occupants divided by the 4 exits.

Theatre Travel Time: 49.2 ft/min - NFPA HB 20th pg. 4-56 - Linear travel speed in a theater where density was a factor
Travel Speed: 147.4 ft/min - Eq. (5) SFPE 4th pg 3-379
k = egress constant: 242 Table 4.2.5 NFPA 20th Edit for a 6.5/13 stair
a = constant: 2.86 feet/min

Density (worst case): 0.137 person/sqft - From density of each seating space above

- Detection Time: 0 Seconds
- Notification Time: 5 Seconds - Smoke detector to FACP to notification device
- Premovement Time: 45 Seconds - Older folks, they know to start moving when alarm goes off
- Travel Time (vertical): 13 Seconds - Horizontal distance times conversion factor
- Travel Time (horizontal): 95 Seconds - For the last person from seat to get out (this is only horizontal time) - distance of 78 feet

Total population in Theatre: 64 People
Discharge rate limited by Doors: 48 Persons/min
Time to exit to doors and out: 80 Seconds - This time is just to get through the door. There is no assumed queuing in this scenario.
Total evacuation time: 3.96 Minutes - Total RSET in minutes

![Figure 73 - Theatre Scenario All Exits Required Safe Egress Time](image)

For the second scenario, the detection time is added back to the calculations. The total amount of time, from the ignition of the fuel package, to the complete evacuation of the occupants is the summation of all components above. This is calculated out to be 8.34 minutes, or 501 seconds, as shown below:
In order to determine if the RSET is less than ASET, FDS was used to evaluate the times at which the ASET criteria was reached (if at all).

An FDS model was built to reflect the theatre area and fuel package. The full FDS input file is attached at the end of this report, but details are shown below for clarity. The storage room and theatre seats are modeled as reflected in the design scenario (door to storage room open).

Based on the fuel package, the simulation was run for 1200 seconds (2.55 times the RSET). The fuel package was inputted as polypropylene, with typical materials characteristics for the other items in the model. Walls were defined as gypsum, floor as concrete and the stage and seats as wood. The ramp function for the fuel package was input exactly as the graph shown above from the SFPE handbook. Sprinklers were spaced along the ceiling in a light hazard density and spacing criteria (coverage of 4.2m x 4.2m), and were set to K5.6 heads. An additional sprinkler was put in the storage room to reflect actual conditions. Two smoke detectors were added to the model, one located in the storage room and one within the vomitory; these would give indication of detection and notification used in the RSET analysis.

Shown below is a graphic rendering of the Theatre model:
Picture 14 - Theatre FDS Model
Results

The location of the chairs within the storage room presents the issue of having a fire event that eliminates a means of egress. Since there are sprinkler heads within the storage room, there is a mechanism to be able to control the fire (suppression may or may not occur).

The first run of the FDS model was to find the time at which the sprinkler activated to determine with the heat release rate would be ‘controlled’. From the FDS output file, this was found to activate at $t = 520.7$ seconds. A rendering of the sprinkler activation time is shown below:

![Picture 17 - Theatre FDS Sprinkler Activation](image)

After the sprinkler activation occurred, the heat release rate for the fuel package was then ‘capped’ at that time, to simulate the sprinkler controlling the fire. Since the SFPE handbook for this shows the HRR curve having growth and decay phase (mass loss), the HRR was ‘uncapped’ on the decay side at an HRR equal to when it was capped. More information about this can be found in the FDS output file attached to the end of this report. However, the HRR was capped on the growth side at $t = 525$ seconds [HRR at this time would be 500kW] and then uncapped on the decay side at $t = 850$ seconds [HRR at this time would be 306kW].

Once the simulation was run again, the results for the ASET / RSET comparison can be made. First, the visibility criteria from above 10m (30 feet) can be found from the FDS models. Shown below is
a rendering of the theatre at $t = 501$ seconds (RSET) to show the visibility within the room. Note, this slice is measured at a distance of 2 m (6 feet) above the walking surface of the theatre:

![Picture 18 - Theatre FDS Visibility at RSET](Image)

As shown above, and expected due to the nature of the high ceilings, the visibility passes within the space at the time of RSET. It is also possible to find the time at which there is total failure of the criteria, i.e., all exits are no longer visible. This occurs at approximately $t = 1000$ seconds, as shown below:
The next criterion listed in the ASET is CO concentration. Similar to the visibility, and due to the high ceilings, there is a large storage reservoir for the smoke to reside in. Shown below is a rendering of the CO concentration at the time of RSET, to illustrate the low levels of CO within the space. The FDS output is measuring the amount is approximately 1/10\textsuperscript{th} of the permitted PPM outlined above:
At the end of the simulation, or 2.43 times the RSET [1200 seconds], there is a considerable greater quantity of CO within the area. This is illustrated below:
The next criterion from the ASET analysis is the temperature in the room. From the slice file below it is found that the temperature outside of the storage room [again measured at 2m above the walking surface] stays relatively cool. Shown below is a slice file of the temperature in the room at $t = 501$:

*Picture 21 - Theatre FDS Carbon Monoxide at 1200 seconds*
The temperature in the space can also be viewed from the side, looking across the theatre. From the slice file shown below it is shown that the temperature in the space again remains relatively cool:
The last criterion is to ensure that the temperature in the storage room doesn’t exceed 500 deg C, which is needed for flashover. From the rendering below, it is shown that the temperature right before sprinkler activation is just over 85 degrees C:

Right after sprinkler activation it is found that the temperature in the room drops down approximately 20 deg C:
From the FDS output file, the total heat release rate for the fuel package [chairs] is shown below. This very closely resembles the curve outlined in the fuel package section of this scenario.
From the above *Required Safe Egress Time* the following is a chart showing the total time of 466 seconds:

![Diagram 1](image1)

*Figure 75 - Theatre FDS Chairs Heat Release Rate*

*Figure 76 - Theatre RSET*
Based on the FDS modeling, below is a comparison between the *Available Safe Egress Time* and the *Required Safe Egress Time*:

![Figure 77 - Theatre ASET vs. RSET](image)

As shown above, all of the *Available Safe Egress Time* criteria are greater than the *Required Safe Egress Time*. Therefore, no additional work is necessary to this area.
GYM SCENARIO

As outlined prior, another one of the high risk areas within the project building is the Gym. It has the capacity for a large number of occupants and the possibility of having moderate to severe hazards located within the area. Parameters of this scenario are outlined below:

- **Fire Initiation and Development** – Gym mats stored under bleachers. Goes from there to the bleachers. Shielded fire.
- **Spread Control and Management of Smoke** – There is no smoke controls system in the gym. Gym is separated from remained of building via 2-hr FRR fire barrier. Scenario is limited to Gym compartment.
- **Fire Detection and Notification** – The Gym area only has occupant notification, there is no smoke / beam detectors within the space. It is assumed that the one manual pull is used by the chaperone.
- **Fire Suppression** – Can the sprinkler system respond effectively to the fire? This is a shielded fire under bleachers. Activation time of sprinkler head (delayed waterflow alarm) vs. signal notification a significant issue.
- **Occupant Behavior and Egress** – Student dance. Capacity is roughly 1,300 occupants.
- **Passive Fire Protection** – As outlined prior, the gym is separated via 2-hr FFR fire barrier.

Pictures of the gym area are shown below, to help give visual to the scenario:

![Picture 26 - Gym Profile View](image-url)
Picture 27 - Gym Bleachers

Picture 28 - Gym Mechanical Systems
Design Fire

As outlined above, the Life Safety Code describes the design fire scenario.

5.5.3.4 Design Fire Scenario 5:

(1) It is a slowly developing fire, shielded from fire protection systems, in close proximity to a high occupancy area.

(2) It addresses the concern regarding a relatively small ignition source causing a significant fire.

For this scenario, it is assumed that there is a student dance occurring within the gym area. The bleachers are folded back in their locked position, and the gym mats are stored under the bleachers. The total occupant load in the gym at the time is 1,300 persons. While not a ‘slowly’ developing fire, or a ‘small’ ignition source; this scenario most closely resembles the Design Fire Scenario outlined in the Life Safety Code.

Fuel Package

For this scenario, the fuel package is a gym mat that is stored under the bleachers. The gym mat is made from polyurethane foam and the bleachers are made from plastic. From the NIST paper titled ‘Numerical Simulation of Fire Spread on Polyurethane Foam Slabs’ (Prasad, Kramer, Marsh, Nyden, Ohlemiller, & Zammarano) it is found that the average heat release rate for a 10cm thick polyurethane foam slab is around 700 kW. The testing done within the paper most closely resembles the gym mats. The test slabs were measured out to be 1.2m x 1.2m square and 10cm thick, which would closely resemble a gym mat. For this scenario, the gym mats are stored under the bleachers, and represent a ‘shielded’ fire as described in the design fire scenario. A graph showing the HRR from the testing is shown below:

![Figure 78 – NIST Figure 7 Gym Mats Heat Release Rate](image)

It was assumed for this that four (4) gym mats were stored under the bleachers. Due to space constraints, this would be the maximum amount of mats that could be stored under the bleachers. Therefore, the total heat release for each was added together to produce a total 2,800kW fire. It
was also assumed (worst-case scenario) that all four gym mats ignited simultaneously. A floorplan showing the gym, and the location of the fuel package, is shown below:

![Figure 79 - Gym Floorplan](image)

For the FDS modeling, explained further in the report, the following parameters were inserted into the file based on the fuel package. The SFPE Handbook, 3rd Edition outlines CO and soot yields, and as well heat of combustion, for flexible polyurethane foam (GM21, which most closely matches the NIST report). This is shown below:

**Table 31 - Yields of Polyurethane Foam**

<table>
<thead>
<tr>
<th>Material</th>
<th>$\Delta H_c$ (kJ/g)</th>
<th>$Y_{CO_2}$</th>
<th>$Y_{CO}$</th>
<th>$Y_{H_2}$</th>
<th>$Y_s$</th>
<th>$\Delta H_{ch}$ (kJ/g)</th>
<th>$\Delta H_{cord}$ (kJ/g)</th>
<th>$\Delta H_{red}$ (kJ/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM21</td>
<td>26.2</td>
<td>1.55</td>
<td>0.010</td>
<td>0.002</td>
<td>0.121</td>
<td>17.6</td>
<td>8.6</td>
<td>6.2</td>
</tr>
<tr>
<td>GM23</td>
<td>27.2</td>
<td>1.51</td>
<td>0.031</td>
<td>0.008</td>
<td>0.227</td>
<td>19.0</td>
<td>10.3</td>
<td>8.7</td>
</tr>
<tr>
<td>GM25</td>
<td>24.6</td>
<td>1.50</td>
<td>0.026</td>
<td>0.005</td>
<td>0.184</td>
<td>17.0</td>
<td>7.2</td>
<td>9.0</td>
</tr>
<tr>
<td>GM27</td>
<td>23.2</td>
<td>1.57</td>
<td>0.042</td>
<td>0.004</td>
<td>0.188</td>
<td>16.4</td>
<td>7.6</td>
<td>8.8</td>
</tr>
</tbody>
</table>
ASET / RSET

ASET

ASET is defined as Available Safe Egress Time. This is defined as the time in which the limits of the desired design objectives occur. These time values should be longer (greater) than the Required Safe Egress Time in order to achieve the desired life safety goals. These are outlined in further detail below:

Visibility levels in the Gym shall remain above 10m (30 feet) (Jin). While occupants in the gym are assumed to be familiar with their surroundings [for the student dance], it cannot always be assumed that the people using the gym will be familiar with their surroundings and where the exits are. Also, it is assumed that there are parents or chaperones during...
this event (which dramatically decreases detection time). These levels are discussed and outlined in the 3rd Edition and 4th Edition of the SFPE Handbook:

Table 32 - Allowable Smoke Densities and Visibilities

<table>
<thead>
<tr>
<th>Degree of Familiarity with Inside Building</th>
<th>Smoke Density (extinction coefficient)</th>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar</td>
<td>0.15 1/m</td>
<td>13 m</td>
</tr>
<tr>
<td>Familiar</td>
<td>0.5 1/m</td>
<td>4 m</td>
</tr>
</tbody>
</table>

- Tenability levels (CO levels) in this scenario shall remain below 1,400 PPM CO for 30 minutes, or 6,000 PPM for 5 minutes (Purser). This is outlined in the 3rd Edition SFPE Handbook Table 2-6B(a) and 4th Edition SFPE Handbook Table 2-6.B1:

Table 33 - Tenability Limits for Exposure

<table>
<thead>
<tr>
<th></th>
<th>5 min Incapacitation</th>
<th>Death</th>
<th>30 min Incapacitation</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>8000–8000 ppm</td>
<td>12,000–16,000 ppm</td>
<td>1400–1700 ppm</td>
<td>2500–4000 ppm</td>
</tr>
<tr>
<td>HCN</td>
<td>150–200 ppm</td>
<td>250–400 ppm</td>
<td>90–120 ppm</td>
<td>170–230 ppm</td>
</tr>
<tr>
<td>Low O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>10–13%</td>
<td>&lt;5%</td>
<td>&lt;12%</td>
<td>5–7%</td>
</tr>
<tr>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>7–8%</td>
<td>&gt;10%</td>
<td>6–7%</td>
<td>&gt;9%</td>
</tr>
</tbody>
</table>

- Temperature Levels in this scenario shall remain under 120 deg C (248 deg F) for 8 minutes, and under 60 deg C (140 deg F) for 30 minutes (Purser). It is assumed for exposure to convective heat that the occupant is at rest for these temperatures. This criterion is outlined in the 3rd Edition (Figure 2-6.26) and the 4th Edition (Figure 2-6.27) of the SFPE Handbook.

Table 34 – Thermal Tolerances for Humans
**RSET**

The Required Safe Egress Time (RSET) is defined as the time from ignition until the time evacuation for all occupants is complete. This includes several time steps along the way within the overall time.

![Figure 81 - Available & Required Safe Egress Time](image)

The gym scenario, as outlined above, has roughly 1,300 occupants in the area when the fire occurs. The gym is served via twelve (12) 3’ doors that are used for egress doors. Shown below is a floor plan of the area, and the exit doors are marked with Red Arrows (notes that this floorplan shows the bleachers in the extended position. For this scenario, they are assumed to be retracted):
The NFPA Handbook and SFPE Handbook outline the following criteria for total evacuation time:

\[ RSET = t_d + t_a + t_n + t_i + t_e \]  \hspace{1cm} (1)

where

- \( t_d \) = time from fire ignition to detection
- \( t_a \) = time from detection to notification of occupants of a fire emergency
- \( t_n \) = time from notification until occupants decide to take action
- \( t_i \) = time from decision to take action until evacuation commences
- \( t_e \) = time from the start of evacuation until it is completed

The RSET elements \( t_d \) and \( t_a \) may involve hardware, such as fire detection devices and fire alarm equipment, and

For this scenario, based on the growth rate of the fire, and based on having chaperones within the area while the dance is occurring, it is assumed that the time from ignition to detection is **100 seconds**. This gives a conservative approach based on the chaperones may not be immediately realize that there is a fire, and would need to verify.

The time from detection to notification is assumed to be roughly **20 seconds** for the chaperone to locate the manual pull station.
The time from notification to the occupants actually starting to egress the area is assumed to **15 seconds**. This takes into account the pre-movement behavior outlined previously in the report, and is reasonable to expect with a large crowd of teenagers within the area.

From this point, all further evacuation times are calculated per the methods outlines in NFPA and SFPE. Both of these references follow similar ways to calculate how long it will take to remove the occupants from the space. The first item to find is the limiting factor for flow through the twelve exit doors. It is assumed that the occupants will use all doors equally for this scenario, based on the location of the fuel package.

Table 4.2.4 of the 20th Edition of the NFPA Handbook outlines the boundary widths of various egress components:

<table>
<thead>
<tr>
<th>Exit Route Element</th>
<th>Boundary Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
</tr>
<tr>
<td>Stairways—walls or side of tread</td>
<td>6.0</td>
</tr>
<tr>
<td>Railings, handrails*</td>
<td>3.5</td>
</tr>
<tr>
<td>Theater chairs, stadium benches</td>
<td>0.0</td>
</tr>
<tr>
<td>Corridor, ramp walls</td>
<td>8.0</td>
</tr>
<tr>
<td>Obstacles</td>
<td>4.0</td>
</tr>
<tr>
<td>Wide concourses, passageways</td>
<td>Up to 18</td>
</tr>
<tr>
<td>Door, archways</td>
<td>6.0</td>
</tr>
</tbody>
</table>

*Where handrails are present, use the value if it results in a lesser effective width.

This scenario only includes doors, which have a boundary width of 6”. The doors on the floorplan all measure to be 3’ (36”) doors, so the effective width is actually 24”.

Table 4.2.8 of the 20th Edition of the NFPA Handbook outlines the maximum specific flow of exit route components. For doorways, this is 24 persons / min/ft of effective width.

Since it is assumed that the occupants will use the exit doors equally, this gives an occupant load per door as 108 persons. Therefore, the time for occupants to exit the doors is found to be **2.26 minutes**. However, it is not reasonable to assume that they will be waiting at the doors for the alarm to sound. Therefore, the travel distance must be found.

From the floorplans, it is found that if an occupant were standing in the middle of the gym, they would need at most to travel 75 feet to an exit. Travel speeds to the exit are found via the density versus the area of the room, and the egress components outlined in the tables below:
Table 36 - Constants for Egress Calculations

<table>
<thead>
<tr>
<th>Exit Route Element</th>
<th>$k_1$</th>
<th>$k_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor, Aisle, Ramp, Doorway</td>
<td>275</td>
<td>1.40</td>
</tr>
<tr>
<td>Stair Rise (in.)</td>
<td>Tread (in.)</td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>10</td>
<td>196</td>
</tr>
<tr>
<td>7.0</td>
<td>11</td>
<td>212</td>
</tr>
<tr>
<td>6.5</td>
<td>12</td>
<td>229</td>
</tr>
<tr>
<td>6.5</td>
<td>13</td>
<td>242</td>
</tr>
</tbody>
</table>

Note: 1 in. = 25.4 mm

The density is found by dividing the occupant load by the area of the room. For this scenario, there are 1,300 occupants within 8,150 square feet of area. This gives a density of 0.160 person / ft. From the equation above, the speed of the occupant is then determined via the following:

$$S = k - akD$$

$$S = 275 - 2.86 \times 275 \times 0.16$$

$$S = 149.5 \text{ ft/min}$$

Using this, the speed for someone in the middle of the gym to get to an exit can be determined by multiplying their speed by the distance. Previously it was noted that this was 75', therefore the travel time is 30 seconds. Based on the density of the occupants, and the number of exits, it would not be assumed that there is any queuing at the doors.

The total amount of time, from the ignition of the fuel package, to the complete evacuation of occupants from there is then the summation of all the components from above. This is calculated out to be 5.01 minutes or 301 seconds, as shown below:

**Adams 14 High School - Gym Evacuation Times**

<table>
<thead>
<tr>
<th>Exit</th>
<th>Clear width (inches)</th>
<th>Boundary Layer (inches) NFPA HB Table 4.2.4</th>
<th>Effective Width (inches)</th>
<th>Effective Width (feet)</th>
<th>Max. Spec. Flow Rate for Doors</th>
<th>Max Flow (persons/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 12</td>
<td>36</td>
<td>12</td>
<td>24</td>
<td>2.00</td>
<td>24</td>
<td>48</td>
</tr>
</tbody>
</table>

Total Estimated Occupants During Dance | 108 people

*This number is the 1,300 occupants divided by the 12 exits

Travel Speed | 149.5 ft/min | Eq. (5) SFPE 4th pg 3-379

$k = k_1$ and $a = 2.86$ when calculating speed in feet per minute and density in persons per square foot

$k = k_2$ and $a = 0.266$ when calculating speed in meters per second and density in persons per square meter

Detection Time: 100 Seconds Ignition to detection

Notification Time: 20 Seconds Recognize fire, walk to pull station

Premovement Time: 15 Seconds All the kids hear fire alarm and start to exit

Travel Time: 30 Seconds For the last kid in the middle of the gym to get out.

Total population in Gym: 108 People This is 1,300 occupants / 12 doors

Discharge rate limited by Doors | 48 Persons / min

Time to exit to doors and out: 2.26 Minutes Time to get through door.

Total evacuation time: 5.01 Minutes Total RSET in minutes

301 Seconds Total RSET in seconds

**Figure 83 - Gym Scenario Required Safe Egress Time**
FDS Modeling

In order to determine if the RSET is less than ASET, FDS was used to evaluate the times at which the ASET criteria was reached (if at all).

An FDS model was built to reflect the gym area and fuel package. The full FDS input file is attached at the end of this report, but details are shown below for clarity. The bleachers were modeled in their retracted position, with no other obstructions in the way.

Based on the RSET analysis, the simulation was run for 800 seconds (2.6 times the RSET). The fuel package was inputted as polyurethane foam, with the bleacher material defined as plastic (PMMA). The ramp function for the fire was input based on the fuel package graph shown prior in the section of this report. Sprinklers were spaced along the ceiling in a coverage pattern of 3m x 3.6m (roughly 10’ x 12’) to reflect Ordinary Hazard coverage. Details on the sprinklers and spacing can be found in the attached FDS input file. **Note, the data sheet from the manufacturer refers to the bleachers being non-combustible. The bleachers are constructed from steel and fire-retardant high density plastic, with an ignition temperature [AIT] of over 350 deg C. It is therefore assumed that the bleachers do not contribute to the fuel package.**

Shown below is a graphic rendering of the Gym model:

![Gym FDS Model](image)

*Picture 30 - Gym FDS Model*

A close up view of the fuel package (gym mats), and the storage underneath the bleachers is shown below:
Shown below is a rendering that outlines where the exits are:
Results

Due to the location of the fire under the bleachers, it is outlined previously that this is what is considered a ‘shielded’ fire. Since the sprinkler head discharge does not have an adequate way of penetrating the bleachers to control the fire, the full heat release rate outlined in the fuel package section above was modeled. Results and explanations from that are outlined below:

The first run of the FDS model was to find the time for sprinkler activation to compare to the human detection time. It was found from the output file that the first sprinkler activated at $t = 179.9$ seconds. A rendering of the sprinkler activation time is shown below:

From the ASET analysis above, the object is to find the time at which the criteria fails. First, the visibility within the gym, with the marker set to 10m (30 ft). It is found that the first exit that is blocked at roughly 200 seconds:
At 300 seconds, it is found that all the exits on the right side (east side), and the bottom left hand corner of the gym have failed the performance criteria, as shown below:
Total failure of the visibility criteria occurs at 446 seconds, as shown below:
As outlined above, the visibility levels for the gym do not meet the criteria outlined.

The second ASET criteria are the carbon monoxide levels within the area. Due to the large space, and there is a minimal amount of CO dispersion throughout the space. The CO levels are roughly $1/10^{th}$ of the ASET criteria of 1,400 PPM, as shown below:
While the marker shows bounded space that ‘exceeds’, it is still measured on a factor of $1/10^{th}$ less than the prescribed amount. Therefore, the CO criterion passes for this scenario.

The last criterion is the temperature within the space. Again, due to the large volume and nature of the area, the temperature at 300 seconds, when measured 2m above the finished floor, meets the criteria, as shown below:
The location of the fire reaches relatively high temperatures (above 180 deg C); however this is beneath the bleachers and not within the path of egress.

From the FDS output file, the total heat release rate for the fuel package [mats] is shown below. This very closely resembles the curve outlined in the fuel package section of this scenario.
From the output above, and the original ASET values, it is shown that 2 of the 3 criteria pass, while the visibility portion fails. Shown below is a chart of the visibility in the middle of the room to illustrate the failure. As shown, the visibility in the middle of the room sharply decreases around the time of RSET. The device that is measuring this is located in the center of the room on the x and y axis, and 2m above the floor (same as the height of the slice files).

![Graph](image)

**Figure 85 - Gym FDS Visibility in Middle of Room**

When a device is placed near the fire, it is found that the visibility in that area is drastically reduced (which would follow logically with the smoke density). Shown below is a chart outlining the visibility near the fire:
From the above *Required Safe Egress Time* the following is a chart showing the total time of 300 seconds:

![Gym Visibility - Near Fire](image)

*Figure 86 - Gym FDS Visibility Near Fire*

![RSET - Gym Scenario](image)

*Figure 87 - Gym RSET*
Based on the FDS modeling, below is a comparison between the *Available Safe Egress Time* and the *Required Safe Egress Time*:

![ASET vs. RSET](image)

*Figure 88 - Gym ASET vs. RSET*

As shown above and outlined previously, the visibility fails the required egress time. This will need to be evaluated by the building owners and stakeholders to evaluate what corrections need to be made to Gym to prevent this from happening. Below are a few bullet points of possible corrections:

- Enforce International Fire Code [304.1.3] criteria for not allowing for storage of mats under bleachers.
- Provide an NFPA 92 compliant smoke control system for the area to keep smoke layer above 2m (costly).
- Limit the number of occupants in the area [not realistic].
Ongoing Compliance

During the course of the building life, it is expected that the owner maintain the building systems (fire alarm, fire protection, etc.) in order to ensure the continued performance of the building. It is imperative that these guidelines and requirements be followed; the owner is ultimately responsible for the overall function and operation of the building.

These compliance requirements are in the form of annual testing; NFPA 13 & 72 ITM requirements, and ensuring that the overall integrity of the passive fire protection systems in the building remains intact. Due diligence for building owners in terms of maintaining the building systems is an important aspect to the overall safety of the building.
CONCLUSION

This report briefly outlines the prescriptive and performance requirements for the Adams 14 High School, and any modifications to the code that are mentioned above.

Should there be any questions, comments or concerns, please feel free to contact me at:

Todd L. Brand  
Mechanical / Fire Protection  
BCER Engineering, Inc.  
303-422-7400 (w)  
720-560-1334 (m)

Appendices

Appendix A – Life Safety Sheets  
Appendix B – Fire Alarm Design Sheets  
Appendix C – Fire Alarm As-Built Sheets  
Appendix D – Fire Sprinkler Sheets  
Appendix E – FDS Input File for Theatre Scenario  
Appendix F – FDS Output File for Theatre Scenario  
Appendix G – FDS Input File for Gym Scenario  
Appendix H – FDS Output File for Gym Scenario  
Appendix I – Computer Based Evacuation  
Appendix J – Fire Safety and Evacuation Plans
References


ICC/ANSI A117.1 Handicapped Accessibility Standards – 1998


ASHRAE / IESNA Standard 90.1-1999

CalPoly MSFPE Slides
Appendix A – Life Safety Sheets

Sheets A4.01 – A4.24
Appendix B – Fire Alarm Design Sheets

Sheets FA1.0 – FA5.01
Appendix C – Fire Alarm As-Built Sheets

Sheets FA-000 – FA-701
ADAMS COUNTY SCHOOL DISTRICT #14
HIGH SCHOOL/COMMUNITY LEARNING CENTER
FIRE ALARM SYSTEM

SITE: ADAMS COUNTY SCHOOL #14
7200 QUEBEC PARKWAY
COMMERCCE CITY, CO 80022

GENERAL CONTRACTOR
ADOLFSON & PETERSON CONSTRUCTION
797 VENTURA ST.
AURORA, CO 80011
PHONE: 303-363-7101

INSTALLER
ENCORE ELECTRIC
2107 W COLLEGE AVE
ENGLEWOOD, CO 80110
PHONE: 303-934-1234
FAX: 303-937-8900
CONTACT: DANIEL REIPLER

6240 SMITH ROAD
DENVER, CO 80216
SALES: 720-941-2210
SERVICE: 720-941-2210
FAX: 303-355-0615
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**Table Notes:**
- All changes must be documented in the change log section.
- Each change must include the reason for the change and a description of the change.

**Important Notice:**
- All rights reserved by SimpleGrinnell LP, 2006.
Appendix D - Fire Sprinkler Sheets

Sheets FP4.01 – FP4.24
Appendix E – FDS Input File for Theatre Scenario

FDS Input File for Theatre Scenario
Final Project - Theatre
This is the final FDS model for the theatre scenario for the final project. Refer to the LSR for the parameters of the scenario.

This run is with the four stacks of chairs, and assuming that radiant ignition will ignite the other stacks, or that the sprinkler will control it. The HRR was capped when the sprinkler activated, and then resumed when the HRR hit the same level on the rise as the descent to simulate the loss of mass.

This is with multiple fuel packages (sets of chairs) in the storage room.

**************************************************
&HEAD CHID='Final Project Theatre' /

&TIME T_END= 1200.0/

&MESH ID='1', IJK=190,135,50, XB=-4.0,34.0, 0.0,27.0, 0.0,10.0/

This is 0.2M resolution.

&REAC ID='POLYPROPYLENE',
  C=3.0,
  H=6.0,
  O=0.0,
  N=0.0,
  HEAT_OF_COMBUSTION=43400,
  CO_YIELD=0.0240,
  SOOT_YIELD=0.059,
  IDEAL=.TRUE. /

  MASS_EXTINCTION_COEFFICIENT=8.70E3,
  VISIBILITY_FACTOR=3.0/

This is from SFPE 3rd Ed., Table 3-4.14, pg 3-112

&MATL ID='YELLOW PINE',
  FYI = 'Quintiere, Fire Behavior - NIST NRC Validation',
  SPECIFIC_HEAT = 2.85,
  CONDUCTIVITY = 0.1400,
  DENSITY = 640.0/

&MATL ID='GYPSUM PLASTER',
  FYI='Quintiere, Fire Behavior',
  CONDUCTIVITY = 0.48,
  SPECIFIC_HEAT = 0.84,
  DENSITY = 1440.0/
&MATL_ID = 'CONCRETE',
  CONDUCTIVITY = 1.0,
  SPECIFIC_HEAT = 0.88,
  DENSITY = 2100.0 /

&MATL_ID = 'CHAIR',
  CONDUCTIVITY = 0.2,
  SPECIFIC_HEAT = 2.2,
  DENSITY = 930.0 /

&SURF_ID = 'WOOD',
  COLOR = 'SLATE GRAY',
  MATL_ID = 'YELLOW PINE',
  THICKNESS = 0.2,
  BURN_AWAY = .TRUE. /

&SURF_ID = 'WALL',
  COLOR = 'WHITE',
  MATL_ID = 'GYPSUM PLASTER',
  THICKNESS = 0.2 /

&SURF_ID = 'FLOOR',
  COLOR = 'BURLY WOOD',
  MATL_ID = 'CONCRETE',
  THICKNESS = 0.2 /

&SURF_ID = 'SEATS',
  COLOR = 'NAVY',
  MATL_ID = 'CONCRETE',
  THICKNESS = 0.2 /

&SURF_ID = 'CHAIRS',
  COLOR = 'GREEN',
  MATL_ID = 'CHAIR',
  THICKNESS = 0.2,
  HRRPUA = 1800,
  IGNITION_TEMPERATURE = 300,
  RAMP_Q = 'tsquared',
  BURN_AWAY = .TRUE. /

*******************************************************************************
FIRE - THIS IS 1 STACK OF CHAIRS - ASSUMED 1M X 1M IN DIMENSIONS
- LOCATED IN CORNER OF STORAGE ROOM - THERE ARE FOUR STACKS OF
CHAIRS FOR THIS SCENARIO... CAN THE ONE SPRINKLER CONTAIN THIS?

&SURF_ID = 'Burner',
  RAMP_Q = 'tsquared',
  HRRPUA = 1800.0,
  COLOR = 'RED' /

&RAMP_ID = 'tsquared', T = 0.0, F = 0.001 /
&RAMP_ID = 'tsquared', T = 50.0, F = 0.001 /
&RAMP ID='tsquared', T= 100.0, F=0.001 /
&RAMP ID='tsquared', T= 150.0, F=0.001 /
&RAMP ID='tsquared', T= 200.0, F=0.01 /
&RAMP ID='tsquared', T= 250.0, F=0.01 /
&RAMP ID='tsquared', T= 300.0, F=0.02 /
&RAMP ID='tsquared', T= 350.0, F=0.02 /
&RAMP ID='tsquared', T= 400.0, F=0.03 /
&RAMP ID='tsquared', T= 450.0, F=0.04 /
&RAMP ID='tsquared', T= 500.0, F=0.02 /
&RAMP ID='tsquared', T= 525.0, F=0.28 /
&RAMP ID='tsquared', T= 550.0, F=0.33 /
&RAMP ID='tsquared', T= 600.0, F=0.83 /
&RAMP ID='tsquared', T= 650.0, F=1.00 /
&RAMP ID='tsquared', T= 700.0, F=0.56 /
&RAMP ID='tsquared', T= 750.0, F=0.50 /
&RAMP ID='tsquared', T= 800.0, F=0.33 /
&RAMP ID='tsquared', T= 850.0, F=0.17 /
&RAMP ID='tsquared', T= 900.0, F=0.06 /
&RAMP ID='tsquared', T= 950.0, F=0.01 /
&RAMP ID='tsquared', T= 1000.0, F=0.00 /
&RAMP ID='tsquared', T= 1050.0, F=0.00 /
&RAMP ID='tsquared', T= 1100.0, F=0.00 /
&RAMP ID='tsquared', T= 1150.0, F=0.00 /

&OBST XB=-4.0,-3.0, 0.0,1.0, 2.5,3.5, SURF_IDS='Burner','INERT','INERT' /
&OBST XB=-2.0,-1.0, 0.0,1.0, 2.5,3.5, SURF_ID='CHAIRS' /
&OBST XB=-4.0,-3.0, 2.0,3.0, 2.5,3.5, SURF_ID='CHAIRS' /
&OBST XB=-2.0,-1.0, 2.0,3.0, 2.5,3.5, SURF_ID='CHAIRS' /

THEATRE OBSTRUCTIONS

LOWER STORAGE ROOM
&OBST XB=-4.0,0.0, 0.0,5.2, 0.0,2.5, SURF_ID='WALL' /
&OBST XB=-4.0,0.0, 0.0,5.2, 5.5,10.0, SURF_ID='WALL' /
&OBST XB=-0.3,0.0, 0.0,5.2, 2.5,5.5, SURF_ID='WALL' /

MIDDLE STORAGE ROOM
&OBST XB=-4.0,0.0, 7.8,19.2, 0.0,10.0, SURF_ID='WALL' /

UPPER STORAGE ROOM
&OBST XB=-4.0,0.0, 21.8,27.0, 0.0,10.0, SURF_ID='WALL' /

UPPER EXIT
&OBST XB=12.2,21.1, 25.2,25.5, 2.5,10.0, SURF_ID='WALL' /
&OBST XB=20.8,21.1, 25.5,27.0, 2.5,10.0, SURF_ID='WALL' /

LOWER EXIT
&OBST XB=12.2,21.1, 1.5,1.8, 2.5,10.0, SURF_ID='WALL' /
OBST XB=20.8, 21.1, 0.0, 1.5, 2.5, 10.0, SURF_ID='WALL'/
FRONT STAGE
&OBST XB=22.2, 25.5, 4.2, 22.8, 0.0, 3.5, SURF_ID='WOOD'/
REAR STAGE
&OBST XB=25.6, 34.0, 0.0, 27.0, 0.0, 3.5, SURF_ID='WOOD'/
UPPER STAGE DIVIDING WALL
&OBST XB=25.4, 25.7, 21.2, 27.0, 3.5, 10.0, SURF_ID='WALL'/
&OBST XB=25.4, 25.7, 22.8, 27.0, 0.0, 3.5, SURF_ID='WALL'/
LOWER STAGE DIVIDING WALL
&OBST XB=25.4, 25.7, 0.0, 5.8, 3.5, 10.0, SURF_ID='WALL'/
&OBST XB=25.4, 25.7, 0.0, 4.2, 0.0, 3.5, SURF_ID='WALL'/
FLOOR LOWER VOMITORY
&OBST XB=0.0, 3.6, 0.0, 7.8, 0.0, 2.5, SURF_ID='FLOOR'/
&OBST XB=-4.0, 0.0, 5.2, 7.8, 0.0, 2.5, SURF_ID='FLOOR'/
FLOOR UPPER VOMITORY
&OBST XB=0.0, 3.6, 19.2, 27.0, 0.0, 2.5, SURF_ID='FLOOR'/
&OBST XB=-4.0, 0.0, 19.2, 27.0, 0.0, 2.5, SURF_ID='FLOOR'/
FLOOR MIDSECTION
&OBST XB=3.6, 12.2, 0.0, 27.0, 0.0, 2.5, SURF_ID='FLOOR'/
FLOOR LOWER EXIT
&OBST XB=12.2, 21.1, 0.0, 1.8, 0.0, 2.5, SURF_ID='FLOOR'/
FLOOR UPPER EXIT
&OBST XB=12.2, 21.1, 25.2, 27.0, 0.0, 2.5, SURF_ID='FLOOR'/
LOWER SEATS
&OBST XB=12.2, 20.2, 1.8, 25.2, 0.0, 0.5, SURF_ID='SEATS'/
&OBST XB=12.2, 18.6, 1.8, 25.2, 0.5, 1.0, SURF_ID='SEATS'/
&OBST XB=12.2, 17.0, 1.8, 25.2, 1.0, 1.50, SURF_ID='SEATS'/
&OBST XB=12.2, 15.4, 1.8, 25.2, 1.5, 2.0, SURF_ID='SEATS'/
&OBST XB=12.2, 13.8, 1.8, 25.2, 2.0, 2.5, SURF_ID='SEATS'/
UPPER SEATS - BOTTOM
&OBST XB=0.0, 8.86, 0.0, 5.2, 2.5, 3.0, SURF_ID='SEATS'/
&OBST XB=0.0, 7.26, 0.0, 5.2, 3.0, 3.5, SURF_ID='SEATS'/
&OBST XB=0.0, 5.66, 0.0, 5.2, 3.5, 4.0, SURF_ID='SEATS'/
&OBST XB=0.0, 4.06, 0.0, 5.2, 4.0, 4.5, SURF_ID='SEATS'/
&OBST XB=0.0, 2.46, 0.0, 5.2, 4.5, 5.0, SURF_ID='SEATS'/
&OBST XB=0.0, 0.86, 0.0, 5.2, 5.0, 5.5, SURF_ID='SEATS'/
UPPER SEATS - MIDDLE
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&OBST XB=0.0, 7.26, 7.8, 19.2, 3.0, 3.5, SURF_ID='SEATS'/
&OBST XB=0.0, 5.66, 7.8, 19.2, 3.5, 4.0, SURF_ID='SEATS'/
&OBST XB=0.0, 4.06, 7.8, 19.2, 4.0, 4.5, SURF_ID='SEATS'/
&OBST XB=0.0, 2.46, 7.8, 19.2, 4.5, 5.0, SURF_ID='SEATS'/
UPPER SEATS - UPPER
&OBST XB=0.0, 8.86, 21.8, 27.0, 2.5, 3.0, SURF_ID='SEATS'/
&OBST XB=0.0, 7.26, 21.8, 27.0, 3.0, 3.5, SURF_ID='SEATS'/
**SMOKE DETECTOR**

&PROP ID='Smoke Detector',
   QUANTITY='CHAMBER OBSCURATION',
   ALPHA_E=1.8,
   BETA_E=-1.0,
   ALPHA_C=1.0,
   BETA_C=-0.80,
   ACTIVATION_OBSCURATION=10.0 /

Storage Room Smoke Detector
&DEVIC ID='SD_1',
   PROP_ID='Smoke Detector',
   XYZ=-2.4,4.2,5.4, LATCH=.FALSE./

Vomitory Smoke Detector
&DEVIC ID='SD_2',
   PROP_ID='Smoke Detector',
   XYZ=-2.0,6.5,9.99, LATCH=.FALSE./

**SPRINKLERS**

&PART ID='water drops',
   WATER=.TRUE.,
   AGE=5.00/

&PROP ID='K-5.6',
   QUANTITY='SPRINKLER LINK TEMPERATURE',
   RTI=50.,
   C_FACTOR=0.7,
   ACTIVATION_TEMPERATURE=68.,
   OFFSET=0.10,
   PART_ID='water drops',
   FLOW_RATE=189.3,
   DROPLET_VELOCITY=10.,
   SPRAY_ANGLE=30.,80. /

SPRINKLER SPACING IS ROUGHLY 14' X 14' OR 4.2M X 4.2M

STORAGE ROOM SPRINKLER
&DEVIC ID='SPR_STR', XYZ=-2.0,2.0,5.49, PROP_ID='K-5.6' /

OVERHEAD SPRINKLERS
&DEVIC ID='SPR_R1_1', XYZ=2.0, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_2', XYZ=6.2, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_3', XYZ=10.4, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_4', XYZ=14.6, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_5', XYZ=18.8, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_6', XYZ=23.0, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_7', XYZ=27.2, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R1_8', XYZ=31.4, 1.1, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R2_0', XYZ=-2.2, 6.5, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R2_1', XYZ=2.0, 5.3, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R2_2', XYZ=6.2, 5.3, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R2_3', XYZ=10.4, 5.3, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R2_4', XYZ=14.6, 5.3, 9.99, PROP_ID='K-5.6' /
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&DEVC ID='SPR_R2_7', XYZ=27.2, 5.3, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R2_8', XYZ=31.4, 5.3, 9.99, PROP_ID='K-5.6' /
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&DEVC ID='SPR_R4_1', XYZ=2.0, 13.7, 9.99, PROP_ID='K-5.6' /
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&DEVC ID='SPR_R4_3', XYZ=10.4, 13.7, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R4_4', XYZ=14.6, 13.7, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R4_5', XYZ=18.8, 13.7, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R4_6', XYZ=23.0, 13.7, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R4_7', XYZ=27.2, 13.7, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R4_8', XYZ=31.4, 13.7, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R5_1', XYZ=2.0, 17.9, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R5_2', XYZ=6.2, 17.9, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R5_3', XYZ=10.4, 17.9, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R5_4', XYZ=14.6, 17.9, 9.99, PROP_ID='K-5.6' /
&DEVC ID='SPR_R5_5', XYZ=18.8, 17.9, 9.99, PROP_ID='K-5.6' /
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Appendix F – FDS Output File for Theatre Scenario

FDS Output File for Theatre Scenario
Fire Dynamics Simulator

Compilation Date : Fri, 29 Oct 2010
Version          : 5.5.3 Serial

OpenMP Disabled

SVN Revision No. : 7031

Job TITLE        :
Job ID string    : Final Project Theatre

Grid Dimensions, Mesh 1

   Cells in the X Direction       76
   Cells in the Y Direction       54
   Cells in the Z Direction       20

Physical Dimensions, Mesh 1

   Length (m)               38.000
   Width (m)                27.000
   Height (m)               10.000
   Initial Time Step (s)    0.250

Miscellaneous Parameters

   Simulation Start Time (s)    0.0
   Simulation End Time (s)      1200.0
   LES Calculation
   Smagorinsky Constant        0.20
   Turbulent Prandtl Number    0.50
   Turbulent Schmidt Number    0.50
   Ambient Temperature (C)     20.00

Species Information

   WATER VAPOR
   Gas Species
   Molecular Weight (g/mol)    18.00
   Initial Mass Fraction       0.006

   MIXTURE_FRACTION_1
   Mixture Fraction Variable
   Initial Mass Fraction       0.000

   MIXTURE_FRACTION_2
Mixture Fraction Variable
Initial Mass Fraction 0.000

Gas Phase Reaction Information

Complete (CO2 Production) Reaction
Mixture Fraction Reaction
Molecular Weight, Fuel (g/mol) 42.00
Heat of Combustion (kJ/kg) 41175.
Stoich. Coeff., O_2 4.272
Stoich. Coeff., CO_2 2.759
Stoich. Coeff., H2O 2.989
Stoich. Coeff., Soot 0.227
Stoich. Coeff., CO 0.036
Stoich. Coeff., N_2 0.000
Stoichiometric Value of Z 0.067

Null (Extinction) Reaction
Mixture Fraction Reaction
Molecular Weight, Fuel (g/mol) 42.00
Heat of Combustion (kJ/kg) 0.
Stoich. Coeff., O_2 0.000
Stoich. Coeff., CO_2 0.000
Stoich. Coeff., H2O 0.000
Stoich. Coeff., Soot 0.000
Stoich. Coeff., CO 0.000
Stoich. Coeff., N_2 0.000
Stoichiometric Value of Z 1.000

Material Information

1 YELLOW PINE
Quintiere, Fire Behavior - NIST NRC Validation
Emissivity 0.900
Density (kg/m3) 640.0
Specific Heat (kJ/kg/K) 2.85
Conductivity (W/m/K) 0.1400

2 GYPSUM PLASTER
Quintiere, Fire Behavior
Emissivity 0.900
Density (kg/m3) 1440.0
Specific Heat (kJ/kg/K) 0.84
Conductivity (W/m/K) 0.4800

3 CONCRETE
Emissivity 0.900
Density (kg/m3) 2100.0
Specific Heat (kJ/kg/K) 0.88
Conductivity (W/m/K)  1.0000

4 CHAIR
Emissivity  0.900
Density (kg/m3)  930.0
Specific Heat (kJ/kg/K)  2.20
Conductivity (W/m/K)  0.2000

Surface Conditions

0 INERT (DEFAULT)
Wall or Vent Temperature (C)  20.0

1 WOOD
Material List
   1 YELLOW PINE
Layer 1
   Thickness (m):  0.20000
   Density (kg/m3):  640.00
   YELLOW PINE, Mass fraction:  1.00
Total surface density  128.000 kg/m2
Reaction products considered from the first  2.00 layers.
Solid Phase Nodes (m):
   0  0.00000
   1  0.00026
   2  0.00078
   3  0.00183
   4  0.00392
   5  0.00809
   6  0.01645
   7  0.03316
   8  0.06658
   9  0.13342
  10  0.16684
  11  0.18355
  12  0.19191
  13  0.19608
  14  0.19817
  15  0.19922
  16  0.19974
  17  0.20000
Back ing to void

2 WALL
Material List
   1 GYPSUM PLASTER
Layer 1
   Thickness (m):  0.20000
   Density (kg/m3):  1440.00
   GYPSUM PLASTER, Mass fraction:  1.00
Total surface density  288.000 kg/m2
Reaction products considered from the first 2.00 layers.

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Backing to void

3 FLOOR
Material List

1 CONCRETE

Layer 1
  Thickness (m): 0.20000
  Density (kg/m³): 2100.00
  CONCRETE, Mass fraction: 1.00

Total surface density 420.000 kg/m²

Reaction products considered from the first 2.00 layers.

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Backing to void

4 SEATS
Material List

1 CONCRETE

Layer 1
Thickness (m): 0.20000
Density (kg/m3): 2100.00
CONCRETE, Mass fraction: 1.00
Total surface density 420.000 kg/m2

Reaction products considered from the first 2.00 layers.

Solid Phase Nodes (m):
0 0.00000
1 0.00052
2 0.00157
3 0.00366
4 0.00785
5 0.01623
6 0.03298
7 0.06649
8 0.13351
9 0.16702
10 0.18377
11 0.19215
12 0.19634
13 0.19843
14 0.19948
15 0.20000

Backing to void

5 CHAIRS
Material List
1 CHAIR
Layer 1
Thickness (m): 0.20000
Density (kg/m3): 930.00
CHAIR, Mass fraction: 1.00
Total surface density 186.000 kg/m2

Reaction products considered from the first 2.00 layers.

Solid Phase Nodes (m):
0 0.00000
1 0.00026
2 0.00078
3 0.00183
4 0.00392
5 0.00809
6 0.01645
7 0.03316
8 0.06658
9 0.13342
10 0.16684
11 0.18355
12 0.19191
13 0.19608
14 0.19817
15 0.19922
16 0.19974
17 0.20000
Backing to void

HRR Per Unit Area (kW/m²)  1800.0

6 Burner
Wall or Vent Temperature (°C)  20.0
HRR Per Unit Area (kW/m²)  1800.0

7 OPEN
Passive Vent to Atmosphere

8 MIRROR
Symmetry Plane

9 INTERPOLATED

10 PERIODIC

11 HVAC

Device Properties

1 Smoke Detector
   Activation Obscuration (%/m)  10.00
   Alpha_c or L  1.00
   Beta_c  -0.80
   Alpha_e  1.80
   Beta_e  -1.00
   Smokeview ID smoke_detector

2 K-5.6
   RTI (m-s)^1/2  50.0
   C-Factor (m/s)^1/2  0.70
   Activation Temperature (°C)  68.0
   Flow Rate (L/min)  189.30
   K-Factor (L/min/atm**0.5)  10.00
   Particle Class water drops
   Smokeview ID sprinkler_pendent

Device Coordinates

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   ID: SD_1, Quantity: CHAMBER OBSCURATION
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   ID: SD_2, Quantity: CHAMBER OBSCURATION
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<td>14.60 26.30 9.99</td>
<td>SPR_R7_4</td>
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</table>
58 Coords: 18.80 26.30 9.99, Make: K-5.6, ID: SPR_R7_5, Quantity: SPRINKLER LINK TEMPERATURE
59 Coords: 23.00 26.30 9.99, Make: K-5.6, ID: SPR_R7_6, Quantity: SPRINKLER LINK TEMPERATURE
60 Coords: 27.20 26.30 9.99, Make: K-5.6, ID: SPR_R7_7, Quantity: SPRINKLER LINK TEMPERATURE
61 Coords: 31.40 26.30 9.99, Make: K-5.6, ID: SPR_R7_8, Quantity: SPRINKLER LINK TEMPERATURE
62 Coords: 17.00 13.50 6.25, Make: null, ID: Layer Height Middle, Quantity: LAYER HEIGHT
63 Coords: 17.00 13.50 5.50, Make: null, ID: Temp Middle, Quantity: TEMPERATURE
64 Coords: 17.00 13.50 5.50, Make: null, ID: CO Middle, Quantity: VOLUME FRACTION
65 Coords: 17.00 13.50 5.50, Make: null, ID: Visibility Middle, Quantity: VISIBILITY

PLOT3D Information

Sampling Interval (s) 240.0
1 Quantity: TEMPERATURE
2 Quantity: U-VELOCITY
3 Quantity: V-VELOCITY
4 Quantity: W-VELOCITY
5 Quantity: HRRPV

Slice File Information, Mesh 1

Sampling Interval (s) 1.200
1 Nodes: 42 42 0 54 0 20, Quantity: TEMPERATURE
2 Nodes: 4 4 0 54 0 20, Quantity: TEMPERATURE
3 Nodes: 0 76 26 26 0 20, Quantity: TEMPERATURE
4 Nodes: 0 76 12 12 0 20, Quantity: TEMPERATURE
5 Nodes: 0 76 0 54 11 11, Quantity: TEMPERATURE
6 Nodes: 0 76 0 54 4 4, Quantity: TEMPERATURE
7 Nodes: 42 42 0 54 0 20, Quantity: SOOT VISIBILITY
8 Nodes: 0 76 26 26 0 20, Quantity: SOOT VISIBILITY
9 Nodes: 0 76 0 54 11 11, Quantity: SOOT VISIBILITY
10 Nodes: 0 76 0 54 4 4, Quantity: SOOT VISIBILITY
11 Nodes: 42 42 0 54 0 20, Quantity: CARBON MONOXIDE VOLUME FRACTION
12 Nodes: 0 76 26 26 0 20, Quantity: CARBON MONOXIDE VOLUME FRACTION
13 Nodes: 0 76 0 54 11 11, Quantity: CARBON MONOXIDE VOLUME FRACTION
14 Nodes: 0 76 0 54 4 4, Quantity: CARBON MONOXIDE VOLUME FRACTION
Radiation Model Information

Number of control angles  104
Time step increment         3
Angle increment             5
Theta band N_phi   Solid angle
1:        4  0.12
2:       12  0.11
3:       16  0.13
4:       20  0.12
5:       20  0.12
6:       16  0.13
7:       12  0.11
8:        4  0.12

Using gray gas absorption.
Mean beam length  2.500 m

Run Time Diagnostics

Time Step       1   May 17, 2013  23:07:29
----------------------------------------------
CPU/step:     0.967 s, Total CPU:      0.97 s
Time step:  0.25000 s, Total time:     0.25 s
Max CFL number:  0.94E-02 at ( 63, 35, 13)
Max divergence:  0.12E-05 at ( 56, 14, 15)
Min divergence: -0.13E-05 at ( 40, 42, 16)

Time Step       2   May 17, 2013  23:07:29
----------------------------------------------
CPU/step:     0.343 s, Total CPU:      1.31 s
Time step:  0.25000 s, Total time:     0.50 s
Max CFL number:  0.94E-02 at ( 25,  3, 13)
Max divergence:  0.13E-03 at (  2,  2,  8)
Min divergence: -0.13E-05 at ( 40, 42, 16)
Total Heat Release Rate:              0.012 kW

Time Step       3   May 17, 2013  23:07:30
----------------------------------------------
CPU/step:     0.265 s, Total CPU:      1.58 s
Time step:  0.25000 s, Total time:     0.75 s
Max CFL number:  0.93E-02 at ( 25,  3, 13)
Max divergence:  0.25E-03 at (  2,  2,  8)
Min divergence: -0.14E-05 at ( 40, 42, 16)
Total Heat Release Rate:              0.025 kW

Time Step       4   May 17, 2013  23:07:30
----------------------------------------------
CPU/step:     0.437 s, Total CPU:      2.01 s
Time step:  0.25000 s, Total time:     1.00 s
Max CFL number: 0.93E-02 at (25, 3, 13)
Max divergence: 0.36E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.037 kW

Time Step 5 May 17, 2013 23:07:30
------------------------------------------------------------------
CPU/step: 0.296 s, Total CPU: 2.31 s
Time step: 0.25000 s, Total time: 1.25 s
Max CFL number: 0.93E-02 at (25, 3, 13)
Max divergence: 0.48E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.049 kW

Time Step 6 May 17, 2013 23:07:31
------------------------------------------------------------------
CPU/step: 0.312 s, Total CPU: 2.62 s
Time step: 0.25000 s, Total time: 1.50 s
Max CFL number: 0.92E-02 at (25, 3, 13)
Max divergence: 0.38E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.060 kW
Radiation Loss to Boundaries: 0.009 kW

Time Step 7 May 17, 2013 23:07:31
------------------------------------------------------------------
CPU/step: 0.406 s, Total CPU: 3.03 s
Time step: 0.25000 s, Total time: 1.75 s
Max CFL number: 0.92E-02 at (25, 3, 13)
Max divergence: 0.45E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.072 kW
Radiation Loss to Boundaries: 0.011 kW

Time Step 8 May 17, 2013 23:07:31
------------------------------------------------------------------
CPU/step: 0.281 s, Total CPU: 3.31 s
Time step: 0.25000 s, Total time: 2.00 s
Max CFL number: 0.92E-02 at (25, 3, 13)
Max divergence: 0.51E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.083 kW
Radiation Loss to Boundaries: 0.012 kW

Time Step 9 May 17, 2013 23:07:32
------------------------------------------------------------------
CPU/step: 0.296 s, Total CPU: 3.60 s
Time step: 0.25000 s, Total time: 2.25 s
Max CFL number: 0.91E-02 at (25, 3, 13)
Max divergence: 0.58E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.095 kW
Radiation Loss to Boundaries: 0.014 kW

Time Step 10 May 17, 2013 23:07:32

CPU/step: 0.468 s, Total CPU: 4.07 s
Time step: 0.25000 s, Total time: 2.50 s
Max CFL number: 0.91E-02 at (25, 3, 13)
Max divergence: 0.64E-03 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.106 kW
Radiation Loss to Boundaries: 0.023 kW

Time Step 20 May 17, 2013 23:07:36

CPU/step: 0.343 s, Total CPU: 7.50 s
Time step: 0.25000 s, Total time: 5.00 s
Max CFL number: 0.90E-02 at (75, 21, 18)
Max divergence: 0.14E-02 at (2, 2, 8)
Min divergence: -0.14E-05 at (40, 42, 16)
Total Heat Release Rate: 0.262 kW
Radiation Loss to Boundaries: 0.087 kW

Time Step 30 May 17, 2013 23:07:40

CPU/step: 0.363 s, Total CPU: 11.14 s
Time step: 0.25000 s, Total time: 7.50 s
Max CFL number: 0.25E-01 at (2, 2, 8)
Max divergence: 0.44E-02 at (2, 2, 8)
Min divergence: -0.15E-05 at (40, 42, 16)
Total Heat Release Rate: 0.883 kW
Radiation Loss to Boundaries: 0.295 kW

Time Step 40 May 17, 2013 23:07:44

CPU/step: 0.381 s, Total CPU: 14.94 s
Time step: 0.25000 s, Total time: 10.00 s
Max CFL number: 0.82E-01 at (2, 2, 8)
Max divergence: 0.10E-01 at (2, 1, 8)
Min divergence: -0.27E-04 at (3, 3, 8)
Total Heat Release Rate: 2.840 kW
Radiation Loss to Boundaries: 0.953 kW

Time Step 50 May 17, 2013 23:07:48

CPU/step: 0.374 s, Total CPU: 18.69 s
Time step: 0.25000 s, Total time: 12.50 s
Max CFL number: 0.16E+00 at (2, 1, 8)
Max divergence: 0.96E-02 at (1, 1, 8)
Min divergence: -0.79E-03 at (2, 2, 9)
Total Heat Release Rate: 3.753 kW
Radiation Loss to Boundaries: 1.242 kW
Time Step  60   May 17, 2013  23:07:52
-------------------------------------------- --
CPU/step: 0.417 s, Total CPU: 22.85 s
Time step: 0.25000 s, Total time: 15.00 s
Max CFL number: 0.30E+00 at ( 2, 1, 9)
Max divergence: 0.93E-02 at ( 1, 1, 9)
Min divergence: -0.56E-02 at ( 2, 1, 10)
Total Heat Release Rate: 3.120 kW
Radiation Loss to Boundaries: 0.969 kW

Time Step  70   May 17, 2013  23:07:56
-------------------------------------------- --
CPU/step: 0.404 s, Total CPU: 26.89 s
Time step: 0.25000 s, Total time: 17.50 s
Max CFL number: 0.27E+00 at ( 2, 0, 10)
Max divergence: 0.75E-02 at ( 1, 2, 8)
Min divergence: -0.74E-02 at ( 1, 1, 9)
Total Heat Release Rate: 1.840 kW
Radiation Loss to Boundaries: 0.551 kW

Time Step  80   May 17, 2013  23:08:00
-------------------------------------------- --
CPU/step: 0.381 s, Total CPU: 30.70 s
Time step: 0.25000 s, Total time: 20.00 s
Max CFL number: 0.34E+00 at ( 0, 1, 9)
Max divergence: 0.37E-02 at ( 2, 1, 8)
Min divergence: -0.34E-02 at ( 1, 1, 10)
Total Heat Release Rate: 1.362 kW
Radiation Loss to Boundaries: 0.426 kW

Time Step  90   May 17, 2013  23:08:04
-------------------------------------------- --
CPU/step: 0.359 s, Total CPU: 34.29 s
Time step: 0.25000 s, Total time: 22.50 s
Max CFL number: 0.24E+00 at ( 0, 4, 11)
Max divergence: 0.30E-02 at ( 2, 2, 8)
Min divergence: -0.15E-02 at ( 1, 5, 11)
Total Heat Release Rate: 1.066 kW
Radiation Loss to Boundaries: 0.348 kW

Time Step 100   May 17, 2013  23:08:08
-------------------------------------------- --
CPU/step: 0.360 s, Total CPU: 37.89 s
Time step: 0.25000 s, Total time: 25.00 s
Max CFL number: 0.19E+00 at ( 0, 5, 11)
Max divergence: 0.37E-02 at ( 2, 1, 8)
Min divergence: -0.11E-02 at ( 1, 7, 11)
Total Heat Release Rate: 1.290 kW
Radiation Loss to Boundaries: 0.417 kW

Time Step 200   May 17, 2013  23:08:48
-------------------------------------------- --
CPU/step: 0.371 s, Total CPU: 1.25 min
Time step: 0.250000 s, Total time: 50.00 s
Max CFL number: 0.25E+00 at (  1,  1, 10)
Max divergence: 0.73E-02 at (  1,  1,  8)
Min divergence: -0.16E-02 at (  1,  1, 11)
Total Heat Release Rate: 1.823 kW
Radiation Loss to Boundaries: 0.614 kW

Time Step 300   May 17, 2013  23:09:26
-------------------------------------------- --
CPU/step: 0.366 s, Total CPU: 1.86 min
Time step: 0.250000 s, Total time: 75.00 s
Max CFL number: 0.25E+00 at (  1,  1, 10)
Max divergence: 0.69E-02 at (  1,  1,  8)
Min divergence: -0.16E-02 at (  1,  1, 11)
Total Heat Release Rate: 1.802 kW
Radiation Loss to Boundaries: 0.640 kW

Time Step 400   May 17, 2013  23:10:04
-------------------------------------------- --
CPU/step: 0.368 s, Total CPU: 2.47 min
Time step: 0.250000 s, Total time: 100.00 s
Max CFL number: 0.25E+00 at (  9, 16, 20)
Max divergence: 0.68E-02 at (  1,  1,  8)
Min divergence: -0.16E-02 at (  1,  1, 11)
Total Heat Release Rate: 1.803 kW
Radiation Loss to Boundaries: 0.652 kW

Time Step 500   May 17, 2013  23:10:43
-------------------------------------------- --
CPU/step: 0.360 s, Total CPU: 3.07 min
Time step: 0.250000 s, Total time: 125.00 s
Max CFL number: 0.25E+00 at (  1,  1, 10)
Max divergence: 0.69E-02 at (  1,  1,  8)
Min divergence: -0.18E-02 at (  1,  1, 11)
Total Heat Release Rate: 1.813 kW
Radiation Loss to Boundaries: 0.679 kW

Time Step 600   May 17, 2013  23:11:20
-------------------------------------------- --
CPU/step: 0.362 s, Total CPU: 3.68 min
Time step: 0.250000 s, Total time: 150.00 s
Max CFL number: 0.25E+00 at (  0,  1, 10)
Max divergence: 0.68E-02 at (  1,  1,  8)
Min divergence: -0.17E-02 at (  1,  1, 11)
Total Heat Release Rate: 1.822 kW
Radiation Loss to Boundaries: 0.691 kW

Time Step 700   May 17, 2013  23:11:57
-------------------------------------------- --
CPU/step: 0.355 s, Total CPU: 4.27 min
Time step: 0.250000 s, Total time: 175.00 s
Max CFL number: 0.40E+00 at (1, 1, 10)
Max divergence: 0.29E-01 at (1, 1, 8)
Min divergence: -0.76E-02 at (1, 1, 11)
Total Heat Release Rate: 9.787 kW
Radiation Loss to Boundaries: 3.403 kW

Time Step 800  May 17, 2013  23:12:34
-------------------------------------------- --
CPU/step: 0.355 s, Total CPU: 4.86 min
Time step: 0.25000 s, Total time: 200.00 s
Max CFL number: 0.48E+00 at (1, 1, 10)
Max divergence: 0.53E-01 at (1, 1, 8)
Min divergence: -0.15E-01 at (1, 1, 11)
Total Heat Release Rate: 17.921 kW
Radiation Loss to Boundaries: 6.260 kW

-------------------------------------------- --
CPU/step: 0.358 s, Total CPU: 5.45 min
Time step: 0.25000 s, Total time: 225.00 s
Max CFL number: 0.49E+00 at (1, 1, 10)
Max divergence: 0.54E-01 at (1, 1, 8)
Min divergence: -0.16E-01 at (1, 1, 11)
Total Heat Release Rate: 17.991 kW
Radiation Loss to Boundaries: 6.477 kW

Time Step 1000  May 17, 2013  23:13:49
-------------------------------------------- --
CPU/step: 0.367 s, Total CPU: 6.07 min
Time step: 0.25000 s, Total time: 250.00 s
Max CFL number: 0.49E+00 at (1, 1, 10)
Max divergence: 0.55E-01 at (1, 1, 8)
Min divergence: -0.16E-01 at (1, 1, 11)
Total Heat Release Rate: 18.001 kW
Radiation Loss to Boundaries: 6.654 kW

Time Step 1100  May 17, 2013  23:14:27
-------------------------------------------- --
CPU/step: 0.363 s, Total CPU: 6.67 min
Time step: 0.25000 s, Total time: 275.00 s
Max CFL number: 0.53E+00 at (1, 1, 10)
Max divergence: 0.79E-01 at (2, 1, 8)
Min divergence: -0.20E-01 at (1, 1, 11)
Total Heat Release Rate: 26.995 kW
Radiation Loss to Boundaries: 9.865 kW

Time Step 1200  May 17, 2013  23:15:09
-------------------------------------------- --
CPU/step: 0.367 s, Total CPU: 7.28 min
Time step: 0.25000 s, Total time: 300.00 s
Max CFL number: 0.59E+00 at (1, 1, 10)
Max divergence: 0.11E+00 at (2, 1, 8)
Min divergence: -0.29E-01 at (  1,  1, 11)
Total Heat Release Rate: 35.949 kW
Radiation Loss to Boundaries: 13.151 kW

Time Step    1300   May 17, 2013  23:15:55
-------------------------------------------- --
CPU/step:     0.378 s, Total CPU:      7.91 min
Time step:  0.25000 s, Total time:   325.00 s
Max CFL number:  0.61E+00 at (  1,  1, 10)
Max divergence:  0.11E+00 at (  2,  1,  8)
Min divergence: -0.32E-01 at (  1,  1, 11)
Total Heat Release Rate: 36.003 kW
Radiation Loss to Boundaries: 13.492 kW

Time Step    1400   May 17, 2013  23:16:34
-------------------------------------------- --
CPU/step:     0.368 s, Total CPU:      8.53 min
Time step:  0.25000 s, Total time:   350.00 s
Max CFL number:  0.61E+00 at (  1,  1, 10)
Max divergence:  0.10E+00 at (  2,  1,  8)
Min divergence: -0.31E-01 at (  1,  1, 11)
Total Heat Release Rate: 35.993 kW
Radiation Loss to Boundaries: 13.833 kW

Time Step    1500   May 17, 2013  23:17:13
-------------------------------------------- --
CPU/step:     0.371 s, Total CPU:      9.14 min
Time step:  0.25000 s, Total time:   375.00 s
Max CFL number:  0.64E+00 at (  1,  1, 10)
Max divergence:  0.14E+00 at (  2,  1,  8)
Min divergence: -0.36E-01 at (  1,  1, 11)
Total Heat Release Rate: 44.966 kW
Radiation Loss to Boundaries: 17.183 kW

Time Step    1600   May 17, 2013  23:17:57
-------------------------------------------- --
CPU/step:     0.414 s, Total CPU:      9.83 min
Time step:  0.25000 s, Total time:   400.00 s
Max CFL number:  0.68E+00 at (  1,  1, 10)
Max divergence:  0.17E+00 at (  2,  1,  8)
Min divergence: -0.48E-01 at (  1,  1, 11)
Total Heat Release Rate: 54.090 kW
Radiation Loss to Boundaries: 20.675 kW

Time Step    1700   May 17, 2013  23:18:40
-------------------------------------------- --
CPU/step:     0.416 s, Total CPU:     10.53 min
Time step:  0.25000 s, Total time:   425.00 s
Max CFL number:  0.71E+00 at (  1,  1, 10)
Max divergence:  0.20E+00 at (  2,  1,  8)
Min divergence: -0.55E-01 at (  1,  1, 11)
Total Heat Release Rate: 63.183 kW
Radiation Loss to Boundaries: 24.280 kW

Time Step  1800   May 17, 2013  23:19:21

-------------------------------
CPU/step: 0.391 s, Total CPU: 11.18 min
Time step: 0.25000 s, Total time: 450.00 s
Max CFL number: 0.75E+00 at ( 1, 1, 10)
Max divergence: 0.23E+00 at ( 2, 1, 8)
Min divergence: -0.66E-01 at ( 1, 1, 11)
Total Heat Release Rate: 72.418 kW
Radiation Loss to Boundaries: 27.947 kW

Time Step  1900   May 17, 2013  23:20:02

-------------------------------
CPU/step: 0.392 s, Total CPU: 11.83 min
Time step: 0.20183 s, Total time: 474.01 s
Max CFL number: 0.90E+00 at ( 1, 1, 9)
Max divergence: 0.73E+00 at ( 2, 1, 8)
Min divergence: -0.18E+00 at ( 1, 1, 10)
Total Heat Release Rate: 226.787 kW
Radiation Loss to Boundaries: 81.133 kW


-------------------------------
CPU/step: 0.367 s, Total CPU: 12.44 min
Time step: 0.18129 s, Total time: 493.58 s
Max CFL number: 0.89E+00 at ( 2, 1, 8)
Max divergence: 0.10E+01 at ( 1, 2, 8)
Min divergence: -0.24E+00 at ( 2, 1, 11)
Total Heat Release Rate: 358.215 kW
Radiation Loss to Boundaries: 128.422 kW

Time Step  2100   May 17, 2013  23:21:18

-------------------------------
CPU/step: 0.369 s, Total CPU: 13.06 min
Time step: 0.16283 s, Total time: 510.47 s
Max CFL number: 0.99E+00 at ( 1, 1, 8)
Max divergence: 0.12E+01 at ( 1, 2, 8)
Min divergence: -0.29E+00 at ( 1, 1, 10)
Total Heat Release Rate: 444.632 kW
Radiation Loss to Boundaries: 161.556 kW


-------------------------------
CPU/step: 0.371 s, Total CPU: 13.68 min
Time step: 0.12949 s, Total time: 524.78 s
Max CFL number: 0.98E+00 at ( 1, 1, 8)
Max divergence: 0.16E+01 at ( 2, 1, 8)
Min divergence: -0.59E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 18525
Total Heat Release Rate: 478.035 kW
Radiation Loss to Boundaries: 166.273 kW
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<td>CPU/step:</td>
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<td>No. of Lagrangian Particles:</td>
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<td>Total Heat Release Rate:</td>
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<td>Radiation Loss to Boundaries:</td>
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<td>CPU/step:</td>
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<td>Min divergence:</td>
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<td>Min divergence:</td>
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<td>No. of Lagrangian Particles:</td>
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<tr>
<td>Max CFL number:</td>
<td>0.93E+00 at (1,1,8)</td>
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<tr>
<td>Max divergence:</td>
<td>0.16E+01 at (2,1,8)</td>
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<tr>
<td>Min divergence:</td>
<td>-0.45E+00 at (1,1,11)</td>
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No. of Lagrangian Particles: 23383
Total Heat Release Rate: 473.395 kW
Radiation Loss to Boundaries: 155.687 kW

Time Step 2800  May 17, 2013  23:25:57
-------------------------------------------- --
CPU/step: 0.388 s, Total CPU: 17.59 min
Time step: 0.12949 s, Total time: 602.48 s
Max CFL number: 0.91E+00 at ( 1, 1, 8)
Max divergence: 0.16E+01 at ( 2, 1, 8)
Min divergence: -0.51E+00 at ( 4, 4, 11)
No. of Lagrangian Particles: 23306
Total Heat Release Rate: 458.741 kW
Radiation Loss to Boundaries: 156.623 kW

Time Step 2900  May 17, 2013  23:26:37
-------------------------------------------- --
CPU/step: 0.390 s, Total CPU: 18.24 min
Time step: 0.12949 s, Total time: 615.43 s
Max CFL number: 0.90E+00 at ( 1, 1, 8)
Max divergence: 0.14E+01 at ( 2, 1, 8)
Min divergence: -0.46E+00 at ( 4, 4, 11)
No. of Lagrangian Particles: 23248
Total Heat Release Rate: 447.991 kW
Radiation Loss to Boundaries: 148.913 kW

Time Step 3000  May 17, 2013  23:27:17
-------------------------------------------- --
CPU/step: 0.388 s, Total CPU: 18.89 min
Time step: 0.12751 s, Total time: 628.10 s
Max CFL number: 0.93E+00 at ( 1, 1, 8)
Max divergence: 0.15E+01 at ( 2, 1, 8)
Min divergence: -0.53E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 23534
Total Heat Release Rate: 434.567 kW
Radiation Loss to Boundaries: 144.402 kW

-------------------------------------------- --
CPU/step: 0.383 s, Total CPU: 19.52 min
Time step: 0.12751 s, Total time: 640.85 s
Max CFL number: 0.85E+00 at ( 1, 1, 8)
Max divergence: 0.15E+01 at ( 2, 1, 8)
Min divergence: -0.41E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 23486
Total Heat Release Rate: 435.972 kW
Radiation Loss to Boundaries: 151.037 kW

Time Step 3200  May 17, 2013  23:28:36
-------------------------------------------- --
CPU/step: 0.378 s, Total CPU: 20.15 min
Time step: 0.12751 s, Total time: 653.60 s
Max CFL number: 0.89E+00 at ( 1, 1, 8)
Max divergence: 0.16E+01 at ( 2, 1, 8)
Min divergence: -0.51E+00 at ( 4, 4, 11)
No. of Lagrangian Particles: 23538
Total Heat Release Rate: 440.217 kW
Radiation Loss to Boundaries: 146.025 kW

Time Step 3300 May 17, 2013 23:29:15
-------------------------------------------- --
CPU/step: 0.382 s, Total CPU: 20.79 min
Time step: 0.12751 s, Total time: 666.35 s
Max CFL number: 0.85E+00 at ( 1, 1, 10)
Max divergence: 0.14E+01 at ( 2, 1, 8)
Min divergence: -0.47E+00 at ( 4, 4, 11)
No. of Lagrangian Particles: 23512
Total Heat Release Rate: 420.744 kW
Radiation Loss to Boundaries: 147.228 kW

Time Step 3400 May 17, 2013 23:29:56
-------------------------------------------- --
CPU/step: 0.398 s, Total CPU: 21.45 min
Time step: 0.12751 s, Total time: 679.10 s
Max CFL number: 0.90E+00 at ( 1, 1, 10)
Max divergence: 0.14E+01 at ( 2, 1, 8)
Min divergence: -0.52E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 23500
Total Heat Release Rate: 406.085 kW
Radiation Loss to Boundaries: 136.790 kW

Time Step 3500 May 17, 2013 23:30:36
-------------------------------------------- --
CPU/step: 0.393 s, Total CPU: 22.11 min
Time step: 0.12751 s, Total time: 691.85 s
Max CFL number: 0.80E+00 at ( 1, 1, 10)
Max divergence: 0.12E+01 at ( 2, 1, 8)
Min divergence: -0.51E+00 at ( 4, 4, 11)
No. of Lagrangian Particles: 23445
Total Heat Release Rate: 401.328 kW
Radiation Loss to Boundaries: 140.455 kW

Time Step 3600 May 17, 2013 23:31:18
-------------------------------------------- --
CPU/step: 0.403 s, Total CPU: 22.78 min
Time step: 0.14026 s, Total time: 705.85 s
Max CFL number: 0.90E+00 at ( 1, 1, 8)
Max divergence: 0.13E+01 at ( 2, 1, 8)
Min divergence: -0.45E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 23212
Total Heat Release Rate: 393.436 kW
Radiation Loss to Boundaries: 137.923 kW

-------------------------------------------- --
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<tr>
<th>Time Step</th>
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<td>Total Heat Release Rate: 387.822 kW</td>
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<td>Radiation Loss to Boundaries: 136.630 kW</td>
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<td>No. of Lagrangian Particles: 23305</td>
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<td>Total Heat Release Rate: 377.196 kW</td>
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<td>Radiation Loss to Boundaries: 133.179 kW</td>
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<td>No. of Lagrangian Particles: 22924</td>
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<tr>
<td>Total Heat Release Rate: 361.917 kW</td>
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<td>Radiation Loss to Boundaries: 132.727 kW</td>
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<td>CPU/step: 0.414 s, Total CPU: 25.45 min</td>
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<td>Max CFL number: 0.88E+00 at ( 5, 3, 11)</td>
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<td>Max divergence: 0.13E+01 at ( 2, 1, 8)</td>
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<td>Total Heat Release Rate: 361.917 kW</td>
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<td>Radiation Loss to Boundaries: 130.035 kW</td>
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<td>Time step: 0.13300 s, Total time: 774.28 s</td>
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<td>Max CFL number: 0.83E+00 at ( 1, 1, 10)</td>
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<tr>
<td>Max divergence: 0.12E+01 at ( 2, 1, 8)</td>
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<td>Min divergence: -0.35E+00 at ( 1, 1, 11)</td>
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<tr>
<td>No. of Lagrangian Particles: 23021</td>
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<td>Total Heat Release Rate: 354.542 kW</td>
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Radiation Loss to Boundaries: 126.604 kW

Time Step 4200 May 17, 2013 23:35:26
-------------------------------------------- --
CPU/step: 0.406 s, Total CPU: 26.81 min
Time step: 0.14435 s, Total time: 787.85 s
Max CFL number: 0.90E+00 at ( 1, 1, 10)
Max divergence: 0.12E+01 at ( 2, 1, 8)
Min divergence: -0.36E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 22759
Total Heat Release Rate: 345.193 kW
Radiation Loss to Boundaries: 124.385 kW

Time Step 4300 May 17, 2013 23:36:07
-------------------------------------------- --
CPU/step: 0.405 s, Total CPU: 27.48 min
Time step: 0.14435 s, Total time: 802.29 s
Max CFL number: 0.88E+00 at ( 1, 1, 10)
Max divergence: 0.12E+01 at ( 2, 1, 8)
Min divergence: -0.45E+00 at ( 4, 4, 11)
No. of Lagrangian Particles: 23059
Total Heat Release Rate: 336.524 kW
Radiation Loss to Boundaries: 121.165 kW

Time Step 4400 May 17, 2013 23:36:49
-------------------------------------------- --
CPU/step: 0.407 s, Total CPU: 28.16 min
Time step: 0.14435 s, Total time: 816.72 s
Max CFL number: 0.84E+00 at ( 1, 1, 10)
Max divergence: 0.12E+01 at ( 2, 1, 8)
Min divergence: -0.34E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 23129
Total Heat Release Rate: 327.938 kW
Radiation Loss to Boundaries: 118.234 kW

Time Step 4500 May 17, 2013 23:37:31
-------------------------------------------- --
CPU/step: 0.405 s, Total CPU: 28.83 min
Time step: 0.14435 s, Total time: 831.16 s
Max CFL number: 0.89E+00 at ( 5, 5, 10)
Max divergence: 0.11E+01 at ( 2, 1, 8)
Min divergence: -0.34E+00 at ( 1, 1, 11)
No. of Lagrangian Particles: 23120
Total Heat Release Rate: 313.761 kW
Radiation Loss to Boundaries: 113.012 kW

Time Step 4600 May 17, 2013 23:38:13
-------------------------------------------- --
CPU/step: 0.406 s, Total CPU: 29.51 min
Time step: 0.14435 s, Total time: 845.59 s
Max CFL number: 0.84E+00 at ( 1, 1, 10)
Max divergence: 0.11E+01 at ( 2, 1, 8)
Min divergence: -0.34E+00 at (  1,  1, 11)
No. of Lagrangian Particles:         23211
Total Heat Release Rate:            314.541 kW
Radiation Loss to Boundaries:       112.979 kW

Time Step    4700   May 17, 2013  23:38:53
-------------------------------------------- --
CPU/step:     0.388 s, Total CPU:     30.16 min
Time step:  0.15340 s, Total time:   860.26 s
Max CFL number:  0.87E+00 at (  4,  5, 10)
Max divergence:  0.89E+00 at (  2,  1,  8)
Min divergence: -0.35E+00 at (  4,  4, 11)
No. of Lagrangian Particles:         23054
Total Heat Release Rate:            265.596 kW
Radiation Loss to Boundaries:        97.369 kW

Time Step    4800   May 17, 2013  23:39:34
-------------------------------------------- --
CPU/step:     0.398 s, Total CPU:     30.82 min
Time step:  0.14061 s, Total time:   875.71 s
Max CFL number:  0.75E+00 at (  4,  5, 10)
Max divergence:  0.64E+00 at (  1,  1,  8)
Min divergence: -0.33E+00 at (  4,  4, 11)
No. of Lagrangian Particles:         23073
Total Heat Release Rate:            202.119 kW
Radiation Loss to Boundaries:        77.309 kW

Time Step    4900   May 17, 2013  23:40:14
-------------------------------------------- --
CPU/step:     0.389 s, Total CPU:     31.47 min
Time step:  0.16363 s, Total time:   890.91 s
Max CFL number:  0.90E+00 at (  5,  5, 10)
Max divergence:  0.51E+00 at (  1,  1,  8)
Min divergence: -0.19E+00 at (  4,  4, 11)
No. of Lagrangian Particles:         23172
Total Heat Release Rate:            151.805 kW
Radiation Loss to Boundaries:        62.100 kW

Time Step    5000   May 17, 2013  23:40:55
-------------------------------------------- --
CPU/step:     0.391 s, Total CPU:     32.12 min
Time step:  0.15901 s, Total time:   906.31 s
Max CFL number:  0.85E+00 at (  4,  5, 10)
Max divergence:  0.29E+00 at (  1,  1,  8)
Min divergence: -0.15E+00 at (  4,  4, 11)
No. of Lagrangian Particles:         22705
Total Heat Release Rate:            97.345 kW
Radiation Loss to Boundaries:        45.611 kW

Time Step    5100   May 17, 2013  23:41:37
-------------------------------------------- --
CPU/step:     0.404 s, Total CPU:     32.79 min
Time step: 0.14779 s, Total time: 921.67 s
Max CFL number: 0.90E+00 at (4, 5, 10)
Max divergence: 0.23E+00 at (2, 1, 8)
Min divergence: -0.13E+00 at (4, 4, 11)
No. of Lagrangian Particles: 23164
Total Heat Release Rate: 69.388 kW
Radiation Loss to Boundaries: 36.713 kW

---

CPU/step: 0.387 s, Total CPU: 33.44 min
Time step: 0.14713 s, Total time: 937.40 s
Max CFL number: 0.81E+00 at (5, 5, 9)
Max divergence: 0.12E+00 at (2, 1, 8)
Min divergence: -0.86E-01 at (4, 4, 11)
No. of Lagrangian Particles: 23200
Total Heat Release Rate: 40.829 kW
Radiation Loss to Boundaries: 27.699 kW

---

CPU/step: 0.387 s, Total CPU: 34.08 min
Time step: 0.14862 s, Total time: 952.77 s
Max CFL number: 0.75E+00 at (5, 5, 10)
Max divergence: 0.47E-01 at (2, 1, 8)
Min divergence: -0.26E-01 at (4, 4, 11)
No. of Lagrangian Particles: 23367
Total Heat Release Rate: 17.123 kW
Radiation Loss to Boundaries: 19.583 kW

Time Step 5400 May 17, 2013 23:43:39
---

CPU/step: 0.385 s, Total CPU: 34.72 min
Time step: 0.15499 s, Total time: 968.15 s
Max CFL number: 0.97E+00 at (4, 5, 9)
Max divergence: 0.27E-01 at (1, 2, 8)
Min divergence: -0.21E-01 at (4, 4, 11)
No. of Lagrangian Particles: 23228
Total Heat Release Rate: 11.547 kW
Radiation Loss to Boundaries: 17.383 kW

Time Step 5500 May 17, 2013 23:44:18
---

CPU/step: 0.381 s, Total CPU: 35.36 min
Time step: 0.15911 s, Total time: 983.90 s
Max CFL number: 0.91E+00 at (4, 5, 10)
Max divergence: 0.14E-01 at (2, 2, 8)
Min divergence: -0.14E-01 at (4, 4, 11)
No. of Lagrangian Particles: 23066
Total Heat Release Rate: 6.437 kW
Radiation Loss to Boundaries: 15.248 kW

24
Time Step    5600   May 17, 2013  23:44:58
-------------------------------------------- --
CPU/step:     0.388 s, Total CPU:     36.01 min
Time step:  0.15610 s, Total time:   999.60 s
Max CFL number:  0.98E+00 at (  4,  5, 10)
Max divergence:  0.38E-02 at (  3,  1, 11)
Min divergence: -0.70E-02 at (  4,  4, 11)
No. of Lagrangian Particles:         22919
Total Heat Release Rate:              0.323 kW
Radiation Loss to Boundaries:        12.812 kW

Time Step    5700   May 17, 2013  23:45:38
-------------------------------------------- --
CPU/step:     0.390 s, Total CPU:     36.66 min
Time step:  0.14399 s, Total time:  1014.95 s
Max CFL number:  0.90E+00 at (  5,  5, 10)
Max divergence:  0.42E-02 at (  1,  2, 11)
Min divergence: -0.42E-02 at (  5,  4, 11)
No. of Lagrangian Particles:         23451
Radiation Loss to Boundaries:        12.382 kW

Time Step    5800   May 17, 2013  23:46:18
-------------------------------------------- --
CPU/step:     0.387 s, Total CPU:     37.30 min
Time step:  0.16329 s, Total time:  1030.47 s
Max CFL number:  0.80E+00 at (  5,  5, 10)
Max divergence:  0.32E-02 at (  2,  1, 11)
Min divergence: -0.26E-02 at (  5,  4,  9)
No. of Lagrangian Particles:         22913
Radiation Loss to Boundaries:        11.944 kW

Time Step    5900   May 17, 2013  23:46:57
-------------------------------------------- --
CPU/step:     0.383 s, Total CPU:     37.94 min
Time step:  0.14193 s, Total time:  1045.96 s
Max CFL number:  0.91E+00 at (  4,  5, 10)
Max divergence:  0.29E-02 at (  2,  1, 11)
Min divergence: -0.39E-02 at (  4,  5, 10)
No. of Lagrangian Particles:         22771
Radiation Loss to Boundaries:        11.525 kW

Time Step    6000   May 17, 2013  23:47:36
-------------------------------------------- --
CPU/step:     0.377 s, Total CPU:     38.57 min
Time step:  0.16371 s, Total time:  1061.19 s
Max CFL number:  0.88E+00 at (  5,  5, 10)
Max divergence:  0.30E-02 at (  2,  1, 11)
Min divergence: -0.22E-02 at (  6,  5, 11)
No. of Lagrangian Particles:         22827
Radiation Loss to Boundaries:        11.129 kW

CPU/step: 0.431 s, Total CPU: 39.29 min
Time step: 0.15264 s, Total time: 1076.56 s
Max CFL number: 0.84E+00 at (4, 4, 10)
Max divergence: 0.31E-02 at (1, 2, 11)
Min divergence: -0.22E-02 at (4, 4, 10)
No. of Lagrangian Particles: 22851
Radiation Loss to Boundaries: 10.762 kW

Time Step 6200 May 17, 2013 23:49:10

CPU/step: 0.434 s, Total CPU: 40.01 min
Time step: 0.15693 s, Total time: 1091.97 s
Max CFL number: 0.94E+00 at (4, 5, 10)
Max divergence: 0.29E-02 at (1, 2, 11)
Min divergence: -0.21E-02 at (5, 4, 11)
No. of Lagrangian Particles: 22752
Radiation Loss to Boundaries: 10.404 kW


CPU/step: 0.440 s, Total CPU: 40.74 min
Time step: 0.16063 s, Total time: 1107.31 s
Max CFL number: 0.89E+00 at (4, 5, 9)
Max divergence: 0.27E-02 at (1, 2, 11)
Min divergence: -0.22E-02 at (4, 5, 10)
No. of Lagrangian Particles: 23210
Radiation Loss to Boundaries: 10.062 kW

Time Step 6400 May 17, 2013 23:50:41

CPU/step: 0.445 s, Total CPU: 41.48 min
Time step: 0.17149 s, Total time: 1122.65 s
Max CFL number: 0.92E+00 at (5, 5, 9)
Max divergence: 0.26E-02 at (2, 1, 11)
Min divergence: -0.16E-02 at (4, 6, 8)
No. of Lagrangian Particles: 22984
Radiation Loss to Boundaries: 9.736 kW

Time Step 6500 May 17, 2013 23:51:27

CPU/step: 0.439 s, Total CPU: 42.22 min
Time step: 0.15948 s, Total time: 1138.39 s
Max CFL number: 0.96E+00 at (5, 5, 9)
Max divergence: 0.28E-02 at (1, 2, 11)
Min divergence: -0.20E-02 at (5, 5, 9)
No. of Lagrangian Particles: 23123
Radiation Loss to Boundaries: 9.398 kW

Time Step 6600 May 17, 2013 23:52:12

CPU/step: 0.432 s, Total CPU: 42.94 min
Time step: 0.14716 s, Total time: 1153.55 s
Max CFL number: 0.82E+00 at ( 5, 5, 10)
Max divergence: 0.25E-02 at ( 2, 3, 11)
Min divergence: -0.21E-02 at ( 5, 4, 11)
No. of Lagrangian Particles: 23057
Radiation Loss to Boundaries: 9.089 kW

Time Step 6700 May 17, 2013 23:52:57
-------------------------------------------- --
CPU/step: 0.441 s, Total CPU: 43.67 min
Time step: 0.16330 s, Total time: 1168.66 s
Max CFL number: 0.94E+00 at ( 5, 5, 10)
Max divergence: 0.24E-02 at ( 2, 1, 11)
Min divergence: -0.14E-02 at ( 4, 4, 11)
No. of Lagrangian Particles: 23055
Radiation Loss to Boundaries: 8.803 kW

Time Step 6800 May 17, 2013 23:53:44
-------------------------------------------- --
CPU/step: 0.448 s, Total CPU: 44.42 min
Time step: 0.15116 s, Total time: 1183.83 s
Max CFL number: 0.82E+00 at ( 4, 4, 10)
Max divergence: 0.24E-02 at ( 1, 2, 11)
Min divergence: -0.19E-02 at ( 5, 4, 9)
No. of Lagrangian Particles: 23271
Radiation Loss to Boundaries: 8.526 kW

Time Step 6900 May 17, 2013 23:54:30
-------------------------------------------- --
CPU/step: 0.446 s, Total CPU: 45.16 min
Time step: 0.12960 s, Total time: 1199.15 s
Max CFL number: 0.73E+00 at ( 4, 4, 10)
Max divergence: 0.22E-02 at ( 2, 1, 11)
Min divergence: -0.17E-02 at ( 5, 5, 10)
No. of Lagrangian Particles: 22943
Radiation Loss to Boundaries: 8.250 kW

Time Step 6906 May 17, 2013 23:54:33
-------------------------------------------- --
CPU/step: 0.439 s, Total CPU: 45.21 min
Time step: 0.15681 s, Total time: 1200.02 s
Max CFL number: 0.86E+00 at ( 4, 5, 7)
Max divergence: 0.22E-02 at ( 2, 1, 11)
Min divergence: -0.17E-02 at ( 5, 5, 10)
No. of Lagrangian Particles: 23410
Radiation Loss to Boundaries: 8.235 kW

DEVICE Activation Times

1  SD_1  183.0 s
2  SD_2                             304.2 s
3  SPR_STR                          520.7 s
4  SPR_R1_1                      No Activation
5  SPR_R1_2                      No Activation
6  SPR_R1_3                      No Activation
7  SPR_R1_4                      No Activation
8  SPR_R1_5                      No Activation
9  SPR_R1_6                      No Activation
10 SPR_R1_7                      No Activation
11 SPR_R1_8                      No Activation
12 SPR_R2_0                      No Activation
13 SPR_R2_1                      No Activation
14 SPR_R2_2                      No Activation
15 SPR_R2_3                      No Activation
16 SPR_R2_4                      No Activation
17 SPR_R2_5                      No Activation
18 SPR_R2_6                      No Activation
19 SPR_R2_7                      No Activation
20 SPR_R2_8                      No Activation
21 SPR_R3_1                      No Activation
22 SPR_R3_2                      No Activation
23 SPR_R3_3                      No Activation
24 SPR_R3_4                      No Activation
25 SPR_R3_5                      No Activation
26 SPR_R3_6                      No Activation
27 SPR_R3_7                      No Activation
28 SPR_R3_8                      No Activation
29 SPR_R4_1                      No Activation
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31 SPR_R4_3                      No Activation
32 SPR_R4_4                      No Activation
33 SPR_R4_5                      No Activation
34 SPR_R4_6                      No Activation
35 SPR_R4_7                      No Activation
36 SPR_R4_8                      No Activation
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38 SPR_R5_2                      No Activation
39 SPR_R5_3                      No Activation
40 SPR_R5_4                      No Activation
41 SPR_R5_5                      No Activation
42 SPR_R5_6                      No Activation
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52 SPR_R6_7                      No Activation
53 SPR_R6_8                      No Activation
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55  SPR_R7_2                      No Activation
56  SPR_R7_3                      No Activation
57  SPR_R7_4                      No Activation
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61  SPR_R7_8                      No Activation

CPU Time Usage, Mesh 1

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Time Stepping Wall Clock Time (s): 2824.584
Total Elapsed Wall Clock Time (s): 2836.825

STOP: FDS completed successfully
Appendix G – FDS Input File for Gym Scenario

FDS Input File for Gym Scenario
Final Project - Gym
This is the final FDS model for the gym scenario for the final project. Refer to the LSR for the parameters of the scenario.

*****************************************************
&HEAD CHID='Final Project Gym'/

&TIME T_END= 800.0/

&MESH ID='1', IJK=70,80,20, XB=0.0,35.0, 0.0,40.0, 0.0,10.0/
This is a 0.5m resolution.

&REAC ID='POLYURETHANE FOAM',
  C=1.0,
  H=1.75,
  O=0.0,
  N=0.065,
  HEAT_OF_COMBUSTION=25300,
  CO_YIELD=0.025,
  SOOT_YIELD=0.104,
  MASS_EXTINCTION_COEFFICIENT=8.70E3,
  VISIBILITY_FACTOR=3.0,
  IDEAL=.TRUE. /

FYI this is from SFPE HB 3rd Ed. p3-112: GM35 - rigid poly foam

&MATL ID='PMMA',
  FYI='Drysdale, 3rd Ed. pg. 37',
  SPECIFIC_HEAT=1.42,
  CONDUCTIVITY=0.19,
  DENSITY=1190.0/

&MATL ID='POLY FOAM',
  FYI='Drysdale, 3rd Ed. pg. 37',
  SPECIFIC_HEAT=1.40,
  CONDUCTIVITY=0.034,
  DENSITY=20.0/

&SURF ID='BLEACHERS',
  COLOR='DARK SLATE GRAY',
  MATL_ID='PMMA',
  THICKNESS=0.2 /
  BURN_AWAY=.TRUE. /

&SURF ID='MAT',
  COLOR='ORANGE',
  MATL_ID='POLY FOAM',
  THICKNESS=0.2 /
  BURN_AWAY=.TRUE. /
FIRE - This is based on the NIST paper titled "Numerical Simulation of Fire Spread on Polyurethane Foam Slabs".

&SURF ID='Burner',
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SURF_IDS='Burner','MAT','MAT' /

GYM BLEACHERS

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&DEVC ID='SPR_R11_8', XYZ=24.5, 37.8, 9.9, PROP_ID='K-5.6' /
&DEVC ID='SPR_R11_9', XYZ=27.5, 37.8, 9.9, PROP_ID='K-5.6' /
&DEVC ID='SPR_R11_10', XYZ=30.5, 37.8, 9.9, PROP_ID='K-5.6' /
&DEVC ID='SPR_R11_11', XYZ=33.5, 37.8, 9.9, PROP_ID='K-5.6' /

*************************************************************
SLICE FILES
*************************************************************

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&SLCF QUANTITY='TEMPERATURE', PBY=20.0/
&SLCF QUANTITY='TEMPERATURE', PBZ=2.0/

&SLCF QUANTITY='visibility', PBX=17.5/
&SLCF QUANTITY='visibility', PBY=20.0/
&SLCF QUANTITY='visibility', PBZ=2.0/

&SLCF QUANTITY='carbon monoxide', PBX=17.5/
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*************************************************************
Layer Heights
*************************************************************

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&DEVC XB=17.5,17.5, 20.0,20.0, 0.0,15.0, QUANTITY='LAYER HEIGHT',
ID='Layer Height Middle Room' /

Temperature

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CO

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&DEVC XYZ=18.0, 20.0, 2.0, QUANTITY='carbon monoxide', ID='CO Middle Room' /

Visibility

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&DEVC XYZ=18.0, 20.0, 2.0, QUANTITY='visibility', ID='Visibility Middle Room' /

&TAIL /
Appendix H – FDS Output File for Gym Scenario

FDS Output File for Gym Scenario
Fire Dynamics Simulator

Compilation Date : Fri, 29 Oct 2010
Version          : 5.5.3 Serial

OpenMP Disabled

SVN Revision No. : 7031

Job TITLE        :
Job ID string    : Final Project Gym

Grid Dimensions, Mesh  1

Cells in the X Direction            70
Cells in the Y Direction            80
Cells in the Z Direction            20

Physical Dimensions, Mesh  1

Length (m)                       35.000
Width  (m)                       40.000
Height (m)                       10.000
Initial Time Step (s)            0.250

Miscellaneous Parameters

Simulation Start Time (s)            0.0
Simulation End Time (s)             800.0
LES Calculation
Smagorinsky Constant               0.20
Turbulent Prandtl Number            0.50
Turbulent Schmidt Number            0.50
Ambient Temperature (C)             20.00

Species Information

WATER VAPOR
Gas Species
Molecular Weight (g/mol)            18.00
Initial Mass Fraction              0.006

MIXTURE_FRACTION_1
Mixture Fraction Variable
Initial Mass Fraction              0.000

MIXTURE_FRACTION_2

1
Mixture Fraction Variable
Initial Mass Fraction 0.000

Gas Phase Reaction Information

Complete (CO2 Production) Reaction
Mixture Fraction Reaction
Molecular Weight, Fuel (g/mol) 14.66
Heat of Combustion (kJ/kg) 21553.
Stoich. Coeff., O_2 1.302
Stoich. Coeff., CO_2 0.861
Stoich. Coeff., H2O 0.868
Stoich. Coeff., Soot 0.140
Stoich. Coeff., CO 0.013
Stoich. Coeff., N_2 0.033
Stoichiometric Value of Z 0.076

Null (Extinction) Reaction
Mixture Fraction Reaction
Molecular Weight, Fuel (g/mol) 14.66
Heat of Combustion (kJ/kg) 0.
Stoich. Coeff., O_2 0.000
Stoich. Coeff., CO_2 0.000
Stoich. Coeff., H2O 0.000
Stoich. Coeff., Soot 0.000
Stoich. Coeff., CO 0.000
Stoich. Coeff., N_2 0.000
Stoichiometric Value of Z 1.000

Material Information

1 PMMA
Drysdale, 3rd Ed. pg. 37
Emissivity 0.900
Density (kg/m3) 1190.0
Specific Heat (kJ/kg/K) 1.42
Conductivity (W/m/K) 0.1900

2 POLY FOAM
Drysdale, 3rd Ed. pg. 37
Emissivity 0.900
Density (kg/m3) 20.0
Specific Heat (kJ/kg/K) 1.40
Conductivity (W/m/K) 0.0340

Surface Conditions

0 INERT (DEFAULT)
Wall or Vent Temperature (C) 20.0
1 BLEACHERS
   Material List
   1  PMMA

Layer 1
   Thickness (m): 0.20000
   Density (kg/m3): 1190.00
   PMMA, Mass fraction: 1.00
   Total surface density 238.000 kg/m2
   Reaction products considered from the first 2.00 layers.
   Solid Phase Nodes (m):
   0  0.00000
   1  0.00026
   2  0.00078
   3  0.00183
   4  0.00392
   5  0.00809
   6  0.01645
   7  0.03316
   8  0.06658
   9  0.13342
  10  0.16684
  11  0.18355
  12  0.19191
  13  0.19608
  14  0.19817
  15  0.19922
  16  0.19974
  17  0.20000

Backing to void

2 MAT
   Material List
   1  POLY FOAM

Layer 1
   Thickness (m): 0.20000
   Density (kg/m3): 20.00
   POLY FOAM, Mass fraction: 1.00
   Total surface density 4.000 kg/m2
   Reaction products considered from the first 2.00 layers.
   Solid Phase Nodes (m):
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   1  0.00105
   2  0.00316
   3  0.00737
   4  0.01579
   5  0.03263
   6  0.06632
   7  0.13342
   8  0.16737
   9  0.18421
  10  0.19263
11  0.19684
12  0.19895
13  0.20000
Backing to void

3 Burner
  Wall or Vent Temperature (C)  20.0
  HRR Per Unit Area (kW/m²)  2800.0

4 OPEN
  Passive Vent to Atmosphere

5 MIRROR
  Symmetry Plane

6 INTERPOLATED

7 PERIODIC

8 HVAC

Device Properties

1 K-5.6
  RTI (m-s)^1/2  50.0
  C-Factor (m/s)^1/2  0.70
  Activation Temperature (C)  57.0
  Flow Rate (L/min)  189.30
  K-Factor (L/min/atm**0.5)  10.00
  Particle Class  water drops
  Smokeview ID  sprinkler_pendent

Device Coordinates

1 Coords:  1.50  1.80  9.90, Make: K-5.6, ID: SPR_R1_0, Quantity: SPRINKLER LINK TEMPERATURE
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112 Coords:  9.50  34.20  9.90, Make: K-5.6, ID: SPR_R10_3, Quantity: SPRINKLER LINK TEMPERATURE
139 Coords:    34.00     1.00     2.00, Make: null, ID: Visibility Near Fire, Quantity: VISIBILITY
140 Coords:  18.00    20.00     2.00, Make: null, ID: Visibility Middle Room, Quantity: VISIBILITY

PLOT3D Information

Sampling Interval (s)             160.0
1 Quantity: TEMPERATURE
2 Quantity: U-VELOCITY
3 Quantity: V-VELOCITY
4 Quantity: W-VELOCITY
5 Quantity: HRRPUV

Slice File Information, Mesh     1

Sampling Interval (s)             0.800
1 Nodes:  35  35  0  80  0  20, Quantity: TEMPERATURE
2 Nodes:  0  70  40  40  0  20, Quantity: TEMPERATURE
3 Nodes:  0  70  0  80  4  4, Quantity: TEMPERATURE
4 Nodes:  35  35  0  80  4  4, Quantity: TEMPERATURE
5 Nodes:  0  70  40  40  0  20, Quantity: SOOT VISIBILITY
6 Nodes:  0  70  0  80  4  4, Quantity: SOOT VISIBILITY
7 Nodes:  35  35  0  80  0  20, Quantity: CARBON MONOXIDE
VOLUME FRACTION
8 Nodes:  0  70  40  40  0  20, Quantity: CARBON MONOXIDE
VOLUME FRACTION
9 Nodes:  0  70  0  80  4  4, Quantity: CARBON MONOXIDE
VOLUME FRACTION

Radiation Model Information

Number of control angles  104
Time step increment         3
Angle increment             5
Theta band N_phi Solid angle
1:     4  0.12
2:    12  0.11
3:    16  0.13
4:    20  0.12
5:    20  0.12
6:    16  0.13
7:    12  0.11
8:     4  0.12

Using gray gas absorption.
Mean beam length  2.500 m
Run Time Diagnostics

Time Step       1   May 10, 2013  21:51:39
-------------------------------------------- --
CPU/step:     1.466 s, Total CPU:  1.47 s
Time step:  0.250000 s, Total time:   0.25 s
Max CFL number:  0.97E-02 at ( 2, 22, 6)
Max divergence:  0.13E-05 at ( 69, 73, 10)
Min divergence: -0.13E-05 at ( 15, 59, 18)

Time Step       2   May 10, 2013  21:51:39
----------------------------------------------
CPU/step:     0.437 s, Total CPU:  1.90 s
Time step:  0.250000 s, Total time:   0.50 s
Max CFL number:  0.96E-02 at ( 2, 22, 6)
Max divergence:  0.73E-04 at ( 63, 2, 3)
Min divergence: -0.13E-05 at ( 15, 59, 18)
Total Heat Release Rate: 0.009 kW

Time Step       3   May 10, 2013  21:51:40
-------------------------------------------- --
CPU/step:     0.406 s, Total CPU:  2.31 s
Time step:  0.250000 s, Total time:   0.75 s
Max CFL number:  0.96E-02 at ( 2, 22, 6)
Max divergence:  0.18E-03 at ( 63, 2, 3)
Min divergence: -0.13E-05 at ( 15, 59, 18)
Total Heat Release Rate: 0.023 kW

Time Step       4   May 10, 2013  21:51:40
-------------------------------------------- --
CPU/step:     0.655 s, Total CPU:  2.96 s
Time step:  0.250000 s, Total time:  1.00 s
Max CFL number:  0.95E-02 at ( 2, 22, 6)
Max divergence:  0.32E-03 at ( 63, 2, 3)
Min divergence: -0.13E-05 at ( 15, 59, 18)
Total Heat Release Rate: 0.041 kW

Time Step       5   May 10, 2013  21:51:41
-------------------------------------------- --
CPU/step:     0.390 s, Total CPU:  3.35 s
Time step:  0.250000 s, Total time:  1.25 s
Max CFL number:  0.95E-02 at ( 2, 22, 6)
Max divergence:  0.50E-03 at ( 63, 2, 3)
Min divergence: -0.13E-05 at ( 15, 59, 18)
Total Heat Release Rate: 0.063 kW

Time Step       6   May 10, 2013  21:51:41
-------------------------------------------- --
CPU/step:     0.437 s, Total CPU:  3.79 s
Time step:  0.250000 s, Total time:  1.50 s
Max CFL number: 0.94E-02 at ( 2, 22, 6)
Max divergence: 0.51E-03 at ( 63, 1, 3)
Min divergence: -0.13E-05 at (15, 59, 18)
Total Heat Release Rate: 0.090 kW
Radiation Loss to Boundaries: 0.011 kW

Time Step 7 May 10, 2013 21:51:42
-------------------------------------------- --
CPU/step: 0.702 s, Total CPU: 4.49 s
Time step: 0.25000 s, Total time: 1.75 s
Max CFL number: 0.94E-02 at ( 2, 22, 6)
Max divergence: 0.63E-03 at ( 63, 2, 3)
Min divergence: -0.13E-05 at (15, 59, 18)
Total Heat Release Rate: 0.122 kW
Radiation Loss to Boundaries: 0.034 kW

Time Step 8 May 10, 2013 21:51:42
-------------------------------------------- --
CPU/step: 0.421 s, Total CPU: 4.91 s
Time step: 0.25000 s, Total time: 2.00 s
Max CFL number: 0.93E-02 at ( 2, 22, 6)
Max divergence: 0.81E-03 at ( 63, 2, 3)
Min divergence: -0.13E-05 at (15, 59, 18)
Total Heat Release Rate: 0.158 kW
Radiation Loss to Boundaries: 0.055 kW

Time Step 9 May 10, 2013 21:51:43
-------------------------------------------- --
CPU/step: 0.452 s, Total CPU: 5.37 s
Time step: 0.25000 s, Total time: 2.25 s
Max CFL number: 0.93E-02 at ( 2, 22, 6)
Max divergence: 0.10E-02 at ( 63, 2, 3)
Min divergence: -0.14E-05 at (15, 59, 18)
Total Heat Release Rate: 0.201 kW
Radiation Loss to Boundaries: 0.070 kW

Time Step 10 May 10, 2013 21:51:44
-------------------------------------------- --
CPU/step: 0.749 s, Total CPU: 6.12 s
Time step: 0.25000 s, Total time: 2.50 s
Max CFL number: 0.93E-02 at ( 2, 22, 6)
Max divergence: 0.12E-02 at ( 63, 2, 3)
Min divergence: -0.14E-05 at (15, 59, 18)
Total Heat Release Rate: 0.250 kW
Radiation Loss to Boundaries: 0.085 kW

Time Step 20 May 10, 2013 21:51:49
-------------------------------------------- --
CPU/step: 0.513 s, Total CPU: 11.25 s
Time step: 0.25000 s, Total time: 5.00 s
Max CFL number: 0.17E-01 at ( 63, 2, 3)
Max divergence: 0.13E-01 at ( 63, 2, 3)
<table>
<thead>
<tr>
<th>Time Step</th>
<th>Date</th>
<th>Time</th>
<th>CPU/step</th>
<th>Total CPU</th>
<th>Time step</th>
<th>Total time</th>
<th>Max CFL number</th>
<th>Max divergence</th>
<th>Min divergence</th>
<th>Total Heat Release Rate</th>
<th>Radiation Loss to Boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>May 10, 2013</td>
<td>21:51:54</td>
<td>0.524 s</td>
<td>16.49 s</td>
<td>0.25000 s</td>
<td>7.50 s</td>
<td>0.25E+00</td>
<td>0.15E+00</td>
<td>-0.30E-03</td>
<td>2.781 kW</td>
<td>0.953 kW</td>
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<tr>
<td>40</td>
<td>May 10, 2013</td>
<td>21:52:00</td>
<td>0.534 s</td>
<td>21.82 s</td>
<td>0.25000 s</td>
<td>10.00 s</td>
<td>0.52E+00</td>
<td>0.12E+00</td>
<td>-0.64E-01</td>
<td>54.501 kW</td>
<td>18.997 kW</td>
</tr>
<tr>
<td>50</td>
<td>May 10, 2013</td>
<td>21:52:05</td>
<td>0.538 s</td>
<td>27.21 s</td>
<td>0.25000 s</td>
<td>12.50 s</td>
<td>0.66E+00</td>
<td>0.15E+00</td>
<td>-0.30E-01</td>
<td>39.577 kW</td>
<td>12.165 kW</td>
</tr>
<tr>
<td>60</td>
<td>May 10, 2013</td>
<td>21:52:11</td>
<td>0.549 s</td>
<td>32.70 s</td>
<td>0.22204 s</td>
<td>14.92 s</td>
<td>0.93E+00</td>
<td>0.19E+00</td>
<td>-0.70E-01</td>
<td>57.661 kW</td>
<td>19.191 kW</td>
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<tr>
<td>70</td>
<td>May 10, 2013</td>
<td>21:52:16</td>
<td>0.557 s</td>
<td>38.27 s</td>
<td>0.19453 s</td>
<td>16.94 s</td>
<td>0.99E+00</td>
<td>0.21E+00</td>
<td>-0.83E-01</td>
<td>63.786 kW</td>
<td>19.191 kW</td>
</tr>
</tbody>
</table>
Radiation Loss to Boundaries: 21.110 kW

Time Step 80 May 10, 2013 21:52:21

CPU/step: 0.510 s, Total CPU: 43.37 s
Time step: 0.19453 s, Total time: 18.89 s
Max CFL number: 0.84E+00 at ( 65, 1, 16)
Max divergence: 0.24E+00 at ( 62, 1, 3)
Min divergence: -0.76E-01 at ( 65, 3, 4)
Total Heat Release Rate: 74.563 kW
Radiation Loss to Boundaries: 24.864 kW

Time Step 90 May 10, 2013 21:52:27

CPU/step: 0.526 s, Total CPU: 48.63 s
Time step: 0.21399 s, Total time: 20.93 s
Max CFL number: 0.94E+00 at ( 66, 1, 13)
Max divergence: 0.28E+00 at ( 62, 1, 3)
Min divergence: -0.78E-01 at ( 65, 3, 4)
Total Heat Release Rate: 82.315 kW
Radiation Loss to Boundaries: 27.483 kW

Time Step 100 May 10, 2013 21:52:32

CPU/step: 0.530 s, Total CPU: 53.93 s
Time step: 0.21399 s, Total time: 23.07 s
Max CFL number: 0.92E+00 at ( 67, 1, 14)
Max divergence: 0.30E+00 at ( 62, 1, 3)
Min divergence: -0.87E-01 at ( 65, 3, 4)
Total Heat Release Rate: 89.545 kW
Radiation Loss to Boundaries: 29.656 kW


CPU/step: 0.519 s, Total CPU: 1.76 min
Time step: 0.16478 s, Total time: 41.24 s
Max CFL number: 0.87E+00 at ( 67, 1, 15)
Max divergence: 0.53E+00 at ( 62, 1, 3)
Min divergence: -0.14E+00 at ( 66, 3, 4)
Total Heat Release Rate: 162.605 kW
Radiation Loss to Boundaries: 54.915 kW

Time Step 300 May 10, 2013 21:54:17

CPU/step: 0.523 s, Total CPU: 2.64 min
Time step: 0.13167 s, Total time: 56.06 s
Max CFL number: 0.88E+00 at ( 65, 1, 15)
Max divergence: 0.69E+00 at ( 62, 1, 3)
Min divergence: -0.24E+00 at ( 65, 3, 4)
Total Heat Release Rate: 217.489 kW
Radiation Loss to Boundaries: 75.128 kW
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<tr>
<td>CPU/step:</td>
<td>0.523 s, Total CPU: 3.51 min</td>
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<tr>
<td>Time step:</td>
<td>0.13704 s, Total time: 69.64 s</td>
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<tr>
<td>Max CFL number:</td>
<td>0.87E+00 at (66, 1, 16)</td>
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<tr>
<td>Max divergence:</td>
<td>0.86E+00 at (62, 1, 3)</td>
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<tr>
<td>Min divergence:</td>
<td>-0.36E+00 at (65, 3, 4)</td>
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<tr>
<td>Total Heat Release Rate:</td>
<td>276.155 kW</td>
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<tr>
<td>Radiation Loss to Boundaries:</td>
<td>94.087 kW</td>
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<table>
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<tr>
<th>Time Step</th>
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<tr>
<td>CPU/step:</td>
<td>0.522 s, Total CPU: 4.38 min</td>
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<td>Time step:</td>
<td>0.12135 s, Total time: 82.72 s</td>
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<tr>
<td>Max CFL number:</td>
<td>0.92E+00 at (65, 1, 15)</td>
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<tr>
<td>Max divergence:</td>
<td>0.99E+00 at (62, 1, 3)</td>
</tr>
<tr>
<td>Min divergence:</td>
<td>-0.35E+00 at (65, 3, 4)</td>
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<tr>
<td>Total Heat Release Rate:</td>
<td>320.505 kW</td>
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<tr>
<td>Radiation Loss to Boundaries:</td>
<td>109.351 kW</td>
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<tr>
<td>CPU/step:</td>
<td>0.520 s, Total CPU: 5.24 min</td>
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<tr>
<td>Time step:</td>
<td>0.12135 s, Total time: 94.86 s</td>
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<tr>
<td>Max CFL number:</td>
<td>0.82E+00 at (67, 1, 12)</td>
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<tr>
<td>Max divergence:</td>
<td>0.12E+01 at (62, 1, 3)</td>
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<tr>
<td>Min divergence:</td>
<td>-0.31E+00 at (65, 3, 4)</td>
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<tr>
<td>Total Heat Release Rate:</td>
<td>372.918 kW</td>
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<tr>
<td>Radiation Loss to Boundaries:</td>
<td>128.348 kW</td>
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</tbody>
</table>

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>CPU/step:</td>
<td>0.517 s, Total CPU: 6.10 min</td>
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<td>Time step:</td>
<td>0.10508 s, Total time: 106.41 s</td>
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<td>Max CFL number:</td>
<td>0.91E+00 at (65, 1, 15)</td>
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<tr>
<td>Max divergence:</td>
<td>0.13E+01 at (62, 1, 3)</td>
</tr>
<tr>
<td>Min divergence:</td>
<td>-0.59E+00 at (65, 3, 4)</td>
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<tr>
<td>Total Heat Release Rate:</td>
<td>433.272 kW</td>
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<tr>
<td>Radiation Loss to Boundaries:</td>
<td>146.356 kW</td>
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</tbody>
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<table>
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<tr>
<th>Time Step</th>
<th>May 10, 2013 21:58:39</th>
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<tr>
<td>CPU/step:</td>
<td>0.517 s, Total CPU: 6.97 min</td>
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<td>Time step:</td>
<td>0.10206 s, Total time: 117.20 s</td>
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<tr>
<td>Max CFL number:</td>
<td>0.84E+00 at (67, 0, 16)</td>
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<tr>
<td>Max divergence:</td>
<td>0.16E+01 at (62, 1, 3)</td>
</tr>
<tr>
<td>Min divergence:</td>
<td>-0.53E+00 at (65, 3, 4)</td>
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<tr>
<td>Total Heat Release Rate:</td>
<td>536.953 kW</td>
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<tr>
<td>Radiation Loss to Boundaries:</td>
<td>169.356 kW</td>
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</tbody>
</table>
CPU/step:  0.513 s, Total CPU:      7.82 min
Time step:  0.10206 s, Total time:   127.40 s
Max CFL number:  0.88E+00 at ( 67, 0, 15)
Max divergence:  0.18E+01 at ( 62, 1, 3)
Min divergence: -0.78E+00 at ( 65, 3, 4)
Total Heat Release Rate:            616.274 kW
Radiation Loss to Boundaries:       188.527 kW

Time Step    1000   May 10, 2013  22:00:23
-------------------------------------------- --
CPU/step:  0.513 s, Total CPU:      8.68 min
Time step:  0.10073 s, Total time:   137.18 s
Max CFL number:  0.92E+00 at ( 65, 1, 16)
Max divergence:  0.21E+01 at ( 62, 1, 3)
Min divergence: -0.92E+00 at ( 65, 3, 4)
Total Heat Release Rate:            707.064 kW
Radiation Loss to Boundaries:       227.870 kW

Time Step    1100   May 10, 2013  22:01:15
-------------------------------------------- --
CPU/step:  0.510 s, Total CPU:      9.53 min
Time step:  0.09927 s, Total time:   146.87 s
Max CFL number:  0.90E+00 at ( 70, 8, 20)
Max divergence:  0.24E+01 at ( 62, 1, 3)
Min divergence: -0.12E+01 at ( 65, 3, 4)
Total Heat Release Rate:            784.557 kW
Radiation Loss to Boundaries:       261.764 kW

Time Step    1200   May 10, 2013  22:02:07
-------------------------------------------- --
CPU/step:  0.515 s, Total CPU:     10.39 min
Time step:  0.08805 s, Total time:   156.25 s
Max CFL number:  0.91E+00 at ( 67, 1, 15)
Max divergence:  0.25E+01 at ( 62, 1, 3)
Min divergence: -0.12E+01 at ( 65, 3, 4)
Total Heat Release Rate:            904.269 kW
Radiation Loss to Boundaries:       296.746 kW

Time Step    1300   May 10, 2013  22:02:58
-------------------------------------------- --
CPU/step:  0.512 s, Total CPU:     11.24 min
Time step:  0.08805 s, Total time:   165.05 s
Max CFL number:  0.91E+00 at ( 64, 3, 4)
Max divergence:  0.29E+01 at ( 62, 1, 3)
Min divergence: -0.14E+01 at ( 65, 3, 4)
Total Heat Release Rate:            1056.307 kW
Radiation Loss to Boundaries:       354.360 kW

Time Step    1400   May 10, 2013  22:03:50
-------------------------------------------- --
CPU/step:  0.514 s, Total CPU:     12.10 min
Time step:  0.08657 s, Total time:   173.59 s
Max CFL number: 0.90E+00 at (64, 3, 4)
Max divergence: 0.32E+01 at (62, 1, 3)
Min divergence: -0.10E+01 at (66, 3, 4)
Total Heat Release Rate: 1185.437 kW
Radiation Loss to Boundaries: 423.507 kW

Time Step 1500 May 10, 2013 22:04:42
-------------------------------------------- --
CPU/step: 0.515 s, Total CPU: 12.95 min
Time step: 0.07769 s, Total time: 181.65 s
Max CFL number: 0.93E+00 at (67, 1, 12)
Max divergence: 0.34E+01 at (63, 1, 3)
Min divergence: -0.19E+01 at (65, 3, 4)
No. of Lagrangian Particles: 9143
Total Heat Release Rate: 1306.093 kW
Radiation Loss to Boundaries: 427.217 kW

Time Step 1600 May 10, 2013 22:05:39
-------------------------------------------- --
CPU/step: 0.564 s, Total CPU: 13.89 min
Time step: 0.07769 s, Total time: 189.42 s
Max CFL number: 0.91E+00 at (67, 0, 14)
Max divergence: 0.25E+01 at (63, 1, 3)
Min divergence: -0.61E+00 at (65, 3, 4)
No. of Lagrangian Particles: 18471
Total Heat Release Rate: 1453.272 kW
Radiation Loss to Boundaries: 499.123 kW

Time Step 1700 May 10, 2013 22:06:36
-------------------------------------------- --
CPU/step: 0.568 s, Total CPU: 14.84 min
Time step: 0.07532 s, Total time: 197.13 s
Max CFL number: 0.85E+00 at (66, 1, 16)
Max divergence: 0.29E+01 at (63, 1, 3)
Min divergence: -0.73E+00 at (65, 3, 4)
No. of Lagrangian Particles: 18384
Total Heat Release Rate: 1612.216 kW
Radiation Loss to Boundaries: 501.569 kW

-------------------------------------------- --
CPU/step: 0.558 s, Total CPU: 15.77 min
Time step: 0.07532 s, Total time: 204.66 s
Max CFL number: 0.94E+00 at (67, 1, 15)
Max divergence: 0.33E+01 at (63, 1, 3)
Min divergence: -0.97E+00 at (65, 3, 4)
No. of Lagrangian Particles: 18265
Total Heat Release Rate: 1732.835 kW
Radiation Loss to Boundaries: 552.099 kW

Time Step 1900 May 10, 2013 22:08:28
-------------------------------------------- --
CPU/step: 0.557 s, Total CPU: 16.70 min
Time step: 0.06728 s, Total time: 211.69 s
Max CFL number: 0.82E+00 at (68, 1, 15)
Max divergence: 0.35E+01 at (63, 1, 3)
Min divergence: -0.88E+00 at (66, 3, 4)
No. of Lagrangian Particles: 18432
Total Heat Release Rate: 1952.003 kW
Radiation Loss to Boundaries: 576.436 kW


CPU/step: 0.546 s, Total CPU: 17.61 min
Time step: 0.06654 s, Total time: 218.08 s
Max CFL number: 0.89E+00 at (69, 1, 15)
Max divergence: 0.34E+01 at (63, 1, 3)
Min divergence: -0.78E+00 at (67, 2, 4)
No. of Lagrangian Particles: 18498
Total Heat Release Rate: 2132.450 kW
Radiation Loss to Boundaries: 616.891 kW

Time Step 2100 May 10, 2013 22:10:19

CPU/step: 0.551 s, Total CPU: 18.53 min
Time step: 0.05921 s, Total time: 224.22 s
Max CFL number: 0.81E+00 at (69, 1, 15)
Max divergence: 0.33E+01 at (63, 1, 3)
Min divergence: -0.93E+00 at (67, 2, 4)
No. of Lagrangian Particles: 19037
Total Heat Release Rate: 2611.356 kW
Radiation Loss to Boundaries: 780.223 kW

Time Step 2200 May 10, 2013 22:11:16

CPU/step: 0.563 s, Total CPU: 19.47 min
Time step: 0.05921 s, Total time: 230.14 s
Max CFL number: 0.86E+00 at (69, 1, 15)
Max divergence: 0.35E+01 at (63, 1, 3)
Min divergence: -0.12E+01 at (66, 2, 9)
No. of Lagrangian Particles: 38185
Total Heat Release Rate: 2732.317 kW
Radiation Loss to Boundaries: 868.704 kW

Time Step 2300 May 10, 2013 22:12:15

CPU/step: 0.588 s, Total CPU: 20.45 min
Time step: 0.05821 s, Total time: 235.90 s
Max CFL number: 0.89E+00 at (67, 1, 10)
Max divergence: 0.36E+01 at (63, 1, 3)
Min divergence: -0.10E+01 at (66, 2, 9)
No. of Lagrangian Particles: 38185
Total Heat Release Rate: 2732.317 kW
Radiation Loss to Boundaries: 868.704 kW

CPU/step:  0.602 s, Total CPU:  21.45 min
Time step:  0.04885 s, Total time:  241.57 s
Max CFL number:  0.91E+00 at ( 65,  2, 13)
Max divergence:  0.37E+01 at ( 63,  2,  3)
Min divergence: -0.13E+01 at ( 66,  2, 11)
No. of Lagrangian Particles:  38820
Total Heat Release Rate:  2488.255 kW
Radiation Loss to Boundaries:  726.036 kW

Time Step    2500   May 10, 2013  22:14:16

CPU/step:  0.607 s, Total CPU:  22.46 min
Time step:  0.05273 s, Total time:  246.99 s
Max CFL number:  0.94E+00 at ( 66,  1, 16)
Max divergence:  0.37E+01 at ( 63,  2,  3)
Min divergence: -0.11E+01 at ( 67,  3,  4)
No. of Lagrangian Particles:  38462
Total Heat Release Rate:  2524.578 kW
Radiation Loss to Boundaries:  673.658 kW

Time Step    2600   May 10, 2013  22:15:18

CPU/step:  0.614 s, Total CPU:  23.48 min
Time step:  0.05847 s, Total time:  252.51 s
Max CFL number:  0.92E+00 at ( 65,  1, 13)
Max divergence:  0.33E+01 at ( 63,  1,  3)
Min divergence: -0.16E+01 at ( 66,  2,  7)
No. of Lagrangian Particles:  38829
Total Heat Release Rate:  2891.805 kW
Radiation Loss to Boundaries:  852.080 kW

Time Step    2700   May 10, 2013  22:16:19

CPU/step:  0.610 s, Total CPU:  24.50 min
Time step:  0.06589 s, Total time:  257.81 s
Max CFL number:  0.88E+00 at ( 65,  1, 13)
Max divergence:  0.32E+01 at ( 63,  1,  3)
Min divergence: -0.10E+01 at ( 67,  2,  8)
No. of Lagrangian Particles:  36102
Total Heat Release Rate:  2665.955 kW
Radiation Loss to Boundaries:  792.591 kW

Time Step    2800   May 10, 2013  22:17:21

CPU/step:  0.614 s, Total CPU:  25.52 min
Time step:  0.05899 s, Total time:  263.87 s
Max CFL number:  0.86E+00 at ( 65,  1, 17)
Max divergence:  0.36E+01 at ( 63,  1,  3)
Min divergence: -0.80E+00 at ( 66,  2,  4)
No. of Lagrangian Particles: 37710
Total Heat Release Rate: 2138.633 kW
Radiation Loss to Boundaries: 512.943 kW

-------------------------------------------- --
CPU/step: 0.618 s, Total CPU: 26.55 min
Time step: 0.05515 s, Total time: 269.67 s
Max CFL number: 0.92E+00 at (66, 1, 13)
Max divergence: 0.24E+01 at (63, 2, 3)
Min divergence: -0.13E+01 at (65, 1, 14)
No. of Lagrangian Particles: 36458
Total Heat Release Rate: 2756.842 kW
Radiation Loss to Boundaries: 845.633 kW

-------------------------------------------- --
CPU/step: 0.602 s, Total CPU: 27.56 min
Time step: 0.05964 s, Total time: 275.78 s
Max CFL number: 0.96E+00 at (67, 2, 14)
Max divergence: 0.28E+01 at (63, 2, 3)
Min divergence: -0.65E+00 at (66, 3, 4)
No. of Lagrangian Particles: 36887
Total Heat Release Rate: 2227.232 kW
Radiation Loss to Boundaries: 676.756 kW

-------------------------------------------- --
CPU/step: 0.609 s, Total CPU: 28.57 min
Time step: 0.07120 s, Total time: 281.64 s
Max CFL number: 0.99E+00 at (65, 1, 12)
Max divergence: 0.27E+01 at (64, 1, 3)
Min divergence: -0.12E+01 at (66, 3, 4)
No. of Lagrangian Particles: 38289
Total Heat Release Rate: 1964.915 kW
Radiation Loss to Boundaries: 521.625 kW

-------------------------------------------- --
CPU/step: 0.614 s, Total CPU: 29.60 min
Time step: 0.05538 s, Total time: 287.65 s
Max CFL number: 0.87E+00 at (66, 1, 15)
Max divergence: 0.28E+01 at (63, 2, 3)
Min divergence: -0.10E+01 at (67, 3, 4)
No. of Lagrangian Particles: 37982
Total Heat Release Rate: 1771.940 kW
Radiation Loss to Boundaries: 590.615 kW

-------------------------------------------- --
CPU/step: 0.607 s, Total CPU: 30.61 min
Time step: 0.06493 s, Total time: 293.92 s

20
Max CFL number:  0.81E+00 at ( 64,  3,  4)
Max divergence:  0.32E+01 at ( 63,  1,  3)
Min divergence: -0.15E+01 at ( 66,  3,  4)
No. of Lagrangian Particles:         36665
Total Heat Release Rate:           1883.441 kW
Radiation Loss to Boundaries:       631.255 kW

-------------------------------------------- --
CPU/step:     0.606 s, Total CPU:     31.62 min
Time step:  0.06369 s, Total time:   300.35 s
Max CFL number:  0.78E+00 at ( 66,  0, 17)
Max divergence:  0.24E+01 at ( 63,  1,  3)
Min divergence: -0.12E+01 at ( 65,  3,  4)
No. of Lagrangian Particles:         35614
Total Heat Release Rate:           1452.218 kW
Radiation Loss to Boundaries:       468.330 kW

Time Step    3500   May 10, 2013  22:24:31
-------------------------------------------- --
CPU/step:     0.617 s, Total CPU:     32.65 min
Time step:  0.06719 s, Total time:   307.44 s
Max CFL number:  0.90E+00 at ( 67,  1, 15)
Max divergence:  0.25E+01 at ( 63,  1,  3)
Min divergence: -0.87E+00 at ( 66,  2,  5)
No. of Lagrangian Particles:         35954
Total Heat Release Rate:           1427.301 kW
Radiation Loss to Boundaries:       491.114 kW

Time Step    3600   May 10, 2013  22:25:30
-------------------------------------------- --
CPU/step:     0.588 s, Total CPU:     33.63 min
Time step:  0.07238 s, Total time:   314.74 s
Max CFL number:  0.93E+00 at ( 65,  1, 13)
Max divergence:  0.20E+01 at ( 63,  1,  3)
Min divergence: -0.11E+01 at ( 65,  3,  4)
No. of Lagrangian Particles:         35550
Total Heat Release Rate:           1259.202 kW
Radiation Loss to Boundaries:       429.058 kW

Time Step    3700   May 10, 2013  22:26:29
-------------------------------------------- --
CPU/step:     0.585 s, Total CPU:     34.60 min
Time step:  0.07871 s, Total time:   322.51 s
Max CFL number:  0.89E+00 at ( 66,  2, 18)
Max divergence:  0.32E+01 at ( 62,  1,  3)
Min divergence: -0.12E+01 at ( 66,  3,  4)
No. of Lagrangian Particles:         36494
Total Heat Release Rate:           1247.904 kW
Radiation Loss to Boundaries:       459.835 kW

-------------------------------------------- --
CPU/step: 0.595 s, Total CPU: 35.59 min
Time step: 0.08372 s, Total time: 330.34 s
Max CFL number: 0.85E+00 at (67, 1, 11)
Max divergence: 0.29E+01 at (62, 1, 3)
Min divergence: -0.12E+01 at (66, 3, 4)
No. of Lagrangian Particles: 35540
Total Heat Release Rate: 1219.937 kW
Radiation Loss to Boundaries: 432.624 kW


CPU/step: 0.617 s, Total CPU: 36.62 min
Time step: 0.08372 s, Total time: 338.71 s
Max CFL number: 0.85E+00 at (64, 3, 4)
Max divergence: 0.28E+01 at (62, 1, 3)
Min divergence: -0.99E+00 at (65, 3, 4)
No. of Lagrangian Particles: 33595
Total Heat Release Rate: 985.950 kW
Radiation Loss to Boundaries: 353.791 kW

Time Step 4000 May 10, 2013 22:29:35

CPU/step: 0.625 s, Total CPU: 37.66 min
Time step: 0.07904 s, Total time: 347.31 s
Max CFL number: 0.82E+00 at (66, 1, 16)
Max divergence: 0.20E+01 at (63, 2, 3)
Min divergence: -0.11E+01 at (65, 3, 4)
No. of Lagrangian Particles: 36956
Total Heat Release Rate: 885.257 kW
Radiation Loss to Boundaries: 321.919 kW

Time Step 4100 May 10, 2013 22:30:35

CPU/step: 0.603 s, Total CPU: 38.67 min
Time step: 0.08106 s, Total time: 356.03 s
Max CFL number: 0.94E+00 at (65, 1, 12)
Max divergence: 0.23E+01 at (62, 1, 3)
Min divergence: -0.81E+00 at (65, 3, 4)
No. of Lagrangian Particles: 34316
Total Heat Release Rate: 829.016 kW
Radiation Loss to Boundaries: 336.474 kW


CPU/step: 0.600 s, Total CPU: 39.67 min
Time step: 0.08917 s, Total time: 364.66 s
Max CFL number: 0.90E+00 at (60, 5, 2)
Max divergence: 0.21E+01 at (62, 2, 3)
Min divergence: -0.13E+01 at (65, 3, 4)
No. of Lagrangian Particles: 35750
Total Heat Release Rate: 808.210 kW
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Min divergence: $-0.59 \times 10^0$ at (66, 3, 4)
No. of Lagrangian Particles: 36649
Total Heat Release Rate: 510.314 kW
Radiation Loss to Boundaries: 223.521 kW

Time Step 4800 May 10, 2013 22:37:43
-------------------------------------------- --
CPU/step: 0.645 s, Total CPU: 45.76 min
Time step: 0.10072 s, Total time: 420.12 s
Max CFL number: 0.89E+00 at (65, 0, 13)
Max divergence: 0.10E+01 at (62, 1, 3)
Min divergence: $-0.66 \times 10^0$ at (65, 3, 4)
No. of Lagrangian Particles: 34188
Total Heat Release Rate: 420.253 kW
Radiation Loss to Boundaries: 192.841 kW

Time Step 4900 May 10, 2013 22:38:45
-------------------------------------------- --
CPU/step: 0.612 s, Total CPU: 46.78 min
Time step: 0.10044 s, Total time: 430.03 s
Max CFL number: 0.92E+00 at (62, 5, 2)
Max divergence: 0.88E+00 at (62, 1, 3)
Min divergence: $-0.41 \times 10^0$ at (66, 2, 4)
No. of Lagrangian Particles: 32964
Total Heat Release Rate: 343.914 kW
Radiation Loss to Boundaries: 164.976 kW

Time Step 5000 May 10, 2013 22:39:51
-------------------------------------------- --
CPU/step: 0.651 s, Total CPU: 47.86 min
Time step: 0.10354 s, Total time: 440.10 s
Max CFL number: 0.84E+00 at (62, 5, 3)
Max divergence: 0.67E+00 at (63, 1, 3)
Min divergence: $-0.70 \times 10^0$ at (65, 3, 4)
No. of Lagrangian Particles: 34470
Total Heat Release Rate: 261.256 kW
Radiation Loss to Boundaries: 146.137 kW

Time Step 5100 May 10, 2013 22:40:56
-------------------------------------------- --
CPU/step: 0.634 s, Total CPU: 48.92 min
Time step: 0.09531 s, Total time: 449.87 s
Max CFL number: 0.92E+00 at (70, 7, 3)
Max divergence: 0.50E+00 at (62, 1, 3)
Min divergence: $-0.35 \times 10^0$ at (63, 2, 4)
No. of Lagrangian Particles: 35544
Total Heat Release Rate: 197.004 kW
Radiation Loss to Boundaries: 122.476 kW

-------------------------------------------- --
CPU/step: 0.618 s, Total CPU: 49.95 min
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<td>5600</td>
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<td>0.644 s</td>
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---------------------------------------------------------------------
CPU/step:   0.627 s, Total CPU:   55.24 min
Time step:  0.10458 s, Total time:   510.32 s
Max CFL number:  0.88E+00 at ( 61,  5,  4)
Max divergence:  0.43E+00 at ( 63,  2,  3)
Min divergence: -0.25E+00 at ( 63,  1,  4)
No. of Lagrangian Particles:        35820
Total Heat Release Rate:            156.847 kW
Radiation Loss to Boundaries:       101.423 kW

---------------------------------------------------------------------
CPU/step:   0.625 s, Total CPU:   56.28 min
Time step:  0.10856 s, Total time:   520.47 s
Max CFL number:  0.91E+00 at ( 70,  7,  3)
Max divergence:  0.39E+00 at ( 63,  1,  3)
Min divergence: -0.29E+00 at ( 63,  2,  4)
No. of Lagrangian Particles:        35429
Total Heat Release Rate:            128.359 kW
Radiation Loss to Boundaries:       88.751 kW

---------------------------------------------------------------------
CPU/step:   0.610 s, Total CPU:   57.30 min
Time step:  0.10147 s, Total time:   530.80 s
Max CFL number:  0.99E+00 at ( 68,  7,  3)
Max divergence:  0.32E+00 at ( 62,  1,  3)
Min divergence: -0.15E+00 at ( 63,  2,  4)
No. of Lagrangian Particles:        34730
Total Heat Release Rate:            115.497 kW
Radiation Loss to Boundaries:       84.139 kW

Time Step  6000   May 10, 2013  22:50:26
---------------------------------------------------------------------
CPU/step:   0.609 s, Total CPU:   58.31 min
Time step:  0.11404 s, Total time:   541.15 s
Max CFL number:  0.83E+00 at ( 68,  7,  2)
Max divergence:  0.32E+00 at ( 62,  1,  3)
Min divergence: -0.22E+00 at ( 63,  2,  4)
No. of Lagrangian Particles:        34873
Total Heat Release Rate:            108.674 kW
Radiation Loss to Boundaries:       79.929 kW

---------------------------------------------------------------------
CPU/step:   0.618 s, Total CPU:   59.34 min
Time step:  0.10008 s, Total time:   551.81 s
Max CFL number:  0.83E+00 at ( 68,  5,  3)
Max divergence:  0.25E+00 at ( 62,  1,  3)
Min divergence: -0.19E+00 at ( 63,  2,  4)
No. of Lagrangian Particles:        35806
Total Heat Release Rate: 84.028 kW
Radiation Loss to Boundaries: 70.649 kW

-------------------------------------------- --
CPU/step: 0.635 s, Total CPU: 1.01 hr
Time step: 0.10705 s, Total time: 563.03 s
Max CFL number: 0.85E+00 at (68, 4, 7)
Max divergence: 0.17E+00 at (62, 1, 3)
Min divergence: -0.68E-01 at (67, 3, 4)
No. of Lagrangian Particles: 35790
Total Heat Release Rate: 68.702 kW
Radiation Loss to Boundaries: 66.094 kW

-------------------------------------------- --
CPU/step: 0.626 s, Total CPU: 1.02 hr
Time step: 0.10984 s, Total time: 574.26 s
Max CFL number: 0.87E+00 at (68, 0, 3)
Max divergence: 0.16E+00 at (62, 1, 3)
Min divergence: -0.74E-01 at (67, 1, 4)
No. of Lagrangian Particles: 37028
Total Heat Release Rate: 58.591 kW
Radiation Loss to Boundaries: 59.770 kW

-------------------------------------------- --
CPU/step: 0.614 s, Total CPU: 1.04 hr
Time step: 0.10850 s, Total time: 585.39 s
Max CFL number: 0.81E+00 at (67, 2, 6)
Max divergence: 0.11E+00 at (62, 1, 3)
Min divergence: -0.81E-01 at (66, 1, 3)
No. of Lagrangian Particles: 36901
Total Heat Release Rate: 44.166 kW
Radiation Loss to Boundaries: 53.031 kW

-------------------------------------------- --
CPU/step: 0.602 s, Total CPU: 1.06 hr
Time step: 0.10850 s, Total time: 596.24 s
Max CFL number: 0.97E+00 at (68, 3, 7)
Max divergence: 0.86E-01 at (62, 1, 3)
Min divergence: -0.79E-01 at (66, 1, 3)
No. of Lagrangian Particles: 35673
Total Heat Release Rate: 31.566 kW
Radiation Loss to Boundaries: 47.037 kW

Time Step 6600  May 10, 2013  22:56:43
-------------------------------------------- --
CPU/step: 0.626 s, Total CPU: 1.08 hr
Time step: 0.10590 s, Total time: 606.80 s
Max CFL number: 0.91E+00 at (68, 2, 2)
Max divergence: 0.83E-01 at (62, 1, 3)
Min divergence: -0.72E-01 at (66, 3, 4)
No. of Lagrangian Particles: 35005
Total Heat Release Rate: 27.803 kW
Radiation Loss to Boundaries: 43.984 kW

Time Step 6700 May 10, 2013 22:57:46
-------------------------------------------------------------
CPU/step: 0.632 s, Total CPU: 1.09 hr
Time step: 0.10162 s, Total time: 616.82 s
Max CFL number: 0.89E+00 at (68, 3, 4)
Max divergence: 0.84E-01 at (62, 1, 3)
Min divergence: -0.68E-01 at (65, 3, 4)
No. of Lagrangian Particles: 35202
Total Heat Release Rate: 28.494 kW
Radiation Loss to Boundaries: 42.573 kW

Time Step 6800 May 10, 2013 22:58:35
-------------------------------------------------------------
CPU/step: 0.488 s, Total CPU: 1.11 hr
Time step: 0.11020 s, Total time: 626.82 s
Max CFL number: 0.97E+00 at (67, 2, 2)
Max divergence: 0.76E-01 at (62, 1, 3)
Min divergence: -0.60E-01 at (65, 2, 4)
No. of Lagrangian Particles: 35063
Total Heat Release Rate: 27.490 kW
Radiation Loss to Boundaries: 40.496 kW

-------------------------------------------------------------
CPU/step: 0.445 s, Total CPU: 1.12 hr
Time step: 0.10096 s, Total time: 637.24 s
Max CFL number: 0.92E+00 at (68, 3, 4)
Max divergence: 0.80E-01 at (62, 1, 3)
Min divergence: -0.77E-01 at (65, 3, 4)
No. of Lagrangian Particles: 35256
Total Heat Release Rate: 28.232 kW
Radiation Loss to Boundaries: 39.279 kW

Time Step 7000 May 10, 2013 23:00:06
-------------------------------------------------------------
CPU/step: 0.460 s, Total CPU: 1.13 hr
Time step: 0.09613 s, Total time: 647.39 s
Max CFL number: 0.87E+00 at (68, 3, 4)
Max divergence: 0.72E-01 at (62, 1, 3)
Min divergence: -0.60E-01 at (65, 2, 4)
No. of Lagrangian Particles: 34707
Total Heat Release Rate: 27.584 kW
Radiation Loss to Boundaries: 37.575 kW

Time Step 7100 May 10, 2013 23:00:52
-------------------------------------------------------------
CPU/step: 0.458 s, Total CPU: 1.14 hr
Time step: 0.10291 s, Total time: 657.71 s
Max CFL number: 0.90E+00 at ( 67, 2, 5)
Max divergence: 0.74E-01 at ( 62, 1, 3)
Min divergence: -0.68E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 35243
Total Heat Release Rate: 28.225 kW
Radiation Loss to Boundaries: 36.378 kW

Time Step 7200 May 10, 2013 23:01:38
-------------------------------------------- --
CPU/step: 0.459 s, Total CPU: 1.16 hr
Time step: 0.10048 s, Total time: 668.03 s
Max CFL number: 0.82E+00 at ( 68, 3, 4)
Max divergence: 0.71E-01 at ( 62, 1, 3)
Min divergence: -0.69E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 34971
Total Heat Release Rate: 27.658 kW
Radiation Loss to Boundaries: 34.907 kW

Time Step 7300 May 10, 2013 23:02:25
-------------------------------------------- --
CPU/step: 0.455 s, Total CPU: 1.17 hr
Time step: 0.09558 s, Total time: 678.18 s
Max CFL number: 0.82E+00 at ( 67, 2, 3)
Max divergence: 0.74E-01 at ( 62, 1, 3)
Min divergence: -0.69E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 35209
Total Heat Release Rate: 28.022 kW
Radiation Loss to Boundaries: 33.631 kW

Time Step 7400 May 10, 2013 23:03:10
-------------------------------------------- --
CPU/step: 0.449 s, Total CPU: 1.18 hr
Time step: 0.10206 s, Total time: 688.26 s
Max CFL number: 0.87E+00 at ( 67, 2, 3)
Max divergence: 0.74E-01 at ( 62, 1, 3)
Min divergence: -0.62E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 35162
Total Heat Release Rate: 27.457 kW
Radiation Loss to Boundaries: 32.074 kW

Time Step 7500 May 10, 2013 23:03:55
-------------------------------------------- --
CPU/step: 0.448 s, Total CPU: 1.19 hr
Time step: 0.09921 s, Total time: 698.33 s
Max CFL number: 0.88E+00 at ( 68, 3, 5)
Max divergence: 0.80E-01 at ( 62, 1, 3)
Min divergence: -0.65E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 35319
Total Heat Release Rate: 29.080 kW
Radiation Loss to Boundaries: 31.389 kW
Time Step    7600   May 10, 2013  23:04:40
-------------------------------------------- --
CPU/step:     0.450 s, Total CPU:      1.21 hr
Time step:  0.10592 s, Total time:   708.62 s
Max CFL number:  0.90E+00 at ( 67,  3,  6)
Max divergence:  0.69E-01 at ( 62,  1,  3)
Min divergence: -0.70E-01 at ( 65,  2,  4)
No. of Lagrangian Particles:         35130
Total Heat Release Rate:             27.044 kW
Radiation Loss to Boundaries:        29.730 kW

Time Step    7700   May 10, 2013  23:05:25
-------------------------------------------- --
CPU/step:     0.448 s, Total CPU:      1.22 hr
Time step:  0.10213 s, Total time:   718.70 s
Max CFL number:  0.95E+00 at ( 68,  3,  5)
Max divergence:  0.77E-01 at ( 62,  1,  3)
Min divergence: -0.59E-01 at ( 65,  2,  4)
No. of Lagrangian Particles:         34990
Total Heat Release Rate:             28.013 kW
Radiation Loss to Boundaries:        28.726 kW

Time Step    7800   May 10, 2013  23:06:10
-------------------------------------------- --
CPU/step:     0.446 s, Total CPU:      1.23 hr
Time step:  0.09890 s, Total time:   729.01 s
Max CFL number:  0.87E+00 at ( 67,  3,  3)
Max divergence:  0.72E-01 at ( 62,  1,  3)
Min divergence: -0.62E-01 at ( 65,  3,  4)
No. of Lagrangian Particles:         34814
Total Heat Release Rate:             27.535 kW
Radiation Loss to Boundaries:        27.425 kW

Time Step    7900   May 10, 2013  23:06:55
-------------------------------------------- --
CPU/step:     0.445 s, Total CPU:      1.24 hr
Time step:  0.10203 s, Total time:   739.03 s
Max CFL number:  0.90E+00 at ( 67,  2,  5)
Max divergence:  0.70E-01 at ( 62,  1,  3)
Min divergence: -0.55E-01 at ( 65,  3,  4)
No. of Lagrangian Particles:         35152
Total Heat Release Rate:             27.221 kW
Radiation Loss to Boundaries:        26.415 kW

Time Step    8000   May 10, 2013  23:07:39
-------------------------------------------- --
CPU/step:     0.441 s, Total CPU:      1.26 hr
Time step:  0.10210 s, Total time:   748.82 s
Max CFL number:  0.84E+00 at ( 67,  2,  2)
Max divergence:  0.74E-01 at ( 62,  1,  3)
Min divergence: -0.54E-01 at ( 65,  3,  4)
No. of Lagrangian Particles: 35611
Total Heat Release Rate: 27.810 kW
Radiation Loss to Boundaries: 25.650 kW

Time Step 8100 May 10, 2013 23:08:24
-------------------------------------------- --
CPU/step: 0.449 s, Total CPU: 1.27 hr
Time step: 0.10790 s, Total time: 759.19 s
Max CFL number: 0.92E+00 at ( 67, 2, 5)
Max divergence: 0.71E-01 at ( 62, 1, 3)
Min divergence: -0.55E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 34766
Total Heat Release Rate: 28.083 kW
Radiation Loss to Boundaries: 24.881 kW

-------------------------------------------- --
CPU/step: 0.481 s, Total CPU: 1.28 hr
Time step: 0.09651 s, Total time: 769.32 s
Max CFL number: 0.88E+00 at ( 67, 2, 2)
Max divergence: 0.70E-01 at ( 62, 1, 3)
Min divergence: -0.59E-01 at ( 65, 2, 4)
No. of Lagrangian Particles: 34993
Total Heat Release Rate: 27.724 kW
Radiation Loss to Boundaries: 23.983 kW

Time Step 8300 May 10, 2013 23:10:42
-------------------------------------------- --
CPU/step: 0.454 s, Total CPU: 1.29 hr
Time step: 0.10140 s, Total time: 779.21 s
Max CFL number: 0.86E+00 at ( 67, 3, 2)
Max divergence: 0.70E-01 at ( 62, 1, 3)
Min divergence: -0.69E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 34900
Total Heat Release Rate: 28.137 kW
Radiation Loss to Boundaries: 23.331 kW

Time Step 8400 May 10, 2013 23:11:27
-------------------------------------------- --
CPU/step: 0.439 s, Total CPU: 1.31 hr
Time step: 0.10140 s, Total time: 789.35 s
Max CFL number: 0.82E+00 at ( 68, 2, 4)
Max divergence: 0.75E-01 at ( 62, 1, 3)
Min divergence: -0.60E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 35364
Total Heat Release Rate: 28.440 kW
Radiation Loss to Boundaries: 22.670 kW

Time Step 8500 May 10, 2013 23:11:27
-------------------------------------------- --
CPU/step: 0.445 s, Total CPU: 1.32 hr
Time step: 0.09847 s, Total time: 799.30 s
Max CFL number: 0.84E+00 at ( 67, 3, 3)
Max divergence: 0.67E-01 at ( 62, 1, 3)
Min divergence: -0.54E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 35162
Total Heat Release Rate: 27.708 kW
Radiation Loss to Boundaries: 21.507 kW

Time Step 8508 May 10, 2013 23:11:31
---------------------------------------------------
CPU/step: 0.431 s, Total CPU: 1.32 hr
Time step: 0.09847 s, Total time: 800.08 s
Max CFL number: 0.83E+00 at ( 68, 3, 9)
Max divergence: 0.67E-01 at ( 62, 1, 3)
Min divergence: -0.54E-01 at ( 65, 3, 4)
No. of Lagrangian Particles: 34995
Total Heat Release Rate: 27.538 kW
Radiation Loss to Boundaries: 21.611 kW

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12 SPR_R1_11                 179.7 s
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Time Stepping Wall Clock Time (s): 4793.135
Total Elapsed Wall Clock Time (s): 4800.529

STOP: FDS completed successfully
Appendix I – Computer Based Evacuation

**Computer Based Evacuation**

There are several computer-based egress simulation models that are available for use to determine the evacuation time of a building. One of the simulation programs used by both professionals and CalPoly is Pathfinder, by Thunderhead Engineering. This program and some of the features are discussed below:

**Evacuation Model Type**

Pathfinder mode appears to be based on optimization and simulation models. Risk assessment is not part of the Pathfinder program. For the types of simulations that would be given in this class (simple and fundamental floor plates), Pathfinder would be appropriate. However, for large and very complex floor plates or buildings with several varying hazard factors, Pathfinder might not be the appropriate program to use. Pathfinder does not integrate results from fire events; also since there is an initial delay in the movement of the occupants, there is sometimes an unnecessary queue that forms.

**Enclosure Representation**

The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. This movement mesh can be entered manually or automatically based on imported data (e.g., FDS geometry). Walls and other impassable areas are represented as gaps in the navigation mesh. These objects are not actually passed along to the simulator, but are represented implicitly because occupants cannot move in places where no navigation mesh has been created. Doors are represented as special navigation mesh edges. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow. Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway. Each stairway implicitly defines two doors. These doors function just like any other door in the simulator but are controlled via the stairway editor in the user interface to ensure that no geometric errors result from a mismatch between stairways and the connecting doors. Occupants are modeled as upright cylinders on the movement mesh and travel using an agent-based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters (maximum speed, exit choice, 3D model, etc.).

**Population Perspective**

Occupants are modeled as upright cylinders on the movement mesh and travel using an agent-based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters (maximum speed, exit choice, 3D model, etc.). Pathfinder uses an occupant profile system that allows the user to specify the speed, initial delay, and size distributions across groups of occupants. Also, each occupant has a size parameter which is the diameter of the circle representing this occupant. Each parameter can be set to a constant value, a uniform distribution between two values, or a Normal distribution. There are also several options to occupant placement.

**Behavioral Perspective**

The user can select one of two modes, either the SFPE mode or the “steering” mode. The SFPE mode uses the set of assumptions that are defined in the SFPE handbook. The door queue is the, in this case, is the mechanism that controls the simulation. The steering mode is dependent on
collision avoidance and occupant interaction more so that the SFPE model. Many times the steering mode results are quicker than the SFPE results. For the steering mode, doors queues are defined and dictated by the occupant density. In Pathfinder, the occupants move in a continuous 3D spatial area; i.e., at each time step, the occupant will examine and re-rationalize, then make the appropriate action. Every occupant is allowed by the user to control the speed, delay, size and appearance of the simulation. Profiles are created that can be grouped together; they can be constant, or be generated (simulation based on uniform/normal distributions. Pathfinder also allows individual occupants to be assigned to individual exits, however it does not provide for complex behaviors, like groups of families or friends. The other possible downside is that occupants will not attempt to optimize door exit loading. They will move towards the nearest exit regardless if there is any queue or obstructions.

Model Validation
As with any program, simulation or software, Pathfinder is subject to an ongoing validation process. As egress movement research develops, the software is continually updated. The validation is also done to verify that the results of the simulation are giving correct results based off of analytical results, and to validate that the program is giving “real-life” results, based from the on-going research.


Model Implementation
Pathfinder is currently deployed using computer based technology. It supports a variety of computer formats, including but not limited to: DXF, FDS model imports, Thunderhead DXF, ACAD.

Model Support
Pathfinder is supported by Thunderhead support group. They can be contacted at support@thunderhead.org
Phone: 1(785)770-8511
Fax: 1(785)532-9102

Model Costs
The cost for the Pathfinder program is shown below:
Annual Lease:  Node-locked - $1,500 / Floating - $2,250
The full service subscription option enables Pathfinder for one year, including tech support and all program updates. This option provides cost-effective access to the latest version of Pathfinder, while simplifying budgeting for software costs.
Standard Perpetual License – Node - $5,000 / Floating - $7,500 (Maint. on each $1,500)
The standard license provides for unlimited-time use of Pathfinder. Support and upgrades are included for one year. Maintenance must be purchased annually after the first year to keep your version up to date.

Appropriateness to Task
The model requires the user to provide the inputs based on known or implied parameters (like speed, gender, etc.) The model makes these options available to the user, and considers all the inputs when running the simulation. These include, but are not limited to: speed of movement, density, queuing, merging, and decision making both pre and post movement. The Pathfinder model produces an output that meets the requirements of the user, when used to prove evacuation times in complex and challenging buildings.
Fire Safety and Evacuation Plans – Appendix J
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**Fire Evacuation Plans**

**Emergency Egress & Escape Routes**

Emergency egress and escape routes shall be defined within the life safety plans. Placards shall be placed at obvious points within the school to allow of occupants to identify the route they need to take for exiting the building during a fire event. Under fire event conditions, the building shall have a ‘complete’ or ‘total’ evacuation; all occupants shall exit. More information regarding this is outlined below. No areas or sections of the building shall remain in place; all students are required to exit the building.

**Critical Equipment**

Some areas of the building that have ‘mission-critical’ or other essential operations require that personnel stay to ensure continued operation of that equipment. Such areas include the server room, construction and trades area (heavy machinery is located within these areas) and possible other locations throughout the school. In a fire event, personnel shall remain at these areas to ensure that all equipment is functioning properly. If the event is within one of these areas, personnel shall remove students and faculty from these areas as quickly as possible.

**Assisted Rescue**

Throughout the building there are areas in which building construction safeguards have been put in place in order to enable disabled students and faculty to safely evacuate the area that they are in and move to these locations. Such disabled persons shall remain in these areas until fire department personnel arrive on scene.

**Accounting for Occupants**

In a fire event, all personnel and students shall be evacuated to the outside of the building. The details of these locations are shown on the life safety plans. Once building evacuation is complete, certain actions shall be taken to account for students and faculty. Teachers shall take roll of all students within their respective classes; the administrative staff shall then account for all teachers and other faculty. These actions shall be by either roll sheets or roll call. If a student is not accounted for, the teacher shall notify the appropriate parties (law enforcement agency) to find the student.

**Emergency Rescue or Medical Aid**

Unless a student or faculty personnel is in need of immediate medical assistance, the faculty of the school shall not initiate any medical response. Faculty shall be directed to wait until authorized emergency medical services have arrived on scene to treat whatever injuries there might be.

**Alternate Means of Notification to Occupants**

Should there be a fire event at the building; notification to the occupants shall be thru the fire alarm system. Should the fire alarm system not be functioning or out of commission, alternate means of notification to the students and faculty shall be thru the public address system. Should the public address system not be functioning, email and text messaging shall be employed, along with one person from the administrative office conducting a room to room notification plan.
Alternate Mean of Notification to Emergency Services
The fire alarm control panel located in the building will report a fire event to the appropriate authorities (fire department). However, other means shall also be employed. The Principal (or Vice Principal in the former’s absence) shall use the dedicated phone line with the Principal’s office, or cell phone, to notify emergency services of a fire or other event, should the fire alarm system fail.

Staff Contacts
Posted within the Principal’s office, the security office, and near the main entrance to the building shall be the names and contact numbers for personnel that can be contacted for further information. These personnel include the Principal, Vice Principal, Security Officer, and department heads. Each person on this list shall have the fire evacuation plans nearby and be able to explain in detail all components of the plan.

Fire Safety Plans

Procedure for Reporting Fire and Other Emergencies
All fire events shall be reported by either automatic or manual means. Automatic shall be defined as ‘automatic detection’ via devices located throughout the building. These devices include smoke detectors, heat detectors, workflow switches. Manual shall be defined as ‘manual or occupant detection’ via occupants that witness the fire event or are alerted to the fire event. Such personnel shall immediately report the fire emergency to 911 and other appropriate parties.

Life Safety Strategy and Procedures for Notifying, Relocating or Evacuating Occupants
This project building is designed in such fashion that ‘total’ and ‘complete’ building evacuation is required when there is a fire event detected. Notification of the fire event shall be through the building’s fire alarm system; audio and visual notification shall alert the occupants to evacuate the building.

Disabled students / faculty shall move to nearest area of refuge and await assistance from the fire department prior to attempting to evacuate the building.

All faculty / personnel shall immediately exit the building; only personnel that are required to operate ‘mission-critical’ components of the building shall stay behind. This only applies when the area that the equipment is located in is not within the fire event area.

Site Plans
Site plans indicating the locations of points of assembly for all occupants, the locations of fire hydrants surrounding the building, and normal routes of fire department vehicle access shall be provided for the project building.

These site plans are located within the Life Safety drawings; refer to the sheets X.YY – X.ZZ for more information.
**Floor Plans**
Floor plans identifying the locations of the following shall be provided:

1. Exits
2. Primary Evacuation Routes
3. Secondary Evacuation Routes
4. Accessible Egress Routes
5. Areas of Refuge
7. Portable Fire Extinguishers
8. Occupant-use hose stations
9. Fire Alarm Annunciators and Controls

These requirements are shown on the life safety sheets for the project building. Refer to sheets A4.01 thru A4.24 for more information.

**Major Fire Hazards**
There are several major fire hazards that are located within the project building. These include, but are not limited to, areas within the building that could have the potential for a fire event to occur.

- Armory - located in the basement of the building, room contains ammunition for various weaponry.
- ‘Prep’ Rooms – located in between each pair of science classrooms, these rooms contain various flammable and combustible liquids.
- Gym storage – various locations on the first floor; these rooms are densely packed with potential high hazard items (wrestling mats, plastics, etc.).
- Main cafeteria and student kitchen – both of these areas have equipment with grease hoods and potential for grease fires.
- Building Ops Storage – cleaning materials, flammable liquids (paints / paint thinners).
- Drama / performing arts – storage area for these rooms contain ‘flammable (thermally thin)’ materials that have potential for fast ignition and fire development.

These areas shall be... ...from the remainder of the building. Safeguards shall be put in place to ensure that these areas are kept clean and tidy, and the potential fuel sources are kept to a minimum.

**Responsible Personnel of Building Systems**
The facility manager (maintenance) shall be the responsible person for all building systems. These systems include the mechanical, electrical, plumbing, fire alarm and fire protection systems. Records of all inspections, testing and maintenance shall be kept either near to the piece of equipment or within the facility manager’s office. The facility manager shall also keep on hand contact numbers for the contractors of all systems for repairs and upgrades in order to ensure continuity of operations.
Responsible Personnel of Fuel Hazards
The facility manager shall be the responsible person for the housekeeping and controlling of all fuel hazards within the building. This person shall be responsible for daily walks of the school to ensure that no ‘un-accounted’ for fuel hazards are within any areas that are not designated for such. This person shall also ensure that all potential fuel hazards, as outlined above, are kept within their designated areas when not in use.

In addition to the facility manager, each department head shall be responsible for their respective area in terms of ensuring that all equipment is properly stored in the assigned room. Diligence should be taken to ensure nightly checks that this is complete.

Maintenance of Plans
The fire safety and evacuation plans outlined above, in addition to the drawings, shall be reviewed on a quarterly basis by the Principal, Vice Principal, and department heads to ensure for continual accuracy. Should there be a need to update the plans, this shall occur at the same time as the review.

Availability
The plans outlined above shall be available to all faculty and staff within the school for reference and review. Plans shall also be located within the Principals office, Security office, and in the Knox Box for fire department review. These plans shall be distributed to teachers and faculty at the beginning of each school year to ensure that staff becomes familiar with the plans and recognizes their individual roles and responsibilities within the plan.
IN CASE OF FIRE

Upon Discovery of Fire:

- Leave area immediately and close doors
- Sound fire alarm
- Call 911
- Leave building via nearest exit

Upon Hearing Fire Alarm:

- Leave building via nearest exit
- Close doors behind you
- Do not use elevator

Upon Hearing Intermittent Signal

- Wait in place and listen for directions
- In case of natural emergency follow directions to shelter
- In case of threat close doors and blinds and await further instructions