FPE 596 Culminating Project
Fire Protection System Analysis of Air National Guard Readiness Center

Prepared by Steven A. Waidelich

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</table>
Abstract

This report analyzes the impact of a fire located in the atrium at the Air National Guard Readiness Center (ANGRC) located at Joint Base Andrews, Maryland. The fifth floor is an enclosed penthouse used to enclose mechanical and electrical equipment. International Building Code (IBC) 2006 and 2005, section 506.1, excludes elevator penthouses of this type from the height and area calculations. The four occupied floors are used for office areas with the three-story atrium opening onto the balcony of the second- and the third-floor office area, and the second-floor conference center.

The prescriptive portion of this analysis looked at all fire and life system requirements, such as the fire alarm and detection system, mass notification, fire suppression, smoke management for the atrium, passive fire protection requirements, and life safety requirements for each intended occupancy. The Department of Defense (DOD) Unified Facilities Criteria (UFC), which takes precedence over the National Fire Protection Association (NFPA) and the International Code Council (IBC) requirements, was used for each of the main occupancies: business, concentrated use, assembly occupancy greater than 300 people, and associated small occupancy such as mechanical, electrical, and communication spaces. The atrium requires a smoke removal system to keep the smoke above the tenability requirements. The life safety code requirements for interior finish, travel distance, and dead-end corridors were all looked at part of the prescriptive analysis.

The performance-based portion of this analysis focused on the atrium with a fluid dynamic simulation (FDS) of the stage burning and the impacts to the smoke plume and movement impact to egress. A performance-based hydraulic model was used to evaluate the egress times available and required. This evaluation was conducted to determine Required Safe Egress Time (RSET) versus the Available Safe Egress Time (ASET) to ensure ample time was available within Margin of Time (MOT) safety factor. The ASET exceeds the RSET Time for the evacuation even with the increased occupant load.

Recommendations are to limit the materials used in the atrium to class A or B. While the UFC 3-600-01, Facilities Fire Protection Engineering simply requires compliance with NFPA 101, the more conservative approach is to follow the IBC for atrium interior finishes. Other recommendations would be to comply with the backup power requirement for the smoke control system. While the fire alarm has a backup battery system, the actual smoke removal system does not, and loss of power would impact the smoke layer for those evacuating during an event. While the stage is used intermittently in the atrium and risk is low, there is always the potential that must be considered.
Introduction

The following section is to determine whether the Air National Guard Readiness Center (ANGRC) standard design meets fire safety goals based on NFPA 101, the Life Safety Code 2018. A prescriptive-based design approach and a performance-based design approach were used to evaluate the building’s safety based upon occupant protection, structural integrity, and systems’ effectiveness. The prescriptive-based approach evaluates the building’s structural fire protection systems, egress design, fire detection and alarm systems, and fire suppression systems using United States Air Force (AF) criteria.

The performance-based design approach analyzes how the building will perform in case of a fire using three performance-based design scenarios. This approach evaluates the building based on the Required Safe Egress Time (RSET) and Available Safe Egress Time (ASET) for occupants to evacuate the building safely in case of a fire. Additionally, the evacuation times were evaluated based on the placement of fire detection. Recommendations and findings to improve the building’s fire safety based on the performance-based design scenarios will be discussed in the results of this report.
Prescriptive Analysis

Building Overview

The Air National Guard Readiness Center (red square in Figure 1), located at Joint Base Andrews, Maryland, was completed in 2010. The five-story building has three distinct design areas. Area A is the main business area with offices, workstations, meeting spaces and collaboration rooms. Area B is the atrium space which includes a reception area for the conference center on the second floor and a pedestrian walkway that is connected to the adjacent office building. According to IBC 2006, 2008, and 2018 editions, Chapter 3104, the pedestrian bridge is a separate building. The pedestrian bridge is not a required means of egress from Areas A, B or C. Area C has a fitness center with locker rooms on the first floor, and a conference center on the second floor with demountable walls to allow flexibility for space utilization.

Figure 1. Air National Guard Readiness Center, aerial view.
The ANGRC is classified as a Mixed-Use Occupancy in NFPA 101 and a Group B occupancy in the IBC. NFPA 101 defines a business occupancy as “an occupancy used in the transaction of business other than for mercantile.” NFPA 101 defines an assembly occupancy as having 50 or more people for deliberations, worship, entertainment, drinking, and etc. The mini atrium located in area B on the first floor and vertical extends to include the third floor. The atrium is both a lobby and used as an assembly occupancy space as needed. Assembly occupancies according to NFPA 101 Chapter 6, Sections 6.1.14.4.1 through 6.1.14.4, require a fire rated wall of one hour and smoke barriers between the assembly occupancy and business occupancies. The constructed walls meet these requirements for up to 300 people in the assembly occupancy.

This building is fully sprinklered and is divided into three distinct building areas with occupancy separation walls of one-hour fire and smoke barrier in compliance with Life Safety Code 101, Chapter 6, Table 6.1.14.4.1.

NFPA 101 (2009), Section 7.4.1.2 (2009) and Section 7.4.1.1 (2018), requires a minimum of two exits for each floor of Area A. The occupant load for each floor does not exceed 500 persons, so three or more exits is not required. An area of refuge was created for each stairway in areas A, to comply with NFPA 101, Chapter 7, section 7.1.2.2.(2) requires a safe haven to meet American disability act for severe mobility impaired individuals, and those needing to wait for assistance to evaluate. These areas of refuge are separate by a one-hour fire rated barrier and resist passage of smoke. The occupant load for the atrium in Area B is less than 300, including the occupancy of the Subway kiosk, which is from the same occupant pool. This loading would require two exits, which are provided and shown in Figure 1. Atrium is provided with a smoke management system that meets NFPA Standard 92. The smoke management system was designed for the atrium as a non-assembly location with interior finishes with class A and B flame spread and smoke development meeting NFPA 101, Chapter 10 requirements. The interior finishes all meet the allow flame spread and smoke development.

The Atrium in Area B is used from time to time for assembly events. A portable stage can be erected in this space as needed. When used, the portable stage obstructs the use of the south atrium doors, but secondary exits within the atria allow access to each of the stairwell exits. Exit doors in Area C are also provided. The travel distance provided meets the required travel distances for a building equipped with an automatic sprinkler system complying with NFPA Standard 13. The required exit load for occupancy of 300 persons is based on the above NFPA Standard. The seating area does not have fixed seating and meets the required travel distance of less than 300 feet and will have aisle spacing at a minimum of 28 inches to support the seating. The remaining occupant load factor is based on NFPA Standard 101 (2009), Chapter 13, Section 12/13.1.7.1 and 12/13.1.7.1.2. The occupant load factor is based on the conservative approach suggested in the NFPA 101 Handbook (2009), Sections 12/13.1.7.1 and 12/13.1.7.1.2 commentary based on the term “concentrated use.” The conservative approach suggested for this analysis is an assembly use of the atrium. The first-floor occupant load factor used is 7 square ft. per person. Area C has the first-floor fitness center with locker rooms.
Egress Analysis and Design

Occupancy Classification/Type and Occupant Load

One component in calculating occupant load was determining occupancy classification/type for each area of the floor. Table 1 shows a breakdown of occupancy type for each floor. Figures 1-5 show the occupancy type on each floor.

The equation below shows how the occupant load was calculated. The area of the room divided by the occupant load factor resulted in the occupant load.

\[
\text{Occupant Load} = \frac{\text{Area of room (ft}^2\text{)}}{\text{Occupant Load Factor (ft}^2\text{ occupant)}}
\]

Once the occupant load was determined for each occupancy type on a floor, they were added together to provide a total occupant load for the entire floor. The calculated occupancy load can also determine if the means of egress provided has met the requirements per NFPA 101 (2009) Table 4.1.1 for the number of occupants on each floor. With the total occupant load calculated, the number of exits required on each floor can be determined. Table 2 shows the required number of exits and number of exits provided on each floor. The design met the requirements per NFPA 101 (2009), Section 7.4.1.2 and (2018) Section 7.4.11 for required number of exits per floor.
Table 1. Occupancy and Occupant Loads.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Occupancy Use</th>
<th>Floor Area (squarefeet)</th>
<th>Occupant Load Factor</th>
<th>Occupant Load (persons)</th>
<th>Total Occupant Load</th>
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<td>410</td>
<td>100</td>
<td>4</td>
<td>676</td>
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<tr>
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<tr>
<td></td>
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<td>30</td>
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<td>COMMUNICATION ROOM</td>
<td>334</td>
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<td>STORAGE</td>
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<td>3</td>
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</table>
Table 2. Number of Exits Required and Provided.

<table>
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<tr>
<th>Floor</th>
<th>Occupants Per Floor</th>
<th>Required No. of Exits</th>
<th>Provided No. of Exits</th>
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<tr>
<td>1</td>
<td>676</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>621</td>
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</tr>
<tr>
<td>5</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Occupancy and Egress/Egress Stairway**

For reference, offices are shown in green, storage spaces are yellow, the Area B assembly is orange, common areas/mercantile spaces are light blue, and exit corridors and egress doors/egress stairways are red. There are utility/storage rooms in Area A and C.

![First Floor Plan](image-url)
The second floor (Figure 3) is divided in the same way as the first floor as seen in Figure 2. Area A is office space. Area B is a small assembly area with an open interconnecting stairway to the first floor that is open to the floor below in the atrium area. Area C is a conference center with four small, subdivided collaboration rooms. The walls of these small rooms can be opened into a large conference area with the largest occupant load of 88. The common area is used by the conference center.

The main entrance to the conference center is through the mezzanine area, which is open to the atrium below. The conference center has two stairwells. One is not enclosed and is open to the first floor while the other is located on the southeast side of the building and is enclosed.

Figure 3. Second Floor Plan.
The third floor (Figure 4) has only Area A, which is office space and utility/storage rooms. There is a balcony that overlooks the atrium. In case of emergency, occupants will need to use the balcony to exit to the emergency stairwells on either end.

Figure 4. Third Floor Plan.
The fourth floor (Figure 5) of Area A is used for business and is configured similarly to floors one through three. The fourth floor also has an executive suite for management, as shown in Figure 5. The fourth floor is not open to the mini atrium.

Figure 5. Fourth Floor Plan.
The fifth floor (see Figure 6) contains the penthouse as well as the mechanical and utility area of the building. It is not used as office space.

Figure 6. Fifth Floor Plan.

**Means of Egress (Appendix H)**

NFPA Standard 101, Chapter 7, Sections 7.3.3.1 and 7.3.3.2 (see Table 3), were used to evaluate the stair exit capacity. The equation, \( C = 146.7 + \left( W_n - 44 / 0.218 \right) \), was used to determine the increase for the stairs are 48 inches in clear width. The increased stair width calculation was used for stairs with an occupant load increase of 165 occupants (Section 7.3.3.1, outlined in magenta). The increased stair width is allowed and helps to accommodate the queening in the stairs due to the confluence of each floor persons entering the stair way to egress. The point of constriction for all spaces will be the stair way doors and the stairs with typical 7-inch x 11-inch stair risers and tread depths. They measure 48 inches in width with a reduction for 6” handrail boundary, and the interior stair construction makes the effective width 29 inches. The corridors are 60 inches in clear width and adequate for the expected occupant load to evacuate through to the stair exit enclosures to the outside.
Table 3. NFPA Standard 101, Chapter 7, Sections 7.3.3.1 and 7.3.3.2
Egress Capacity Factors.

<table>
<thead>
<tr>
<th>Egress Capacity</th>
<th>width [in]</th>
<th>effective width [in]</th>
<th>width per person</th>
<th>Occupant Load</th>
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<tr>
<td>Balcony Door</td>
<td>32</td>
<td>29</td>
<td>0.2</td>
<td>145</td>
</tr>
<tr>
<td>Stair Door</td>
<td>36</td>
<td>29</td>
<td>0.2</td>
<td>145</td>
</tr>
<tr>
<td>stairs</td>
<td>48</td>
<td>36</td>
<td>0.3</td>
<td>120</td>
</tr>
<tr>
<td>Stairs additional capacity</td>
<td></td>
<td></td>
<td></td>
<td>165</td>
</tr>
<tr>
<td>Per Stairway total</td>
<td></td>
<td></td>
<td></td>
<td>285</td>
</tr>
</tbody>
</table>

NFPA Standard 101, Chapter 7, Section 7.3.3.2

<table>
<thead>
<tr>
<th>Area</th>
<th>Stairways (width/person)</th>
<th>Level Components and Ramps (width/person)</th>
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</thead>
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<tr>
<td></td>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Board and care</td>
<td>0.4</td>
<td>10</td>
</tr>
<tr>
<td>Health care, sprinklered</td>
<td>0.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Health care, nonsprinklered</td>
<td>0.6</td>
<td>15</td>
</tr>
<tr>
<td>High hazard contents</td>
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</tr>
<tr>
<td>All others</td>
<td>0.3</td>
<td>7.6</td>
</tr>
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</table>

Table 4. Exit Capacity Required and Provided by Floor.

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<tr>
<th>Floor</th>
<th>Total Occupant load (People)</th>
<th>Required Stair Entry Door Width 0.2*Total Occ (inches)</th>
<th>Provided Stair Entry Door Width (inches)</th>
<th>Required Stair Width 0.3*Total Occ (inches)</th>
<th>Provided Stair Width (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>676</td>
<td>135.2</td>
<td>297</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>621</td>
<td>124.2</td>
<td>132</td>
<td>186.3</td>
<td>192</td>
</tr>
<tr>
<td>3</td>
<td>204</td>
<td>40.8</td>
<td>66</td>
<td>61</td>
<td>96</td>
</tr>
<tr>
<td>4</td>
<td>314</td>
<td>63</td>
<td>66</td>
<td>94.2</td>
<td>96</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>1.2</td>
<td>NA</td>
<td>19.8</td>
<td>NA</td>
</tr>
</tbody>
</table>
Table 5 shows the maximum diagonal dimension of each floor which is the required distance for exit separation (1/3 of the diagonal dimension for sprinklered buildings per NFPA 101, Chapter 5, Section 7.5.1.3). The maximum diagonal distance is used to ensure that if one of the exits becomes unusable, the other exit is still available for egress and meets the travel distance, while still providing exit separation. The design meets the requirements of the requirements of the NFPA 101 (2016).

Table 5. Separation Distances Each Floor.

<table>
<thead>
<tr>
<th>Level</th>
<th>Maximum Diagonal Measurement (feet)</th>
<th>Required Separation Distance (feet)</th>
<th>Provided Separation Distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>311</td>
<td>104</td>
<td>370</td>
</tr>
<tr>
<td>2</td>
<td>306</td>
<td>101</td>
<td>548</td>
</tr>
<tr>
<td>3</td>
<td>317</td>
<td>105</td>
<td>259</td>
</tr>
<tr>
<td>4</td>
<td>321</td>
<td>106</td>
<td>259</td>
</tr>
<tr>
<td>5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

The exit travel distance shall be measured from the most remote point within a story along the natural and unobstructed path of horizontal and vertical egress travel to the entrance of an exit. The exit access travel distance shall not exceed the values shown in Table 6 for each occupancy in a fully sprinklered building. The design meets the requirements of the requirements of the NFPA 101, 2016.

Table 6 shows the common path, dead-end, and travel distance limits by occupancy according to NFPA 101, 2016.

Table 6. Common Path, Dead-End, and Travel Distance Limits.

<table>
<thead>
<tr>
<th>Type of Occupancy</th>
<th>Common Path Limit</th>
<th>Dead-End Limit</th>
<th>Travel Distance Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unsprinklered</td>
<td>Sprinklered</td>
<td>Unsprinklered</td>
</tr>
<tr>
<td></td>
<td>ft m</td>
<td>ft m</td>
<td>ft m</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>2075 6 1/2 m</td>
<td>2075 6 1/2 m</td>
<td>20 6 1/3</td>
</tr>
<tr>
<td>Existing</td>
<td>2075 6 1/2 m</td>
<td>2075 6 1/2 m</td>
<td>20 6 1/3</td>
</tr>
<tr>
<td>Business</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>75 27</td>
<td>100 30</td>
<td>20 6 1/3</td>
</tr>
<tr>
<td>Existing</td>
<td>75 27</td>
<td>100 30</td>
<td>50 15</td>
</tr>
</tbody>
</table>
Summary
A complete analysis of the egress design was provided for the Air National Guard Readiness Center. This analysis included an evaluation of system occupancy types, occupant load, number of exits, required and provided separation distance, required and provided door/stairway widths, and maximum travel distance. Based on the information provided, the egress design of the of the Center meets the requirements of NFPA 101. Overall, the passive life safety protection system was found to be compliant with the requirements of NFPA 101, and UFC 3-600-01. A structural fire protection analysis will be discussed in the next section.

Structural Fire Protection Analysis
The following section will serve as an analysis of the building’s structural fire protection. A prescriptive analysis based on the code of record is performed. The different methods of how to protect the main structure of the building from failure due to fire conditions are discussed. The fire load is modelled, and different thicknesses of insulation is recommended for the structural members.

Construction Type and Fire Resistive Construction Methods
This building has three distinct occupancies as constructed with the occupancy separations meeting Life Safety Code 101, Chapter 6, Table 6.1.14.4.1 for occupancy fire resistive separations.

The facility was constructed using reinforced concrete and used metal curtain walls for the windows. The windows are triple pane and are designed to handle up to 100 mph wind speeds. The foundation is driven piles with concrete pile caps to distribute the building loads from the reinforced concrete columns for the five-story building. The stairwells are reinforced concrete with a two-hour fire rated fire wall. On floors one through three, the balcony walls around the open office plan are one-hour fire and smoke rated. The facility is protected throughout by an automatic sprinkler system and meets the International Building Code requirement for having half the perimeter open to the public way.

Allowable Height, Area, and Stories
The facility follows International Building Code (IBC) Sections 506.2.4 exceptions and was designed to meet Section 508.4. These sections are for use in determining the allowable heights and area of building and are dependent on the construction type. These sections provide for an increase in the allowable square footage dependent upon open public way and the degree of installed sprinkler systems within the building. Tables 7 and 8 show the constructed building square footage and the IBC building classification.
Table 7. Constructed Building Square Footage.

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>IIB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Height</td>
<td>65 ft.</td>
</tr>
<tr>
<td>Total Building Floors 1-4 Gross Area</td>
<td>165,613</td>
</tr>
</tbody>
</table>

Note:

Table 8. IBC 2015/ UFC 1-200-01 Building Classification.

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>I-IV</th>
<th>IIB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Height</td>
<td>75 ft.</td>
<td>65 ft.</td>
</tr>
<tr>
<td>Allowable Area</td>
<td>23,000</td>
<td>23,000</td>
</tr>
<tr>
<td>Allowable Stories</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Building floor plans showing the fire resistive barriers are located in Appendix A.

**Flammability**

The building’s interior wall and ceiling finishes are in accordance with NFPA 101, Table A10.2.2 (Table 9). Occupancies for Assembly-new, and Business and ambulatory care-new are outlined in red. NFPA Standard 101, Chapter 38, Sections 38.3.3.2 and 38.3.3.3 requires the use of Class A or B interior wall finishes in all exits and exit access corridors and using Class I and II finishes for the flooring. See notes in the table.
Table 9. NFPA Standard 101 Table A10.2.2. Interior Finish Classification Limitations.

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Exits</th>
<th>Exit Access Corridors</th>
<th>Other Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly — new</td>
<td>A</td>
<td>A or B</td>
<td>A or B</td>
</tr>
<tr>
<td>&gt;500 occupants lead</td>
<td>1 or H</td>
<td>1 or H</td>
<td>NA</td>
</tr>
<tr>
<td>≤500 occupants lead</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Educational — new</td>
<td>A</td>
<td>A or B</td>
<td>A or B on low partitions*</td>
</tr>
<tr>
<td>Educational — existing</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Daycare centers — new</td>
<td>A</td>
<td>A or B</td>
<td>A or B</td>
</tr>
<tr>
<td>Daycare centers — existing</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Daycare homes — new</td>
<td>A or B</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Daycare homes — existing</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Health care — new</td>
<td>A</td>
<td>A</td>
<td>B in lower portion of corridor wall*</td>
</tr>
<tr>
<td>Health care — existing</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Residential and care — (See Chapters 32 and 33)</td>
<td>A</td>
<td>A or B</td>
<td>A or B</td>
</tr>
<tr>
<td>Mercantile — new</td>
<td>A or B</td>
<td>A or B</td>
<td>A or B</td>
</tr>
<tr>
<td>Class A or class B stores</td>
<td>A or B</td>
<td>A or B</td>
<td>Ceilings — A or B; walls — A, B, or C</td>
</tr>
<tr>
<td>Class C stores</td>
<td>A, B, or C</td>
<td>A, B, or C</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Business and ambulatory</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Health care — new</td>
<td>A</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Business and ambulatory</td>
<td>A or B</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>Storage</td>
<td>A or B</td>
<td>A or B</td>
<td>A, B, or C</td>
</tr>
</tbody>
</table>

Required Fire Resistance Ratings

Figures 7 through 11 below show the two-hour fire rated walls in red and the one-hour smoke barriers with one fire resistive barrier for the mini atrium in green. The IBC requires a one-hour fire rated barrier to separate business and assembly occupancy. A one-hour barrier is also required to separate the utility or mechanical spaces from the other occupancies since they are low hazard.
Stairways, elevator shafts, and utility shafts are all 2-hour fire rated walls. All other areas are fire and smoke barriers. Travel distance measurements are also shown.

Figure 7. First Floor Fire and Smoke Walls and Travel Distances.

Figure 8. Second Floor Fire and Smoke Walls and Travel Distances.
Figure 9. Third Floor Fire and Smoke Walls and Travel Distances

Figure 10. Fourth Floor Fire and Smoke Walls and Travel Distances.
Exit Signs

Light emitting diode (LED) exit signage (Figure 12) meets the minimum requirements for all main exit doors to have visible and clearly identifiable exits from any direction as prescribed by NFPA 101, Chapter 7 section 7.10.1.2.1. The Department of Defense (DOD) Unified Facilities Criteria 3-600-01 requires them to be LED-style exit signs. All exit access corridors are provided with arrows indicating the path to the exits.

Exit signs are maintained in accordance with UFC 3-601-01, Table 2-24, Egress Marking Systems ITM Tasks, as seen in Table10.
Table 10. UFC 3-601-01, Table 2-24. Egress Marking Systems ITM Tasks.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual</td>
<td>1. Externally Illuminated and Un-Illuminated Marking</td>
<td>1. Inspect fixture condition and mounting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Ensure that emergency light source, if required, is functional.</td>
</tr>
<tr>
<td></td>
<td>2. Photoluminescent Marking</td>
<td>1. Inspect sign condition and mounting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Inspect charging light source and mounting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Ensure that charging light source is functional (un-switched 5 foot-candles fluorescent or greater). Note: Charging light must be on at all times the building is occupied.</td>
</tr>
<tr>
<td></td>
<td>3. Internally Illuminated Marking</td>
<td>1. Inspect fixture condition and mounting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Ensure that the bulb or light source is functional.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. For photoluminescent marking, ensure that the power source is operational.</td>
</tr>
<tr>
<td></td>
<td>4. Internally Illuminated Marking with Standby Battery Backup</td>
<td>1. Inspect fixture condition and mounting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Ensure that the bulb or light source is functional.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Activate on battery power for not less than 90 minutes to verify battery voltage and capacity.</td>
</tr>
<tr>
<td></td>
<td>5. Internally Illuminated Marking with Emergency Generator Backup</td>
<td>1. Inspect fixture condition and mounting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Ensure that the bulb or light source is functional.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. During regularly scheduled generator and transfer switch maintenance, visually check the operation of each emergency generator-powered fixture.</td>
</tr>
<tr>
<td>5 to 10 years</td>
<td>1. Internally Illuminated Marking with Standby Battery Backup</td>
<td>1. Replace battery or fixture if battery is not replaceable (utilized fixture) in accordance with manufacturer’s estimated service life.</td>
</tr>
</tbody>
</table>

**CAUTION**

Battery-powered emergency egress marking generally requires from 1 to 7 days to initially charge or to re-charge following a 90-minute discharge or activation.

**Emergency Lighting**

Emergency lighting is provided by LED light fixtures (Figure 13) throughout the facility with battery backup inverters that supply the minimum illumination. Lighting is maintained throughout to have a minimum of 2.2 lux for the area. The restrooms and some ancillary spaces do not have sufficient lighting in the event of a power failure. This is based on actual observation with no lighting measurement taken.

![Figure 13. LED Light Fixture.](image)
Emergency lighting are maintained in accordance with the UFC 3-601-0.2 (September 8, 2010) Operation and Maintenance: Inspection, Testing, and Maintenance of Emergency Lighting Systems document as shown in Table 11.

Table 11. UFC 3-601-0.2 Table 2-23. Emergency Lighting Systems ITM Tasks.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual</td>
<td>1. Individual Battery-Powered Lighting Units</td>
<td>1. Activate for not less than 90 minutes to verify battery voltage and capacity.</td>
</tr>
<tr>
<td></td>
<td>2. Central Battery-Powered Lighting Systems</td>
<td>1. Activate for not less than 90 minutes to verify battery voltage and capacity.</td>
</tr>
<tr>
<td></td>
<td>3. Emergency Generator-Powered Lighting Systems</td>
<td>1. During regularly scheduled generator and transfer switch maintenance, visually check operation of each emergency generator-powered fixture.</td>
</tr>
<tr>
<td>5 to 10 years</td>
<td>Individual Fixtures’ Replaceable Batteries or Unitized Fixtures</td>
<td>1. Replace battery or complete unitized fixture in accordance with manufacturer’s estimated service life.</td>
</tr>
</tbody>
</table>

**CAUTION**

Battery-powered emergency lights generally require from 1 to 7 days to initially charge or to re-charge following a 90-minute discharge or activation.

**Summary**

The structural protection analysis of the ANGRC, which included construction type, occupancy classifications, and fire-resistance requirements showed that the ANGRC was compliant with the fire-resistance requirements for separation of occupancies, interior finishes, and exterior wall separation distance according to NFPA 101(2016). The fire alarm and detection systems will be discussed in the next section.

**Fire Alarm and Detection Systems**

The following section will serve as an analysis of the building systems in place that are used for fire alarm and detection within this building. A prescriptive analysis, based on the code of record and NFPA 72, was used to determine the adequacy of the system within this building. The fire alarm and detection devices present within this building were documented and evaluated based on engineering standards.

**Fire Alarm and Mass Notification System**

The facility fire alarm is a combination voice evacuation and mass notification system. The fire alarm panel is a Simplex 4100U, as pictured in Figure 14.
Simplex Annunciator panels are located near each entrance and exit doors, as well as on the outer balcony or in the hallway near each elevator lobby on each floor.

Table 12. Example of Simplex 4100U battery calculations.

<table>
<thead>
<tr>
<th>Battery Set #1 (Cabinet/Charger #1)</th>
<th>Qty</th>
<th>Standby Current</th>
<th>Alarm Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabinet #1 Card Power</td>
<td></td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Current Draw For 100 Watt Or 95-Watt Amplifiers</td>
<td>0</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Current Draw for Flex 35 and 50 Watt Amplifiers</td>
<td>0</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Power for External Peripheral Devices</td>
<td>0.01040</td>
<td>2.70400</td>
<td></td>
</tr>
</tbody>
</table>

Additional Current Draws

RUI Connected Peripheral Devices
MAPNET/ID Net Device Addresses ordered Aged
Spare addressable point capacity included for battery calc.

<table>
<thead>
<tr>
<th>Qty</th>
<th>Standby Current</th>
<th>Alarm Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

0.010 <- Sub Totals --> 2.704

Standby Time = 2d 0.250 Hrs
Alarm Time = 5/65 Mins.

Minimum Battery Required per NFPA72 2010
2081-0272 6.2 AH 0.570
20% Safety Margin Included

Battery Supplied 2081-0272 6.2 AH

Note: Shop drawings and calculations were not available. Table 12 is an example of battery calculations for this system.

The system is an addressable system with all notification and initiation appliances having their own addresses. The mass notification systems are interconnected as required by UFC 4-0.21-01 and NFPA 72 (2016). The notification appliances use a dual combination strobe with the fire alarm in a clear lens and the mass notification systems in an amber lens (see Figure 15). The new UFC 4-21-01 and UFC 3-600-01 now requires a clear dual strobe for fire and mass notification.

Figure 15. Example of Multi-Candela Addressable Combination Strobe Assembly.
Alarm Notification Appliances

When the alarm notification appliances were installed, they were spaced and set for 15/30cd depending on the room size. These devices are field programmable for visible and audible settings. Figure 16 below provides the manufacturer product information and selection guides for this product. The following sections-Product Selection, Strobe Specifications, and the TrueAlert Strobe LEGACY Compatibility Reference, are highlighted to provide more information on the specific appliances.
IDNAC SLC Operation Advantage

TrueAlert V/I/O Appliances with Addressable Strobes on IDNAC SLCs provide visible notification using a single two-wire circuit that also confirms connection to the individual notification appliance’s electronic circuit. This operation increases circuit supervision integrity by providing supervision that extends beyond the appliance wiring connections.

Reduced current allows efficient IDNAC SLC operation. With IDNAC SLCs, a constant 29 VEMS source voltage is maintained, even during battery standby, allowing strobes to operate at higher voltage with lower current and ensuring a consistent current draw and voltage drop margin under both primary power and secondary battery standby. Efficiencies include wiring distances up to 2 to 3 times farther than with conventional notification, or support for more appliances per IDNAC SLC, or use of smaller gauge wiring, or combinations of these benefits, all providing installation and maintenance savings with high assurance that appliances that operate during normal system testing will operate during worst case alarm conditions.

Reducing Installation and Testing Time. With separate controls on the same two-wire SLC, installation time and expense for both retrofit and new construction can be significantly reduced. When Class B wiring is used, wiring can be "T" tapped, allowing more savings in distance, wire, conduit (size and utilization), and overall installation efficiency. Use of the magnet test feature improves installation efficiency. TrueAlert device reports conveniently identify information about each connected appliance.

By providing an amber lens strobe with a clear lens strobe, the combination strobe assembly allows a single electrical installation to provide both types of visible notification.

TrueAlert Addressable Diagnostics

Test Features. Controllers can be selected to pulse each appliance’s LED when it receives a supervision poll. When the controller is selected for diagnostic mode, the appliance magnet test feature provides a response at the individual appliance being tested.

Silent Appliance Magnet Test. In this test mode, in response to the magnet test, the appliance LED pulses sequentially to conveniently indicate the appliance’s address.

Operational Appliance Testing. In this test mode, after the address is indicated by pulsing the appliance LED, the strobe will briefly flash to indicate proper operation.

TrueStart Instrument Two (TSIT). The 2nd generation of the Simplex TrueStart Test Instrument adds testing of IDNAC SLC wiring and TrueAlert (and TrueAlert E5) appliances to its ability to test IDCs, NACs, and IDNet communications before connection to the control panel. Please contact your local Simplex representative for additional information.

TrueAlert Addressable Wiring Isolator

Isolator Model 4905-9929 is available for remote mounting on TrueAlert addressable circuits to isolate short circuiting wiring from functioning wiring. (Refer to data sheet 54905-0001 for additional information.)

TrueAlert Device Reports detail type, candle rating, and location per appliance (see example below, amber lens type is AMB).

Product Selection

<table>
<thead>
<tr>
<th>Model</th>
<th>Housing Color</th>
<th>Description</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4905-9208</td>
<td>Red</td>
<td>Multi-Candela Addressable Combination Strobe assembly with amber lens, ALERT strobe on top and clear lens, FIRE strobe on bottom, intensity selectable as 5, 10, 20, 50, 75, or 110 candela</td>
<td>10 ⅞&quot; H x 5 ⅜&quot; W x 3 ⅞&quot; D (273 mm x 130 mm x 100 mm)</td>
</tr>
<tr>
<td>4905-9211</td>
<td>White</td>
<td>Surface Mount Adapter Skirt, use to cover surface mounted electrical boxes</td>
<td>10 ⅞&quot; H x 5 ⅜&quot; W x 1 ⅝&quot; D (267 mm x 133 mm x 44 mm) Total depth with strobe assembly = 5 ⅜&quot; (143 mm)</td>
</tr>
<tr>
<td>4905-9837</td>
<td>Red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4905-9847</td>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4905-9840</td>
<td>Red</td>
<td>Adapter Plate for mounting to installed Simplex Model 2075-0145 box; for flush mounted boxes only</td>
<td>12 ⅞&quot; H x 5 ⅛&quot; W x 0.06 thick (313 mm x 146 mm x 1.5 mm)</td>
</tr>
</tbody>
</table>

TrueAlert Device Reports Reference

<table>
<thead>
<tr>
<th>SERVICE PORT</th>
<th>CUSTOM LABEL</th>
<th>DEPARTMENT</th>
<th>TYPE</th>
<th>CANDLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>714-1-1</td>
<td>Location Label . . . up to 40 characters</td>
<td>V/O</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>714-1-2</td>
<td>Break Room 8</td>
<td>A/V</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>714-1-3</td>
<td>Boiler Room Fire</td>
<td>A/V</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>714-1-4</td>
<td>Boiler Room Alert</td>
<td>AMB</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>
## TrueAlert Strobe and IDNAC SLC Controller Compatibility Reference

<table>
<thead>
<tr>
<th>Compatible Controller</th>
<th>Data Sheet Reference</th>
<th>Controller Output</th>
<th>IDNAC SLC Output Voltage</th>
<th>Appliance Voltage Design Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>4100ES with EPS+ or EPS Power Supply</td>
<td>S4100-0001</td>
<td>IDNAC SLC</td>
<td>29 VRMS (regulated)</td>
<td>29 VRMS (with 6 VRMS drop)</td>
</tr>
<tr>
<td>4008 IDNAC Repeater</td>
<td>S4008-0004</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Specifications

#### Common Specifications (see page 2 for appliance dimensions)
- **Environmental**: 32° to 122° F (0° to 50° C); 10% to 93%, non-condensing at 100° F (38° C)
- **Connections**: Terminal blocks for 18 AWG to 12 AWG (0.82 mm² to 3.31 mm²); two wires per terminal for in/out wiring
- **Installation Instruction Reference**: Clear/Amber Strobe 579-947, Adapter Skirts 574-760, Adapter Plate 574-761

#### Strobe Specifications
- **Typical Operating Voltage Range**: 23 VRMS to 31 VRMS, Special Application (see below for 17 VRMS rating)
- **Supervisory Requirements**: 1 unit load each, 2 unit loads total per 4906-6208
- **Flash Rate and Synchronized SLC Loading**: 1 Hz; with up to 46 synchronized strobes maximum per NAC, maximum 33 Ω resistance between appliances
- **23 VRMS Current Ratings, for connection to IDNAC Addressable SLCs**:
  - 15 cd: 50 mA
  - 30 cd: 75 mA
  - 75 cd: 137 mA
  - 110 cd: 100 mA

Note: Amber strobes and clear strobes provide notification for two different functions and are not activated at the same time.

## TrueAlert Strobe LEGACY Compatibility Reference

<table>
<thead>
<tr>
<th>Compatible Controller</th>
<th>Data Sheet Reference</th>
<th>Controller Output</th>
<th>Available Strobe Intensity</th>
<th>Appliance Voltage Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>4100ES or 4100U with TrueAlert Power Supply</td>
<td>S4100-0031</td>
<td>TrueAlert Addressable SLC</td>
<td>15, 30, 75, and 110 cd</td>
<td>17 VRMS</td>
</tr>
<tr>
<td>4008 TFS, Remote TrueAlert Power Supply</td>
<td>S4100-0003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TrueAlert Addressable Controller (4009T)</td>
<td>S4009-0003</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Electrical Ratings Difference for Retrofit Applications

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>17 VRMS to 31 VRMS, Special Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candela Setting</td>
<td>15 cd</td>
</tr>
<tr>
<td>Candela Setting, use when connected to TrueAlert Addressable SLCs per above</td>
<td>64 mA</td>
</tr>
</tbody>
</table>

---

Figure 16. Simplex TrueAlert Addressable Notification Appliances Fact Sheet.
**Mass Notification System (MNS)**

The military has been leading the civilian communities for many years on the installation of mass notification systems. Following the September 16, 2013, Washington Navy Yard attack, the July 16, 2015, Chattanooga recruiting office attack, and other attacks, there has been an increased awareness and strengthening of the need to install these systems. The ANGRC installed the mass notification system with campus-wide response. The Simplex 4100U voice evacuation system has panels located in the balcony on the 2nd through 4th floor and by each entrance/exit doors. The campus has amber alert strobes spaced next to each fire strobe. The visible intensity matches the fire alarm strobes for alerting the area to non-fire incidents. The MNS also uses the ad hoc desktop system to alert the people working in their cubicles. These systems are to ensure everyone is aware of the situation. The mass notification design documents are in Appendix D.

**Fire Detection and Alarm Systems**

Figure 17 below is a picture of the manual fire alarm-pull stations, installed throughout the building areas to meet NFPA Standard 101, NFPA 72 and UFC 3-600-01, at the time of design and construction.

![Figure 17. Manual Pull Station.](image)

**Smoke Detectors**

Duct smoke detectors are provided in the supply and return to comply with NFPA 90A. See Figure 20 for air handling supply air CFMs. The duct smoke detectors transmit supervisory signal via a Monaco D-21 transceiver to the off-site emergency dispatch.

Floors 1-4 elevator lobbies have smoke detectors installed per NFPA 101, and NFPA 72. DoD Facility Fire Protection Engineering guidance is to provide a smoke detector at the top of each elevator shaft and in each elevator penthouse. A smoke detector is also located over the main fire alarm panel located in the fire pump and riser room. The elevator lobby detectors are used to comply with NFPA 101 for alternate floor return. Each will activate the fire alarm system. See Figure 18 for the fire alarm sequence of operations.
Figure 18. Fire Alarm Sequence of Operations.

All fire detection and alarm systems are maintained in accordance with the UFC 3-601-0.2 (September 8, 2010) Operation and Maintenance: Inspection, Testing, and Maintenance of Fire Protection Systems document (Table 13). The following is an excerpt from the UFC 3-601-0.2, Section 2-2.2, on Fire Detection and Alarm Systems:

“The type and frequency of Inspection, Testing, and Maintenance (ITM) tasks for fire detection and alarm systems depend on whether the system is being monitored or not. Guidance on the tasks in Table 10 are contained in the “Inspection, Testing, and Maintenance” section of NFPA Standard 72 (NFPA 72). Residential smoke detectors are addressed in Chapter 3 of this UFC."
Table 13. UFC 3-600-01, Fire Detection and Alarm System ITM Tasks.

**WARNING**
Fire alarm systems with more than two abnormal conditions (trouble conditions) are outside their minimum tested or listed operating parameters and may not meet their performance requirement for receipt or transmission of subsequent alarms or additional trouble conditions.

**WARNING**
Any fire alarm system with more than three unexplained activations (fire indication conditions) in a 6-month period is experiencing a system instability that should be evaluated by a technician or engineer, and appropriate corrective measures should be implemented immediately.

**CAUTION**
Alarm systems in a TROUBLE condition should be able to transmit an ALARM condition while in trouble; however, because this is not considered to be a normal or acceptable alarm system status, immediate maintenance action is indicated.

**NOTE:**
Any fire alarm system with more than three explained activations (fire indications) resulting from non-fire events being mistaken for actual fires should be evaluated by a technician or engineer to determine if corrective actions are necessary.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly</td>
<td>1. Control Panels and Annunciator Equipment (unmonitored only)</td>
<td>1. Inspect panel condition (connections, fuses, light-emitting diodes [LED]).</td>
</tr>
<tr>
<td>Annual</td>
<td>1. Control Panel and Annunciator Equipment (monitored)</td>
<td>1. Test to verify proper receipt of alarm, supervisory, and trouble signals (inputs) and operation of notification appliances and auxiliary functions (outputs). 2. Verify that all lamps and LEDs are illuminated. 3. Load test backup batteries (when provided).</td>
</tr>
<tr>
<td></td>
<td>b. Radiant Energy Detectors (Optical Detectors)</td>
<td>1. Test to verify alarm initiation and receipt. 2. Verify no facility change that affects performance.</td>
</tr>
<tr>
<td></td>
<td>c. Gas Detectors</td>
<td>1. Test to verify alarm initiation and receipt. 2. Verify no facility change that affects performance.</td>
</tr>
<tr>
<td></td>
<td>3. Notification Appliances and Voice Communication (telephone, speakers, horns, and strobe lights)</td>
<td>1. Test to verify operability.</td>
</tr>
<tr>
<td></td>
<td>4. Digital Alarm Transmitters and Receivers</td>
<td>1. Test to verify operability.</td>
</tr>
</tbody>
</table>
Smoke Removal Systems

The fire alarm and mass notification control panel sequence of operation in Figure 18, shows in Column M that no smoke detectors activate the smoke removal system. The building’s smoke removal system vents are located at the top of the atrium on the east side of Area C. The three smoke exhaust fans shown in Photo 1 from the outside and Photo 2 shows them from the inside, are designed to exhaust a cumulative total of 9,900 cfm using ½ HP motors per the design drawings. The exhaust fan identification tags on the motors showed 1 hp not the ½ hp motors. This is a data discrepancy between the tag and design drawing shown in Figure 19. ½ hp was used for this report since it seemed closer to what is installed based on performance.

The smoke exhaust system is not activated by any of the smoke detectors in the elevator lobbies on floor level’s one through three or in the balcony areas. In addition, the smoke removal system is activated only by the elevator shaft sprinkler and third floor stairway water flow switches.

The heating, ventilation, and air conditioning (HVAC) sequence of operation in Figure 21 shuts down the outside air supply and opens the outside dampers when the smoke removal system is activated. This allows the smoke to gravity feed through the duct to the outside in
addition to the smoke removal system shown in Photos 1 and 2. Photo 1 shows the exterior fan units and Photo 2 shows the interior located just below the second-floor ceiling exhausting to the second-floor roof of Area C shown in Figures 2 and 3.

Figure 19 shows the air handling units AHU-2A, -2B through AHU-4A through -4B information, in the red rectangle.

Figure 19. Air Handling Units Information.

Figure 20 shows the AHU supplying units in the red rectangle that provide make up air to the atrium area along with cross flows from areas A and C.

Figure 20. Exhaust Fans Information Chart.

Note: Atrium smoke exhaust fans information outlined in red.
Figure 21 shows the complete sequence of operation and activation description for the atrium exhaust fans.

**SMOKE CONTROL**

WHEN IN THE SMOKE CONTROL MODE, AS DETERMINED BY INPUT FROM THE FIRE ALARM SYSTEM, THE FOLLOWING SHALL OCCUR.


AHU—4A AND —4B: THE ASSOCIATED DDC CONTROLLER SHALL FULLY CLOSE THE OUTSIDE RELIEF AIR DAMPERS AND SHALL DE-ENERGIZE THE SUPPLY AND RETURN FANS.

EF—1, —2 AND SF—1: THE ASSOCIATED DDC CONTROLLER SHALL DE-ENERGIZE THE EXHAUST AND SUPPLY FANS.

EF—3 THRU —5: THE ASSOCIATED DDC CONTROLLER SHALL ENERGIZE AND DE-ENERGIZE THE EXHAUST FANS AS NECESSARY TO MAINTAIN SPACE STATIC PRESSURE DIFFERENTIAL SETPOINT.

BCU—1 THRU —4 AND FCU—1 THRU —18: THE ASSOCIATED DDC CONTROLLER SHALL DE-ENERGIZE THE SUPPLY FANS.

AVY—1—5: THE ASSOCIATED DDC CONTROLLER SHALL DE-ENERGIZE THE SUPPLY FAN AND SHALL CLOSE THE AIR VALVE.

MOTORIZED DAMPERS, M1, M2, M3, M4, M5 AND M6 SHALL CLOSE.

ME—3 THRU —5: THE FANS SHALL BE ENERGIZED WHENEVER THE CONTROL PANEL (LOCATED IN THE FIRE PUMP ROOM) IS SWITCHED TO THE ON POSITION. WHEN THE FAN POSITION AT THE CONTROL PANEL IS SWITCHED TO THE OFF POSITION, THE EXHAUST FANS SHALL BE DE-ENERGIZED.

Figure 21. Sequence of Operations for Atrium Smoke Exhaust Fans.

Photo 1. Smoke Removal Vents on Roof.
Photo 2. View of Interior Smoke Management System from the East Balcony
Figure 22. Atrium Smoke Exhaust with an Axisymmetric Plume Rate Calculation.

Project: ANGRC Atrium Smoke Removal Calculation
Routine 1: Atrium Smoke Exhaust with an Axisymmetric Plume

Notes:
1. Makeup air is shown as being supplied by an opening or openings to the outside, but it can also be supplied by mechanical fans.
2. For calculating the volumetric flow rate of smoke exhaust, a value of $K_e = 1.0$ needs to be used except when another value of $K_e$ is supported by test data or an engineering analysis.
3. For smoke control design, a value of $\chi = 0.7$ is almost always used, and other values should be supported by engineering data.

\[ Q_c = \chi \cdot Q \]
\[ z_i = 0.533Q_c^{2/5} \]
\[ n = 0.022Q_c^{1/3}z_i^{5/3} + 0.0042Q_c \quad \text{for} \quad z > z_i \]
\[ n = 0.0208Q_c^{3/5}z_i \quad \text{for} \quad z \leq z_i \]
\[ f_s = T_o + \frac{K_e Q_c}{mC_p} \]
\[ \rho_s = \frac{144p_{atm}}{R(T_o + 460)} \]
\[ V = 60m / \rho_s \]
where
\[ c_p = \text{specific heat (0.24 Btu/lb} \cdot \text{°F).} \]

Input:
- $Q = \boxed{932 \text{ Btu/s}}$
- $z = \boxed{27.00 \text{ ft}}$
- $T_o = \boxed{70.0 \text{ °F}}$
- $p_{atm} = \boxed{14.70 \text{ psi}}$
- $K_e = \boxed{1.0} (\text{See note 2 above})$
- $\chi = \boxed{0.70} (\text{Almost always 0.70})$

Output:
- $Q_c = \boxed{652 \text{ Btu/s}}$
- $z_i = \boxed{7.12 \text{ ft}}$
- $m = \boxed{49.1 \text{ lb/s}}$
- $T_s = \boxed{125.4 \text{ °F}}$
- $\rho = \boxed{0.06780 \text{ lb/ft}^3}$
- $V = \boxed{43,459 \text{ cfm}}$
Figure 23. Atrium Smoke Exhaust with a Balcony Spill Plume Rate Calculation.
Smoke Control System Summary

The smoke control system has a supply air of 32,000 cfm. See Figure 19 for additional information on the supply air for the atrium. The required volume flow rate for the above profile is 43,459 cfm for the atrium area as shown in Figure 22 which shows the atrium smoke exhaust with an axisymmetric plume rate calculation. Figure 23 shows the atrium smoke exhaust with a balcony spill plume rate calculation. The required volume flow rate is 123,716 cfm.

The smoke removal system sequence of operation as shown in Figure 23 indicates activation of smoke removal by either sprinkler, the third-floor stairwell water flow switch, or smoke detectors in the lobby and elevator shafts, using a Simplex monitoring and control module. The third floor Area A is the highest balcony area open to the atrium and represents the highest location to maintain tentability. This does not reflect the areas below the third floor that are do not maintain the tentability requirement by NFPA 101. In fact, these areas with small fires could impact the egress before the smoke management system is activated as shown in the FDS model. This 983 kW (932 btu/s) fire is insufficient to activate the ordinary temperature sprinkler at ceiling height in the atrium or third floor balcony.

Table 15 shows the requirements for light hazard occupancies and specifies ordinary sprinklers with a temperature rating of 135 -170-degree Fahrenheit (57-77 degree Celsius) for the atrium. These mimic the requirements in NFPA 13, Table 7.2.4. Figure 25, DETACT model, indicated sprinkler activation would be at 38 seconds, and the performance model temperature slice file shows the temperature up to the 28 feet does not reach the minimum sprinkler head activation temperature.

Fire and Smoke Barrier Opening Protection

The building is equipped with hinged fire doors that are maintained according to the UFC 3-601-2 shown in Table 14.
Table 14. UFC 3-601-2, Table 2.21. Fire and Smoke Barrier Opening Protection ITM Tasks.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
</table>
| Annual                     | Hinged Fire Doors    | 1. Test magnetic hold-open devices for release on activation of fire alarm.  
|                             |                      | 2. Inspect closers for proper operation.                               |
| (Electric hold-open devices are tested as part of the alarm systems in Table 2.1.) | Sliding Doors | 1. Test magnetic hold-open devices for release on activation of fire alarm.  
|                             |                      | 2. Ensure that weights have a free and unobstructed path of travel.    |
| 1 Year after Construction and Every 6 Years Thereafter | Rolling or Sliding Fire Shutters | 1. Test magnetic hold-open and other mechanical latches for release on activation of fire alarm.  
|                             |                      | 2. Operate the shutter through its entire travel.                     |
| As Part of Building Inspection | Fire and Smoke Dampers | 1. Test electric (magnetic) hold-open and other mechanical latches for release on activation of fire alarm.  
|                             |                      | 2. Inspect travel path for anything that may obstruct or interfere with free operation. |
|                             | Hinged Fire Doors    | 1. Inspect door condition, gaskets, and mounting hardware. Ensure proper lubrication.  
|                             |                      | 2. Inspect fusible links, if present, for paint or other accumulations that slow thermal response. |
|                             | Sliding Doors        | 1. Inspect door condition and mounting hardware. Ensure proper lubrication.  
|                             |                      | 2. Inspect fusible links, if present, for paint or other accumulations that slow thermal response.  
|                             |                      | 3. Inspect travel path for anything that may obstruct or interfere with free operation. |

Summary

The fire alarm and detection and emergency communication system with mass notification complies with the DoD Unified Facility Criteria (UFC), 3-600-01, that was in effect at the time of design and construction. The fire alarm system complies with NFPA 72 and Unified Facilities Criteria 3-600-01. The Department of Defense UFC 3-600-01, *Fire Protection Engineering for Facilities* modifies NFPA 72, for DOD fire protection engineering technical guidance. The analysis included system design, layout, components, and Inspection/Testing/Maintenance. The approved plans provided a sequence of operations showing the sequence of events that would occur at the activation of devices. An analysis of the center’s smoke control system was also conducted. The design meets the requirements of NFPA 72 (2016) and NFPA 92 (2018).

Water-Based Suppression Systems

Table 15 information is from AECOM, and CH2M Hill sprinkler and fire protection design sheet FP-00 in the built drawing. The sprinkler system and fire suppression system requirements are based on occupancy classification and meet both NFPA Standard 13 and the UFC 3-600-01.
Table 15. Fire Protection Requirements.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>LIGHT HAZARD OCCUPANCIES</th>
<th>ORDINARY HAZARD OCCUPANCIES</th>
<th>ORDINARY HAZARD OCCUPANCIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPLICATION AREA</td>
<td>OFFICE AREAS</td>
<td>ELEC RM, WBC STORAGE AREAS, MECH RM</td>
<td>ELEVATOR MACHINE RM, BOILER RM</td>
</tr>
<tr>
<td>DESIGN DENSITY</td>
<td>0.10 GPM/SF (4,100 LPM/SQ METER)</td>
<td>0.15 GPM/SF (6,112 LPM/SQ METER)</td>
<td>0.20 GPM/SF (6,149 LPM/SQ METER)</td>
</tr>
<tr>
<td>DISCHARGE TIME</td>
<td>60 MIN</td>
<td>60 MIN</td>
<td>90 MIN</td>
</tr>
<tr>
<td>SPRINKLER TYPE</td>
<td>QUICK RESPONSE TYPE</td>
<td>QUICK RESPONSE TYPE</td>
<td>QUICK RESPONSE TYPE</td>
</tr>
<tr>
<td>COVERAGE PER SPRINKLER</td>
<td>225 SF (20.0 SQ METERS)</td>
<td>130 SF (12.07 SQ METERS)</td>
<td>120 SF (12.07 SQ METERS)</td>
</tr>
<tr>
<td>HOSE STREAM</td>
<td>250 GPM (945 LPM)</td>
<td>500 GPM (1,895 LPM)</td>
<td>500 GPM (1,895 LPM)</td>
</tr>
<tr>
<td>DESIGN AREA</td>
<td>3,000 SF (278.7 SQ METERS)</td>
<td>3,000 SF (278.7 SQ METERS)</td>
<td>3,000 SF (278.7 SQ METERS)</td>
</tr>
<tr>
<td>SPRINKLER TEMP RATING</td>
<td>ORDINARY TEMPERATURE RATING</td>
<td>ORDINARY TEMPERATURE RATING</td>
<td>INTERMEDIATE TEMPERATURE RATING FOR MECH RM AND ORDINARY TEMPERATURE RATING FOR ELEVATOR MACHINE RM</td>
</tr>
<tr>
<td>SPACE BETWEEN SPRINKLERS</td>
<td>15 FT (4.572 M) MAX</td>
<td>15 FT (4.572 M) MAX</td>
<td>11 FT (3.372 M) MAX</td>
</tr>
<tr>
<td>FLOOR AREA THROUGH ONE RISER</td>
<td>52,000 SF/SYSTEM (4,831 SQ METERS/SYSTEM)</td>
<td>4,831 SQ METERS/SYSTEM (62,000 SF/SYSTEM)</td>
<td>51,000 SF/SYSTEM (4,831 SQ METERS/SYSTEM)</td>
</tr>
</tbody>
</table>

* Sprinkler system shall be designed for a minimum working pressure of 250 psi, maximum velocity shall be 20 feet per second.

Automatic Fire Sprinkler Systems

A combination automatic wet pipe sprinkler and Class I standpipe system was installed throughout the building.

Fire Sprinklers

Automatic sprinklers (Figure 24) have been installed throughout the habitable or occupied space. These are glass bulb sprinklers that are concealed by a cover plate. The cover plate is soldered and will release at a low temperature. The glass bulb is designed to release when the bulb also reaches that temperature. These colored bulbs are associated with a thermal sensitive test for the sprinkler. This test involved subjecting the sprinkler to a closed heated box test to determine its response index (RTI).

Figure 24. Automatic Sprinkler.

The RTI is used in modeling and calculations to determine the sprinklers’ sensitivity and when they would operate in a fire event. The sprinklers that are under the cover plate are intermediate sprinkler heads with an operating temperature of 155-degrees Fahrenheit.
The fifth-floor penthouse mechanical space which is also used for general storage, uses the standard upright spray sprinkler with the 155-degrees Fahrenheit operating temperature.

**Sprinkler System initiate devices**

The sprinkler system has several devices that are interconnected to the building fire alarm system, which is designed to activate in case of a fire sprinkler activation. The devices are as follows:

The Potter Vane Type Water Flow Alarm (Figure 25) senses the water flow inside the sprinkler riser and activates the building fire alarm system. The vane type water flow alarm is less likely to malfunction, and less maintenance is associated with it.

![Figure 25. Potter Vane Type Water Flow Alarm.](image)

Tamper switches such as Figure 26, are used to monitor all water control valves that monitor the water control necessary to ensure the sprinkler system is not shut down.

![Figure 26. Tamper switch.](image)

The sprinkler systems are maintained in accordance with UFC 3-601-01, Table 2-2. Wet Pipe Automatic Sprinkler Systems ITM tasks are shown in Table 16.
Table 16. Wet Pipe Automatic Sprinkler Systems ITM Tasks.

CAUTION
Main drain static or residual test pressures that vary more than 10 percent from the previous test readings or the original acceptance readings require immediate evaluation to determine the cause.

WARNING
Main drain static or residual test pressures that vary more than 20 percent from the previous test readings or the original acceptance readings indicate an emergency situation. Immediate distribution system flow testing (paragraph 2-2.11) is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent to which the sprinkler systems are compromised.

Table 2-2. Wet Pipe Sprinkler Systems ITM Tasks

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly</td>
<td>1. Control Valves (without seal, lock, or electric supervision)</td>
<td>1. Verify valve position.</td>
</tr>
<tr>
<td>Annual</td>
<td>1. Control Valves (sealed, locked, or electrically supervised)</td>
<td>1. Verify valve position.</td>
</tr>
</tbody>
</table>
|           | 2. Waterflow Alarm Devices                     | 1. Operate to verify initiation and receipt of alarm.  
|           |                                                | 2. Verify alarm test valve alignment and tamper switch (if sealed or electrically supervised). |
|           | 3. Alarm Valve and Trim                        | 1. Visually check the exterior of valves, gauges, trim alignment.  
|           |                                                | 2. Verify valve pressure and legibility of the hydraulic nameplate. |
|           | 4. Main Drain                                   | 1. Conduct a main drain test to verify supply (valve position).  
|           |                                                | 2. Document static and residual pressure readings on a 3- by 5-inch (3x5) tag and secure it to the system pressure gauge.  
|           |                                                | 3. Compare results with results from previous main drain tests and original acceptance test.  
|           |                                                | 4. Verify that the results are within acceptable limits or identify corrective measures. |
The Class I combination sprinkler and standpipe system shown in Figure 27 shows the vertical risers as 6 inches in each of the stairways in Area A, and C. Stairways 1, and 3 are at each end of the Area A, and Area C is the conference center stairway. The 4-inch class I standpipe connections are fed from the combination riser. All class I standpipe hose connections are provided with 2 ½” female connections, and there are two 2 ½” hose valves on the roof on Stairwells 3 and 4. The locations of the standpipe locations are also in the Figure 27 single line drawing. The fire pump provides supplemental pressure for the combination system which would include having 100 psi at the roof level to meet NFPA Standard 14.
Figure 27. Fire Protection Riser Diagram.

The risers and standpipes are all maintained in accordance with UFC 3-601-2. 2.2-10. Standpipe Systems, as seen in Table 17.

Table 17. UFC 3-601-2. 2.2-10. Standpipe Systems.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-Annual</td>
<td>1. Hose Connection and Pressure Reducing Valves</td>
<td>1. Inspect for damage, leaking, missing caps, and obstruction.</td>
</tr>
<tr>
<td>2 Years</td>
<td>1. Piping</td>
<td>1. Inspect for damage and pipe supports.</td>
</tr>
<tr>
<td></td>
<td>2. Control Valve</td>
<td>1. Operate valve through entire travel to verify function.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Lubricate stem.</td>
</tr>
<tr>
<td>5 Years</td>
<td>1. Standpipe</td>
<td>1. Conduct flow test to verify flow capacity and minimum discharge pressure. (Test must confirm only flow/pressure—not duration—of supply).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Hydrostatic test to ensure integrity (dry standpipe systems only).</td>
</tr>
</tbody>
</table>
| As Part of Building Inspection | Entire System | 1. Visually check:  
  a. Pipe hangers.  
  b. Connections for obstruction.  
  c. Piping for leaks.  
  d. Riser condition. |
Fire Pump

The fire pump is required based on available pressure from during the design and construction. The fire pump was installed to support the combination standpipe and sprinkler rise have enough pressure to reach the roof at 28 feet. The pressure at the fifth-floor mechanical penthouse meets the requirements in NFPA Standard 14. The building height is outside the base fire department lowest height accessible, but with mutual aid fire companies could reach them. The pump is supplied to meet the required demand for the automatic sprinkler and standpipe systems (Table 18).

The 8-inch city main supports 6-inch lateral to the fire pump located in the first-floor pump room. Figure 28 is the fire pump single line diagram showing the piping configuration for the fire pump with the bypass loop. Table 18 information is shown in Figure 30, the hydraulic water curve, and the information in Figure 28 to show the water demand and supply water supply analysis. The pump meets the demand requirements of the most remote sprinkler and standpipe in accordance with 2011 NFPA 13 and NFPA 14.

Table 18. Fire Pump Schedule.

<table>
<thead>
<tr>
<th>NO.</th>
<th>TYPE</th>
<th>RATED FLOW (GPM)</th>
<th>RATED HEAD (PSI)</th>
<th>PUMP CHURN PRESSURE (PSI)</th>
<th>STATIC SUPPLY PRESSURE (PSI)</th>
<th>DRIVER TYPE</th>
<th>MAX HP</th>
<th>ELECT REQ</th>
<th>PUMP START (PSI)</th>
<th>PUMP STOP (PSI)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI-1</td>
<td>FIRE PUMP</td>
<td>1,000</td>
<td>115</td>
<td>120</td>
<td>74</td>
<td>ELECTRIC</td>
<td>100</td>
<td>440V 30</td>
<td>115</td>
<td>140</td>
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</tr>
<tr>
<td>JF-1</td>
<td>JOCKEY PUMP</td>
<td>10</td>
<td>125</td>
<td>135</td>
<td>74</td>
<td>ELECTRIC</td>
<td>2</td>
<td>440V 30</td>
<td>130</td>
<td>140</td>
<td></td>
</tr>
</tbody>
</table>

NOTES
1. START/STOP POINTS ARE BASED ON PRELIMINARY CALCULATIONS. FINAL SETTINGS SHALL BE DETERMINED DURING FIELD TESTS.
2. IF AVAILABLE SUCTION PRESSURE DOES NOT PERMIT THE FLOWING OF 50% OF RATED PUMP CAPACITY, THE FIRE PUMP SHALL BE OPERATED AT MAXIMUM ALLOWABLE DISCHARGE TO DETERMINE PUMP ACCEPTANCE PER NFPA 20, 14.2.7.2.2.
NFPA Standards 13, 20 and 72 require all fire pumps water control valves and pump starting performance for failed to start and running to be monitored. The fire pump undergoes a 5-year pump performance to test the output. NFPA 25 requires an annual fire pump performance test. In Table 18, the pump performance schedule shows the rated output 1000gpm at 115psi. This was used in the development of water flow curves (Figure 30).

The fire pump is maintained in accordance with UFC 3-601-0.2, Table 2-2.12, Fire Pumps, as seen in Table 19.
Table 2-16. Fire Pumps ITM Tasks

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly</td>
<td>Pump House</td>
<td>1. Inspect for proper condition, ventilation, and heating.</td>
</tr>
<tr>
<td></td>
<td>Control Valve and Isolation Valve</td>
<td>2. Verify proper valve position.</td>
</tr>
<tr>
<td></td>
<td>Pressure Gauges</td>
<td>3. Check reading and verify gauge operability.</td>
</tr>
<tr>
<td>Monthly (Continued)</td>
<td>Controllers</td>
<td>4. Verify that automatic controllers are in the automatic (AUTO) setting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Inspect electric connections.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Operate manual and automatic stations.</td>
</tr>
<tr>
<td></td>
<td>Batteries</td>
<td>5. Verify proper charge.</td>
</tr>
<tr>
<td></td>
<td>Pumps</td>
<td>6. Start and churn to verify operability. (Where equipment permits, allow water to flow back to the source.) Electric pumps shall operate for 10 minutes and engine-driven pumps shall operate for 30 minutes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Verify operation of relief valves.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Verify full level (for engine-driven pumps).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Inspect exhaust system for leaks (for engine-driven pumps).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. For engine driven pumps, start again using second battery set and churn to verify operability. (Where equipment permits, allow water to flow back to the source.)</td>
</tr>
<tr>
<td>2 Years</td>
<td>Control Valve</td>
<td>1. Operate and lubricate valves to ensure operability.</td>
</tr>
<tr>
<td></td>
<td>Controllers</td>
<td>2. Calibrate pressure switches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Exercise circuit breakers and switches to verify operability.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Inspect fuses.</td>
</tr>
<tr>
<td></td>
<td>Pumps</td>
<td>3. Check coupling alignment to ensure that the shaft is aligned.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Check pump shaft end play.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Lubricate bearings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Lubricate couplings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Lubricate right-angle drives.</td>
</tr>
<tr>
<td></td>
<td>Fuel (engine-driven pumps)</td>
<td>4. Sample fuel to verify quality.</td>
</tr>
<tr>
<td></td>
<td>Relief Valves</td>
<td>1. Calibrate valves.</td>
</tr>
<tr>
<td>5 Years</td>
<td>Pump</td>
<td>1. Conduct flow tests to verify pump output. Test may be through a flow meter returning the water to a storage reservoir or through the test header. Recirculation of water to the suction piping is not permitted. In a multi-pump installation, each pump may be tested separately at not less than 100 percent design capacity for 30 minutes.</td>
</tr>
<tr>
<td>WATER SUPPLY DATA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STATIC PRESSURE</td>
<td>74 PSI</td>
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<tr>
<td>RESIDUAL PRESSURE</td>
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<td>PITOT</td>
<td>20 PSI</td>
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<tr>
<td>FLOW @ RESIDUAL</td>
<td>750 GPM</td>
<td></td>
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<tr>
<td>FLOW @ 20 PSI</td>
<td>1,359 GPM</td>
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</tr>
<tr>
<td>DATE OF TEST</td>
<td>06/29/06</td>
<td></td>
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<tr>
<td>TEST PERFORMED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BY: CH2M HILL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE:
SEE DRAWING C-103 FOR HYDRANT LOCATIONS USED FOR FLOW TEST.

Figure 29. Water Supply Data.
Fire water flow test data

Figure 30. Water Flow Test Curve.

The installation water flow at design shows that the water supply was inadequate at indicated in Figure 30 by system demand. The water curve shows the required standpipe system water requirement based on NFPA Standard 14, 2019, Section 7.10.1.1.1 which requires 100 psi at the top of the riser and 500 gpm at the most remote Class I 21/2. A fire pump was needed for the pressure given the 5 stories and required pressure for the Class 1 standpipe. The fire pump requires a rated pressure at 115 psi with a rated capacity of 1000 gpm. This is shown in the Figure 30 above, and the fire pump information is shown in Table 18. The combined curve shows a comfortable margin of safety for both sprinkler system, standpipe, and fire demand, is provided from a combined fire and domestic water system. This water supply is adequate and meets all demand requirements for the fire suppression systems.
## Fire Hydrant and Monitors

<table>
<thead>
<tr>
<th>NOZZLE IDENT. AND LOCATION</th>
<th>FLOW IN G.P.M.</th>
<th>PIPE SIZE</th>
<th>PIPE FITTINGS AND DEVICES</th>
<th>EQUIV. PIPE LENGTH</th>
<th>FRICTION LOSS P.S.I./FOOT</th>
<th>PRESSURE SUMMARY</th>
<th>NORMAL PRESSURE</th>
<th>NOTES</th>
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<td>1</td>
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<td>q = 55</td>
<td>L 10</td>
<td>Y 10</td>
<td>10V 14WN</td>
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<td>Pt 51.75</td>
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<td>L 10</td>
<td>Y 10</td>
<td>10V 14WN</td>
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<td>Y 12</td>
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<tr>
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<td>C = 120</td>
<td>Pt 51.75</td>
<td>P = 6.0</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 31. Hydraulic Hand Calculations.
Figure 31 shows the conceptual calculations with assumptions made from the design as built from the fire suppression system. The actual shop drawings and calculations were not available. The fire suppression system has an 8-inch ductile iron lateral main from the street to the 6-inch ductile iron lateral to the fire pump. The piping and riser are 6-inch ductile iron with Class I standpipe connections supply from 4-inch ductile iron branch mains. Figure 27 shows the single line fire suppression risers and the Class I branch main standpipe configuration. The hydraulic calculations were provided by hand using the hydraulic methods from NFPA Standard 13.

The building was not provided with seismic calculations due to UFC 3-600-01, not requiring them for seismic design classifications of A or B. With regards to the fire protection requirements for the design areas, demand density and the sprinklers as shown in Table 15, the fire pump may have been a smaller size than the one provided. The highest sprinkler demand area is the 5th floor mechanical and elevator penthouse (Figure 32).

![Figure 32. Fifth Floor Sprinkler.](image)

Figure 32 shows the most remote design area and demand on the fifth-floor elevator penthouse. The demand is based on five sprinklers in the elevator machine room space. Table 15 provides the sprinkler design density of 0.20gpm/ft² and a design area of 2500 square feet. Hydraulic
hand calculations (Figure 31) were used to determine the elevation pressure loss in the hydraulic sprinkler calculations. The hydraulic calculation showing steps 1 and 3 sprinklers on the fifth floor show the pressure required to operate. This pressure is supplement by the fire pump that is described on pages 46 and 47 of this report. Table 18 has the pertinent information on the rating of the fire pump. Figure 29 shows the water supply data which was used in the hydraulic sprinkler calculations. The remaining design areas and density meet NFPA Standard 13 and therefore, meet the required water supply as shown by the conceptual calculations.

**Fire Hydrants**

Figure 33 is an example of the fire hydrants that were installed for use in fighting fires that may occur.

![Fire Hydrant](image)

**Figure 33. Example of fire hydrant**

Fire hydrants are monitored and inspected in accordance with UFC 3-601-2.2-11 Hydrants and Monitors (Table 20).

<table>
<thead>
<tr>
<th>Table 20. UFC 3-601-2.2-11 Hydrants and Monitors.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical guidance on the tasks in tables 2-14 and 2-15 is contained in UFC 3-230-02; American Water Works Association (AWWA) Manual 17 (M17) for hydrants and monitors supplied from potable distribution systems; and NFPA 25 for hydrants and monitors supplied by non-potable distribution systems. Flow testing should be accomplished in accordance with AWWA M17, Chapter 6.</td>
</tr>
</tbody>
</table>

**CAUTION**

Flow tests results that vary more than 10 percent from the previous test readings or the original acceptance readings require immediate evaluation to determine the cause.

**WARNING**

Flow tests results that vary more than 20 percent from the previous test readings or the original acceptance readings indicate an emergency situation. Immediate distribution system flow testing (paragraph 2-2.11) is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent to which the sprinkler systems are compromised.

**Inspection, Testing and Maintenance**

Inspection, testing, and maintenance of all systems use the following codes:
Unified Facilities Criteria (UFC) 3-601-0.2, which takes precedence over NFPA Standards, and adjusts the frequency based on earlier system reliability, and applicable NFPA standards.

Summary

The combination wet pipe sprinkler system with a Class I standpipe system meets both the NFPA Standard 14 and codes at the time of design. The sprinkler system has three different occupancy hazard classifications: Light hazard, Ordinary Groups I, and Ordinary Groups II. Light hazard occupancy classification is for the whole building with the following exceptions for ordinary groups I and II. Ordinary Group I is for mechanical rooms, electrical rooms, and miscellaneous storage. This has a design density of 0.15 gpm/ft². Ordinary Group II is the occupancy classification for the elevator penthouses in the 5th floor mechanical mezzanine and elevator penthouses. The Ordinary Group II density is 0.20 gpm/ft². The light hazard areas would include offices, the atrium, the mezzanine, locker rooms, the Subway kiosk, and the remainder of the building. The light hazard design density is at 0.10 gpm/ft². The mechanical rooms and current fire suppression system with the Class I standpipe meets all applicable codes at the time of design and meets the required densities.

The prescription analysis has the building structure as allowable with additional frontage square footage to meet the International Building Code at the time of design. The building is classified as a Type IIA, with structural member or load bearing components having a fire resistive rating. Fire resistive ratings are for vertical openings and shafts extending up to the fifth floor. The one-hour vertical separation fire resistive rating is on both sides of the mini-atrium, which are one hour, as it is three stories or less per NFPA 101. The pipe and heating, ventilation, and air conditioning duct chases are two-hour fire rated as are the stairways as they extend up to the fourth and fifth floors.

The Life Safety Code means of egress is compliant for the travel distance, common path of travel and dead ends. In addition, the stairways from Area A at each end meet the remoteness standard. The building complies with emergency lighting and exit sign requirements based on NFPA 101. The fire ratings are part of the mini-atrium requirements for occupancy separation of the vertical opening. The pedestrian bridge to the other building, which is granted an exception by IBC, is not a required exit. The pedestrian bridge should be labeled as a required exit given the occupant load of the mezzanine during assembly occupancy events.

The combination sprinkler and standpipe system with the fire pump meet the applicable NFPA and the hazard occupancies are per NFPA Standard 13 and NFPA Standard 14. The fire pump has appropriate start and stop pressure and is supported by a jockey pump for pressure maintenance.

The fire alarm and mass notification systems comply with NFPA Standards 70 and 72. The mass notification standard is installed as required by UFC 4-21-01, O&M, Mass Notification. This was published in 2010 without changes. The current system is a Simplex voice evacuation system with mass notification interface and a Monaco transceiver for transmission of the signals to off-site 911 center.
**Performance-Based Analysis**

This section will focus on two design fires and analysis along with their impact to the facility and occupants. Floors one through four have the same office areas. The fifth floor has mechanical and electrical areas with some storage area. This area, commonly called the penthouse, is where the elevator machine rooms are also found. This section will look at some hazards with design fires in the three-story atrium, second floor mezzanine, and third floor office area cubicle.

**Performance Goals**

The performance goals are to create a realistic worst-case scenario design fire to challenge the life safety systems present, to determine a realistic-yet-conservative egress time, to utilize a smoke control system in place to assist in saving occupants not familiar or having knowledge of the building, to determine smoke layer height relative to occupant egress time, and to utilize NFPA 101, the Life Safety Code for scenario evaluation guidance.

**Performance Based/Tenability Criteria**

NFPA Standard 101, Chapter 5, Method 3 Performance Criteria was used for the first-floor atrium area with the stage used for assembly occupancy. The first area to be evaluated was the smoke layer height that is six feet above the third-floor balcony occupants. The second area evaluated was the second-floor mezzanine area with a design fire catching PMMA tables with tablecloths on fire, resulting in soot and a smoke layer affecting the second-floor balcony.

Methods 1 and 3 performance criteria were used to evaluate the second floor’s concentrated business use areas as well as the third floor’s office areas.

The smoke removal system with beam smoke detectors in the atrium area is designed to keep the smoke layer above the third-floor balcony height plus 6 feet to preclude the occupants evacuating in the smoke.

**Design Fires**

Design fires are meant to find and evaluate the most challenging fires in a building. Design fires were selected based on NFPA Standard 101, Life Safety Code (current edition), Chapter 5, which lists five scenarios to aid in deciding the most challenging types of fire to be used in performance-based design. It analyzes the most severe fire a building can withstand while being realistic for the occupancy.

Three design fires scenarios were considered for this project.

Scenario 1 is an atrium design fire involving an electrical fire igniting a portable stage. This is the critical design fire and will be modeled using the Fire Dynamic Simulation (FDS). The FDS model is in Appendix F. This was selected based on the impact to egress and substantial number of people exposed to the fire.

Scenario 2 is on the second-floor reception mezzanine, involves refreshments using chaffing dishes and has a Sterno can overturning and igniting the table. This scenario was considered due to its location and impacts. It was not selected as the fire scenario, as the primary research
showed little to no impact with short-term burning. No sustained fire or smoke was indicated, and the fire was isolated to the area involved.

Scenario 3 is a single workstation fire that was considered due to the 100 plus workstations on any given floor. The primary research was through a traveling fire, and again it was shown to not be a factor for impact to the staff or surrounding area for egress. Because the shop drawings were not available, the hazard occupancy the sprinkler system was designed for was not able to be ascertained. For this scenario, NIST NCSTAR –1-5F, was referred to for the fire research on the single workstation configuration, as it was like the workstations, the building, and material used to construct them for orientation and configuration purposes.

Table 21 shows the design fire fuel, materials involved, and the orientation of all three scenarios.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Fuel Material</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1 – Atrium Fire</td>
<td>Carpet, Plywood</td>
<td>Horizontal with Podium vertical orientation</td>
</tr>
<tr>
<td>Scenario 2 – Mezzanine Fire</td>
<td>High Density Polyethene</td>
<td>Horizontal orientation</td>
</tr>
<tr>
<td>Scenario 3- 3rd Floor Office area signal workstation</td>
<td>Particle Board desk, with plastic laminate</td>
<td>Horizontal particle board desk with plastic laminate.</td>
</tr>
<tr>
<td></td>
<td>Plastic and Textile Laminate</td>
<td>Vertical orientation</td>
</tr>
</tbody>
</table>

Based on the preliminary research and modeling, it was determined that Scenario 1, a stage fire presented the greatest challenge and thus should be the focus of this report.

Scenario 1 is an atrium design fire involving an electrical short igniting a portable stage, indicated by the blue square in Figure 34. This design fire matches NFPA 101 scenario number 5 for a slow-growing fire where the fire suppression system or detection system is ineffective or out of service. This fire is located near large audiences or population areas. The sprinkler system is over 8.23 meters (7 feet) above the first-floor atrium level. The main entrance to the building is through the atrium. The atrium is used on a recurring regular basis, hosting large attendance population events, as seen in Photo 5 and 6 and shown as red colored areas in Figure 34. These events can have occupants on the first floor, second floor mezzanine, and second and third floor balconies on both sides of the atrium. The third-floor balcony may also be filled by people two and three layers deep along the glass wall on the balcony, as seen in Photo 6.

The stage location, the blue square in Figure 34, when erected, obstructs access to the north exit doors for the first-floor occupants without going around the stage to get to them. The first-
floor attendees’ evacuation route to the two northwest personnel doors away from the stage area would be impeded due to the stage’s location. Those attending on the second and third floors would exit from stairways found on each end of the floor.

The temporary portable stage is constructed of a lightweight steel frame with plywood panels and lightweight polyester carpet attached to the plywood floor (see Table 21). The vertical hanging backdrop on the stage is assumed to be of fire-resistant cotton and a velour material as seen in Photo 4. As seen in Photo 5, the podium on the stage is movable. The stage design fire incorporated the mass of the podium into the mass of stage.

Figure 34. First Floor Plan Showing Stage Location.
Photo 4. Stage Located on First Floor.


Photo 5. Stage in First Floor Atrium for an Assembly Occupancy Event.

Design Fire Model

The FDS design fire model used the for the portable stage area measures 4 meters wide by 4 meters long (16m²) and is 12 to 18 inches in height (0.4) meters tall. The NIST Technical Investigation Volume 2, Station Night Club Fire, conducted 6 Olefin carpet sample tests. Appendix K shows the Cone Calorimeter Data for Carpet Flooring at 35 kW/m2 for carpet flooring CF-1 through CF-3 samples. The olefin carpet is a textile closed loop with backing (Figure 35). The stage carpet material was assumed to be closed looped with a polyurethane backing. The test by NIST in the Station Night Club Fire investigation was similar to the stage carpet in appearance and was used to determine the fire growth rate alpha, which was related to the polyurethane with a higher heat release rate than the polyurethane.

Figure 35. Sample of Olefin Carpet.
The Station Night Club fire dynamic simulator carpet input model reconstruction is shown above (Figure 36). This is similar to the Figure 40 for carpet with the plywood deck. NIST does not indicate subfloor deck with the carpet input.

The Station Night Club fire reconstructed input file in Appendix J, the soot levels are a little bit higher as well. The olefin peak HRR rate was used to calculate the alpha for the heat release with their test at the peak heat release rate. The average time for the 30kW testing for our time in calculating our alpha using the following equation:

\[ \dot{Q}(t) = \alpha t^2 \]

\[ \alpha \text{ is equal to } \text{HRRPUA} \cdot V_s^2 \cdot \pi \]

This was divided by 1m² to convert from HRRPUA to Heat flux in kW which allows for comparison between the National Institute for Standards and Technology test data curve in the small laboratory testing for the Station Night Club Volume II report, and the FDS model curve for the Air National Guard Readiness Center portable stage.

\[ \alpha = 627 \text{ kW}/1 \text{ m}^2 \cdot V_s^2 \cdot \pi \]
\[ \alpha = 627 \text{ kW} \cdot 0.001 \text{ Vs}^2 \cdot 3.14 \]
\[ \alpha = 1.94/160s \text{ kW/S} \]
\[ \alpha = 0.0123 \]

\[ \alpha = 983 \text{ kW/} \cdot V_s^2 \cdot \pi \]
\[ \alpha = 983 \text{ kW} \cdot 0.001 \text{ Vs}^2 \cdot 3.14 \]
\[ \alpha = 0.00314/160s \text{ kW/S} \]
\[ \alpha = 0.01963 \]

The NIST test cone calorimeter readings are shown below in Table 24 for 35kW/m². Converted to kW by dividing by 1m² to get to kW to match the curve units in Figures 37 and 38. Using the following equation:

\[ \dot{Q}(t) = \alpha t^2 \]

The average peak heat release rate for from the NIST report at 35kW is 627kW. For the comparison in the calculations, we used the Figure 38 time from our model peak based on the
input file ramp at 160 seconds. Figure 37 shows a green line with the peak heat release rate of 627kW. In Figure 38, the FDS model shows the carpet on the stage to have a peak of 983kW. As the carpets were composed of plastic, Figure 37 used a sample of olefin carpet with a differing characteristic from stage. The stage carpet was assumed to be nylon with polyurethane backing. The backing of the stage night club was undetermined, but with the differing curves, is not the same textile. Our ignitor temperature was a 4500kw with ramp up to 160 seconds. The curves in both Figure 37 and 38 show the similarities primarily with the state car to the application and the stage is elevated on plywood, where the Figure 37 is based on particle board. This will affect the heat release rate and the are both plastic based
The FDS design fire model curve has the heat release peaking at 160 seconds, and decay starting at 400 seconds. This closely matches the HRR curves in Figure 37. The decay for Figure 38 starts at 190 seconds.

Table 22. NIST Table D-19 Test Cone Calorimeter Reading Summary.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>External Thermal Flux, kW/m²</th>
<th>Time to Sustained Ignition, seconds</th>
<th>Time to Peak Heat Release Rate, seconds</th>
<th>Peak Heat Release Rate kW/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF-01</td>
<td>35</td>
<td>38</td>
<td>221</td>
<td>474</td>
</tr>
<tr>
<td>CF-02</td>
<td>35</td>
<td>68</td>
<td>178</td>
<td>718</td>
</tr>
<tr>
<td>CF-03</td>
<td>35</td>
<td>40</td>
<td>206</td>
<td>536</td>
</tr>
<tr>
<td>Average</td>
<td>54</td>
<td>192</td>
<td></td>
<td>627</td>
</tr>
</tbody>
</table>

Figure 37. Heat release Rate versus Time for Carpet Sample Exposed to 35 kW/m².

This allowed us to determine that based on the model, the fuel is the limiting factor for this fire.
Figure 38. Potable Stage Heat Release Rate Data.

The Fire Dynamic Simulator – Smoke View software fuel load inputs are shown below in Figure 39. The full input file is in Appendix F.

```
MATL_ID = 'CARPET'
SPECIFIC_HEAT = 1.0
CONDUCTIVITY = 0.1
DENSITY = 100.0
N_REACTIONS = 1
NU_SPEC = 1
SPEC_ID = 'PROPANE'
REFERENCE_TEMPERATURE = 320.
HEAT_OF_REACTION = 2000.
HEAT_OF_COMBUSTION = 15000.
```

```
MATL_ID = 'PLYWOOD'
SPECIFIC_HEAT = 1.0
CONDUCTIVITY = 0.13
DENSITY = 150.0
N_REACTIONS = 1
NU_SPEC = 1
SPEC_ID = 'PROPANE'
REFERENCE_TEMPERATURE = 200.
HEAT_OF_REACTION = 1800.
HEAT_OF_COMBUSTION = 50000
```

Figure 39. FDS Fuel Load Input Information for Carpet and Plywood.
Evacuation Time Influences

Full-time staff are made thoroughly familiar with the evacuation routes during their newcomer’s orientation. The senior division leadership during fire evacuations exercises takes roll call to determine if anyone is missing.

The facility has a central rally point for the building. Visitors for conferences and other activities are not as familiar as the full-time staff about the building floor evacuation routes, which may cause a delay in evacuating. The evacuation delay may be due to the lack of familiarity with the established evacuation routes. With an estimated 2,000 people, both buildings are designed to evacuate at the same time instead of a zone evacuation. The building has a voice evacuation system interconnected to a mass notification system. When activated, the mass notification system overrides the voice evacuation message, meeting NFPA Standard 72.

Actual fire evacuation drills show total evacuation within 10 minutes. The difficulty is many full-time staff, having experienced quarterly testing and other nuisance alarms, ignore evacuation alarms.

Building Total Evacuation Time

Evacuation times were determined by hand calculation using the SFPE hydraulic model. (See Appendix E) The total evacuation time is based on a special event being held in the atrium space. All occupants are on the balconies in area A or first floor atrium space. mezzanine and balcony in Area B and C used for conference center occupants’ evacuation. The total building evacuation time is 13:00 using all available exits in atrium areas. The exit doors are 36-inch doors with panic hardware. The stairs are the pinch-point, due to the reduction of the inside stair width and the handrails.

Photo 7 shows an example of the atrium being used for the special event, with occupants along the balcony and atrium space with the stage impeding full use of the occupant doors on the opposite end of the doors shown in the photo by the statute.
The second-floor mezzanine is the same as the first floor with the same issues. There is an open stairway between the first-floor atrium area and second floor mezzanine, which while not a required exit, most certainly would be used in an emergency. The evacuation time would be 6 minutes, including pre-movement reaction time, given the occupant load and the same stairs from Area A and the open stairs. Occupants from Area C might exit with Area A, which might need to be considered, even though Area C has two exit stairs for immediate egress.

The calculated evacuation time for Area C is 6 minutes including reaction time. The stairs have a capacity to handle 48 people per minute, with the exit doors able to exit 49 people per minute. If all rooms were to be fully occupied at the same time, 288 people is the calculated Area C largest occupant load. The calculated movement time for 144 people via the stairway results in 3 minutes for the evacuation. The added time consists of reaction time to start moving to the exit and travel on the stairs to the outside.

Assumptions include that the occupant load would be at least 5-10% lower due to staffing vacancies, business travel, vacations, and sick vacation time. The assumption is also that not all staff will exit at the same time, as some will ignore the evacuation alarms, delaying their exiting. The other restricted egress is the smaller door effective width from the balcony into the area of refuge that leads to the exit stairs on each end.
The DETACT input parameters (Table 23) are based on an Air National Guard Readiness Center Area B portable stage fire located in the atrium with sprinklers at a ceiling height of 28 feet. The atrium is open to three floors with balconies on the Area A side of the building and two floors with a mezzanine for the Area B and C of the building. The radial distance used in the DETACT input was from the corner of the stage to the nearest sprinkler at a height of 28 feet. The material is a medium fire. The activation temperature and response time index shown in Table 23 is based on the installed sprinklers.
The Response Time Index (RTI) used for fire sprinklers is determined by the plunge test. This information is provided for the calculations. The ANGRC sprinkler spacing is 20.9 m² per sprinkler for area of coverage. The ceiling height is 8.53 meters (28 feet). The moderate fire growth rate was used to simulate an electrical failure, which was assumed to be a malfunction of the electrical circuit within the electronic equipment. This would eventually lead to a flaming fire; thus, the moderate fire growth rate. If the electrical failure results in a flaming fire, the heat release within the plastic housing would expand at about 150 seconds. The sprinkler actuation was calculated to be at 190 seconds with a 200kW fire. The wet pipe sprinklers are installed 100% throughout the building, UFC 3-600-01. The sprinklers in the atrium are installed for light hazard occupancy with spacing every 225 square feet maximum. These sprinkler heads are intermediate temperature. See Table 14, Fire Protection Requirements, Light Hazard Occupancies column in the table for all sprinkler characteristics.

**Tenability Criteria**

Providing appropriate tenability criteria ensures that the building occupants are not exposed to untenable conditions. NFPA 101, Appendix A, Section A.5.2.2, provides different methods to avoid exposing occupants to untenable conditions and refers to the SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings to establish tenability limits.

**Temperature, 140 (60°C) Limit**

The exposure to heat limit is 140 (60°C) for a smoke layer 6 feet (1.8 meters) above the walking surface. Inhalation of air above 140 (60°C) can cause thermal burns to the respiratory tract.

**Visibility, 10 feet (4 meters) Limit**

If the smoke layer does not descend below 4.9 feet (1.8 meters) as stated in the tenability criteria, it is then assumed the corridor would still be passable for egress. In the SFPE Handbook, it is reported that 4 meters is typically used for occupants familiar with the building geometry.

**Carbon Monoxide, 1400 ppm/min Limit**

Toxic gases impair an individual's ability to self-evacuate by decreasing the amount of oxygen available, causing disorientation and unconsciousness. In building fires, the most common toxic gas is carbon monoxide (CO) according to SFPE HB chapter 6, section 2, Table 2-6. B1. The CO incapacitation levels from exposure for 30 minutes is between 1400-1700 ppm for adults.

**Required Safe Egress Time**

The Required Safe Egress Time (RSET) is the predicted time necessary to evacuate a building or component. The RSET area can be expressed as a combination of detection and notification time, premovement time, action time, and travel time, (Nelson, et. al., SFPE Handbook). Following is the equation used to determine the RSET in Table 26. The RSET is based on the atrium being used for an assembly occupancy event with no one in any of the office space. All
are located in the atrium for the event. The fourth floor is not to the atrium, so calculations for those occupants are combined with the third-floor people and will use the third-floor stair exits. This is the most conservative and high-risk area as the occupant density is higher by combining both floor occupants on the balcony.

\[
RSET = t_d + t_a + t_o + t_i + t_e
\]  
(Equation 2)

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

<table>
<thead>
<tr>
<th>Floor</th>
<th>Detection and Notification Time, ( t_d + t_a ) (sec)</th>
<th>Pre-movement and Action Time, ( t_o + t_i ) (sec)</th>
<th>Travel Time, ( t_e ) (sec)</th>
<th>Stairs Travel Time, ( t_e ) (sec)</th>
<th>RSET Total Time (sec)</th>
<th>1.5 times RSET (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>35</td>
<td>60</td>
<td>40</td>
<td>0</td>
<td>135</td>
<td>202</td>
</tr>
<tr>
<td>2nd</td>
<td>35</td>
<td>60</td>
<td>101</td>
<td>14</td>
<td>210</td>
<td>315</td>
</tr>
<tr>
<td><em>3rd floor balcony</em></td>
<td>35</td>
<td>60</td>
<td>33</td>
<td>269</td>
<td>397</td>
<td>596</td>
</tr>
</tbody>
</table>

Note: *Third and Fourth Floor are combined.

**Detection and Notification Time (Table 24)**

The detection time, \( t_d \), and notification time, \( t_a \), is the time from ignition to the time the occupants are aware of the fire and the need to evacuate. It is assumed detection occurs when occupants become aware of smoke by sight or when the facility fire alarm system is activated, through smoke detectors, sprinklers, or manual pull stations and the building alarm sounds.

Therefore, from Equation 2, \( t_d + t_a = 60 \) seconds. It is believed that this would be a faster time than occupant notification through sight or the smell of smoke for this type of fire.
Pre-Movement and Action Time

Pre-movement time, $t_a$, and action time, $t_i$, is the time taken to perform activities that people are engaged in prior to actual evacuation of the area.

The SFPE Handbook provides discussion regarding pre-movement times in several types of building for three different emergency notification scenarios. Pre-recorded directives using a voice communication system in conjunction with well-trained, uniformed staff that can be seen and heard by all occupants in the space. The estimated delay time to start evacuation is less than 60 seconds.

Therefore, from Equation 2, $t_o + t_i = 60$ seconds.

Travel Time

The occupant travel time was calculated using the hydraulic model of emergency egress from the SFPE Handbook. Travel time, $t_e$, is the time from the start of evacuation until evacuation is complete. The following conditions were assumed using research-based methods for predicting the flow of occupants in emergencies: all persons will start to evacuate at the same instant, occupant flow will not involve any interruptions caused by decisions of the individuals involved, and all or most of the persons involved are free of disabilities that would significantly impede their ability to keep up with the movement of the group.

The travel time for occupants to evacuate depends on the density of occupants in the space. Figure 41 shows the sequence of occupant response to fire.

![Figure 41. Sequence of Occupant Response To Fire.](Reference: Proulx, SFPE Handbook, Figure 3-13.3)
Figure 42. Evacuation Speed as a Function of Density.

Figure 42 illustrates that a density less than 0.05 persons/square feet has a walking speed of 235 ft/min for corridors, ramps, aisles, and doorway exit routes. The sloped lines represent a density greater than 0.05 persons/square feet but less than 0.35 persons/square feet. If the population density exceeds about 0.35 persons/square feet, no movement will take place until enough of the crowd has passed from the crowded area to reduce the density. Between the density limits of 0.05 and 0.35 persons/square feet, the relationship between speed and density can be considered as a linear function. The equation of this function is:

\[ S = k - \alpha D \]  
(Equation 3)

Where,
- \( S \) = speed along the line of travel
- \( D \) = density in persons/square feet
- \( k = 275 \) (constant from SFPE Hbk. Sec. 3, Ch. 14, Table 3-14.2)
- \( \alpha = 2.86 \) (constant from SFPE Hbk. Sec. 3, Ch. 14)

(Nelson, et. al., SFPE Handbook).

Table 25 calculates the travel time to evacuate the ANGRC building. The density (D) is determined by dividing the occupant load by the area. The walking speed is determined by converting the density into movement speed using Figure 42 and Equation 3. The time to evacuate is calculated by dividing the travel distance by the walking speed of the occupants.
Table 25. Travel Time, $t_e$.

<table>
<thead>
<tr>
<th>Occupant Load per Floor (persons)</th>
<th>Floor Exit (Sq. ft.)</th>
<th>Density (D) (persons/Sq. Ft.)</th>
<th>Walking Speed (ft/min)</th>
<th>Travel Distance (ft)</th>
<th>Travel Time, $t_e$, to Evacuate. (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Floor atrium area 300</td>
<td>atrium area only 5978</td>
<td>0.05</td>
<td>240</td>
<td>159</td>
<td>40</td>
</tr>
<tr>
<td>2nd Floor 621</td>
<td>atrium area only 2500</td>
<td>0.25</td>
<td>78</td>
<td>132</td>
<td>101</td>
</tr>
<tr>
<td>*3rd and 4th Floor combined 518</td>
<td>2337</td>
<td>0.23</td>
<td>240</td>
<td>132</td>
<td>33</td>
</tr>
</tbody>
</table>

Note: *Third and Fourth Floor are combined.

Since the density is less than 0.05 persons/square feet, individuals will move at their own pace, independent of the speed of others (Nelson, et. al., SFPE Handbook). The walking speed associated with corridors, aisles, and doorways is approximately 259 ft/min in areas where the density is less than 0.05 persons/square feet.

**Available Safe Egress Time**

The Available Safe Egress Time (ASET) is the time from ignition until the ANGRC or corridor space becomes untenable. The ANGRC ASET analysis was analyzed in the FDS model using the atrium stage fire scenario, which is considered to have the greatest potential impact on egress and tenability during egress. Table 25 with the 1.5 multiplier for conservative safety margin shows the required safe egress time at 596 seconds (10 minutes).

The peak heat release rate of 983 kW is obtained at 3 minutes and forty-five seconds. The smoke is not of a significant density to impede or be an irritant to egress. The amount of ASET is not limited as the smoke removal system maintains the egress with more than the required minimum performance-based egress tentability requirements. The available safe egress is
beyond the RSET of 596 seconds (10 minutes). The amount of smoke shown in Figure 43 is the maximum density for the available egress time

**Egress Tenability**

Table 24 with the 1.5 multiplier for conservative safety margin shows the required safe egress time at 27 minutes with the safety factor. The egress tentability is maintain by the smoke removal system throughout the ASET and RSET. Figure 43 shows the egress and amount of smoke density which does not impact the tentability requirements for egress due to the smoke removal system. Figure 44 shows the atrium without the smoke removal system. The egress soot levels are shown to impact the tentability during the RSET.

![Figure 43. Smoke Density with exhaust at 180 seconds.](image-url)
Visibility

Figures 45 show the visibility at 4 meters are well above the required tenability visibility at 179 seconds. Visibility is tenable for the ASET and RSET time. The visibility is sustained for all egress routes shown in Figure 7-9. The visibility is improved when smoke detectors are activated at 38 seconds. Current smoke removal system of operation is shown in Figure 21 and in Figure 18 which shows activation by the third-floor sprinkler water flow alarm. Figure 44 shows that in 179.6 seconds the visibility is severely impacted for egress without smoke removal based on the materials in Appendix E.
Figure 45. 4 meters visibility at 180 seconds.

Figure 46. Smoke Layer by Floor.

Figure 46 shows the floor heights include floor height plus the additional 6 feet (1.8m) to ensure tenability required by NFPA 101. The first and second floor including balcony areas the smoke layer states above 1.8 meter, which ensure visibility and tenability for these floors. The third-floor smoke layer descends down to the second-floor level at 115 seconds. The smoke layer continues the descend down to the first floor by 300 seconds. This is without the smoke removal system.
**Temperature**

The modeled fuel slice temperature at 180 seconds in Figure 47 is shown to be well below the 60 °C temperature for tenability criteria. There is no impact to egress from the temperature meeting or exceeding 60 °C. Figure 47 shows soot density with no smoke removal at 178 seconds and temperature over the fire is shows a small amount of fire at 147 °C. The soot density coupled with the temperature increase in the immediate area would render tenability be impacted.

Figure 47. Temperature at 180 seconds.

Figure 47 shows the temperature does not rise to impact tenability except in the close proximity of the fire. Egress with the smoke removal system temperature is not a factor for egress.
**Carbon Monoxide**

The carbon monoxide (CO) level in Figure 48 is below 1400ppm irritant level and the minimum level for 35,000 PPM fatal dosage. The CO level shown during the model run shows no residual CO level within the next 5 seconds until the end of the model. The CO is no factor for tenability throughout the facility.

![Figure 48. Carbon Level at 36 Seconds.](image)

**Summary**

In conclusion, design fire scenarios are meant to find and evaluate the most challenging fires in a building. The first scenario fire, while not a fire challenge, was an egress one with limited access doors from the first floor to the stage. The second and third design fires challenged the occupants and the installed sprinkler system due to the amount of plastic being consumed by the fire. Both the second and third floor had a high HRR with limited effectiveness from the sprinkler system. The amount of smoke generated can cause egress and tenability issues.
Evaluation

Both prescriptive and performance-based evaluations of this building show the current design is code compliant with sufficient exits. The performance-based model looked at the first, second, and third floor balcony areas for the population given the exit passageway and the dispersant along the atrium balcony sides. This provides sufficient exit capacity and is within the atrium travel distances per NFPA 101.

While the exit passageway is considered a required means of egress, its 32-inch door opening provides a good exit to the adjacent building through the pedestrian walkway between the building that allows the area to meet the increase occupant load for atrium events due to loss of the fourth floor since it does not have a balcony overlooking the atrium.

When the atrium and mezzanine reception areas are used for events that were not considered in original design, the current systems are adequate, providing protection for these spaces. The user should consider future use when considering events to be held in this space and what the system is capable of to meet the fire and life safety.

In the future, if additional modification or additional materials are added to the atrium space including the total volume of the space, the smoke management system will need to be re-evaluated to see if it is still operating as designed to protect the balcony and atrium floors. Modeled toxicity CO levels are below the incapacitating and death levels.

The design fire for this analysis has the total heat release rate (THRR) with burner 35 kW converted to 3317 Btu/s, using a conversion factor of 1.05 kW to 1 btu/s. The smoke removal system in a small design fire for the analysis was adequate, but with a larger fire or a fire with higher soot content, the smoke removal system would not be able to ensure tenability on the third-floor balcony that is open to the atrium. Recommendation would be to redesign the smoke removal system to provide the 136,709 cfm (64.5 M3/s) which the model indicates would ensure the tenability requirements.

As currently designed, the smoke management and exhaust system have a lag time based on the model of 35 seconds for the delay of the smoke detector activations. The smoke management system currently has a pressure differential of between .5 wg and 1.0 wg on third floor flow switch activation. This is demonstrated by the portable stage design fire, which has exceptionally low soot and heat release generation, resulting in the smoke management system not activating based on thermal considerations. Smoke detectors were modeled as the fire suppression used to lower HRR was not a concern for this fire. In addition, design atrium design fire model HRR slice file shows the temperature on the third floor is not sufficient to activate the sprinkler system on the third-floor balcony or in the atrium ceiling. The smoke management and make up are sufficient for the smoke management to operate. The design fire which has low amount of fuel and similar fires does not generate enough thermal heat release to activate the smoke management system as shown in Figure 21, Smoke Management Sequence of Operations. The results from using the provided exhaust rate of 400,000 cfm showed that the smoke control system was able to maintain tenable conditions for the calculated RSET on Floor 1 and Floor 5.
**Recommendations**

The original basis of design for how the atrium was to be used was not available. The smoke management and other systems data were taken from design drawings by AECOM and CH2M Hill designers on this project. The following are recommendations that should be considered based on current use of the atrium and the mezzanine reception area.

The pedestrian walkway connects Building 3501 from the Area B section floor mezzanine to the second floor of Building 3500 is currently exempt from being a required exit, according to International Building Code 2009. Recommend changing this to a required exit from the 2nd floor mezzanine to the other building. The double doors are fitted with smoke gaskets.

Recommend a comprehensive review and smoke management system analysis of the atrium. The atrium’s future use should be evaluated against the current management system in order to be able to ensure tentability requirements. Modification of the smoke management system to meet tentability requirements based on the atrium use is recommended.

Recommend the smoke management system sequence of operation (Figure 21) be updated to allow the elevator lobby smoke detectors and duct smoke detectors to this activate the smoke management system. With the fire alarm system reprogramming this addition to activate smoke management would ensure tentability of first floor occupants with low fuel and low heat release rate fires.

**Conclusions**

The prescriptive design for the water supply, fire hydrants and fire department vehicle access to the building are compliant with the Unified Facilities Criteria (UFC) 3-600-01. The atrium space is compliant with the egress and travel distances for NFPA 101 assembly occupancy. The required door exit width are also compliant. Interior finishes are assumed to be compliant with NFPA Standard 101, Chapter 10, as no information was available on the actual finishes used.

The combination sprinkler and Class I standpipe system meets the required water flow and pressure requirements with the fire pump. The sprinkler system is compliant with UFC 3-600-01, and NFPA standard 13 with the exception of the atrium ceiling sprinklers. Table 15 shows the sprinklers are K 5.6, NFPA Standard 13 Handbook section 9-4, states the higher the ceiling height, the larger the sprinkler orifice size should be to counter the height. This premise is based on the height allows for a strong plume to develop and small droplets would not be effective to counter this development. The atrium sprinklers should be evaluated given the overall height. The sprinklers are helpful in maintaining the evacuation routes, but given the height its doubtful they would activate in RSET time of 596 seconds.

The fire alarm uses the Simplex addressable panel as power supply extenders on all floors with the mass notification of both audible and visual notification strobes throughout. The elevator lobbies are all equipped with photoelectric smoke detectors and the duct mounted smoke detectors transmit a supervisory signal to the base fire department via the Monaco BT-XM radio transceivers. The transceivers are not capable of transmitting the addressable signal.
provided to Simplex addressable fire alarm panels. This is due to each companies’ propriety systems and are not compatible. The MNS also has prerecorded messages for natural disasters and man-made threats. Each panel is spaced every 200 feet with one at each exit on the ground floor atrium areas. See Appendix B for First and Second Floor plans that illustrate these exit locations adjacent to the atrium spaces.

The smoke removal system is installed to meet NFPA 92 and 204. The smoke management system configuration is the activation of the 3rd Floor sprinkler system. This is a design that does not activate the system when smoke detectors in the elevator lobby or duct smoke detect smoke. The smoke management system also will not operate when manual pull station is activated. The smoke management, based on the fire alarm operation matrix, does not have a fire department manual operation system. The sprinklers rely on heat to activate, and if you have very dense smoke fire the system is not able to maintain the exit pathways clear.

The performance-based design and analysis is based on the atrium area only, as all occupants are located in the atrium areas for assembly events. This analysis is focused on this area and use. The Design fires were based on the NFPA 101, Chapter 5, and show what is considered the areas of greatest risk or hazards. The design fire materials and analysis were used to analyze against a similar configuration from testing done by National Institute Science Technology (NIST) report from The Station Night Club Fire Report Volume II. Figures 37 and 38 show the heat release rate curves from the olefin sample reached peak heat release rate in 160 seconds at 627kW average. The design fire is based a similar material with polyurethane which had a peak heat release rate of 983 kW in 160 seconds. Both have similar curves, but the polyurethane-based sample has a higher heat release rate. The soot values were slightly different as well. The smoke portable stage design fire based on the carpet and backing produced a higher density smoke. All travel distances and required exits required for a A-3 assembly are met, with maximum exit time of 996 seconds, just under 10 minutes. The tentability reliability for visibility is based on the activation of the smoke removal system at 38 seconds as modeled. The smoke management is only activated from the 3rd Floor sprinkler flow switch. With the smoke management system operational the visibility is maintain for tentability. The tentability requirement for temperature is maintained and does not rise to activate the sprinkler system on the third floor. The 60°C temperature is only located near the burner and stage areas. The carbon monoxide levels are well below the irritant fatal dosage levels. The calculations are based on anticipated evacuation times with the exposure. The only area that will require improvement to change the smoke management system to automatically operate from any smoke detector activation, manual pull station which also will allow fire department operation of the smoke removal system. The activation should also activate with all sprinkler activations. The smoke management system while adequate for the design fire, atrium calculations using atrium-calc from John Klote shows that the design is based on 9,900 CFM, and with full volume of the atrium should be 136,000 CFM. This is significantly below what should be available given the size and volume. The recommendation would be to recalculate the requirements for the smoke management system and minimize the use of combustible or flammable materials in atrium, provide crowd managers to assist in the
evacuation should the need arise. The building is overall compliant with the codes required to use the atrium where small fires are anticipated.
References


National Construction Safety Team Act Reports (NIST NCSTAR) –1-5F.


Special Publication (NIST SP)-1019.


Waidelich, S. (2016) FPE 523 and 522 course project report, Crofton, MD.


Photograph credits


Appendices

Appendix A: First Floor Life Safety Fire Separation Plan.
Appendix B: Fire Alarm/MNS Plans for First and Second Floors.
Appendix C: Electrical Legends.
Appendix D: Partial Level 1 Fire Alarm/MNS Plan Segment C.
Appendix E: FDS Input File with No Exhaust System.
Appendix F. Hand Calculations for Event (Atrium) Assembly Egress.
Appendix G: Egress Paths for 1 Through 5 Floors.
Appendix H: Life Safety Drawings.
Appendix I: NIST NCSTAR 2: Cone Calorimeter Data for Carpet Flooring at 35 kW/m².
Appendix A. First Floor Life Safety Fire Separation Plan.
Both floor and ceiling slabs are one-hour fire resistive construction.
Stairwells and elevator shafts are two-hour fire resistive construction.
Red = 2-hour fire resistive rating
Blue = 1-hour fire resistive rating and smoke barrier
Appendix B. Fire Alarm/MNS Plans for First and Second Floors.
Appendix C. Electrical Legends
Appendix D. Partial Level 1 Fire Alarm/MNS Plan Segment C
Appendix E. FDS Input file with No Exhaust System

1 &HEAD CHID=C:\Fire Modeling\FDS\atrium5_3_200702'
2
3 &TIME T_END=800/
4
5 &DUMP DT_HRR=3, DT_SLCF=3, DT_PART=3, /
6
7 &MESH IJK=120,30,20, XB=0,60,0,15,0, 10/ Mesh of 1m
8 &MESH IJK=40,40,40, XB=12,16,11,15,0,4/ Stage Geometry mesh, 0.1m
9 MESH IJK=10,10,10, XB=0,60,15,50,0,10/ Mesh out Y-axis to capture Cleary P4-6
10
11 * * * * * * * * * * * * * * * * * * * * *
12
13 &SPEC ID = 'POLYURETHANE', FORMULA = 'C25.188H42.188O6N2' /
14 &SPEC ID = 'WOOD', FORMULA = 'CH1.7O0.74N0.002' /
15 &SPEC ID = 'OXYGEN', LUMPED_COMPONENT_ONLY = .TRUE. / 
16 &SPEC ID = 'NITROGEN', LUMPED_COMPONENTONLY = .TRUE. /
17 SPEC ID = 'WATER VAPOR', LUMPED_COMPONENT_ONLY = .TRUE. /
18 &SPEC ID = 'CARBON MONOXIDE', LUMPED_COMPONENTONLY = .TRUE. /
19 &SPEC ID = 'CARBON DIOXIDE', LUMPED_COMPONENTONLY = .TRUE. /
20 &SPEC ID = 'HYDROGEN CYANIDE', LUMPED_COMPONENTONLY = .TRUE. / <----YOU WERE MISSING
21 THIS ONE FORWARD SLASH THAT CAUSED THE MODEL TO NOT RUN
22 &SPEC ID = 'SOOT', LUMPED_COMPONENTONLY = .TRUE. /
23
24 &SPEC ID = 'AIR',
25 SPEC_ID(1) = 'OXYGEN', VOLUME_FRACTION(1)=1,
26 SPEC_ID(2) = 'NITROGEN', VOLUME_FRACTION(2)=3.76,
27 BACKGROUND=.TRUE. /
28
29 &SPEC ID = 'PRODUCTS_1',
30 SPEC_ID(1) = 'CARBON DIOXIDE', VOLUME_FRACTION(1) = 19.79113,
31 SPEC_ID(2) = 'CARBON MONOXIDE', VOLUME_FRACTION(2) = 0.166587,
SPEC_ID(3) = 'WATER VAPOR', VOLUME_FRACTION(3) = 20.71987,
SPEC_ID(4) = 'SOOT', VOLUME_FRACTION(4) = 5.60253,
SPEC_ID(5) = 'NITROGEN', VOLUME_FRACTION(5) = 103.30721
SPEC_ID(6) = 'HYDROGEN CYANIDE', VOLUME_FRACTION(6) = 0.188/

SPEC_ID = 'PRODUCTS_2',
SPEC_ID(1) = 'CARBON DIOXIDE', VOLUME_FRACTION(1) = 0.964679,
SPEC_ID(2) = 'CARBON MONOXIDE', VOLUME_FRACTION(2) = 0.003655,
SPEC_ID(3) = 'WATER VAPOR', VOLUME_FRACTION(3) = 0.848241,
SPEC_ID(4) = 'SOOT', VOLUME_FRACTION(4) = 0.035184,
SPEC_ID(5) = 'NITROGEN', VOLUME_FRACTION(5) = 3.838558 /

REAC ID = 'plastic',
FUEL = 'POLYURETHANE',
HEAT_OF_COMBUSTION=26200,
SPEC_ID_NU = 'POLYURETHANE','AIR','PRODUCTS_1',
NU=-1,-27.23436,1 /

REAC ID = 'wood'
FUEL = 'WOOD',
HEAT_OF_COMBUSTION=16400,
SPEC_ID_NU = 'WOOD','AIR','PRODUCTS_2'
NU=-1,-1.02063,1 /

MATL ID = 'CARPET'
SPECIFIC_HEAT = 1.0
CONDUCTIVITY = 0.1
DENSITY = 100.0
N_REACTIONS = 1
NU_SPEC = 1.
SPEC_ID = 'POLYURETHANE'
REFERENCE_TEMPERATURE = 320.
HEAT_OF_REACTION = 2000.
HEAT_OF_COMBUSTION = 15000./

&MATL ID = 'PLYWOOD'
SPECIFIC_HEAT = 1.0
CONDUCTIVITY = 0.13
DENSITY = 150.0
N_REACTIONS = 1
NU_SPEC = 1.
SPEC_ID = 'WOOD'
REFERENCE_TEMPERATURE = 250.
HEAT_OF_REACTION = 3600.
HEAT_OF_COMBUSTION = 35000./

&SURF ID = 'STAGE'
COLOR = 'BROWN'
BURN_AWAY = .TRUE.
MATL_ID(1:2,1) = 'CARPET','PLYWOOD'
THICKNESS(1:2) = 0.005,0.03 /

&VENT XB= 12.5,13.0, 12.0,12.0, 0.5,1.0, SURF_ID='FIRE1', COLOR='RED'/
&OBST XB= 12.5,15.5, 12.0,15.0, 0.5,1.00, SURF_ID='STAGE', BULK_DENSI

&S_LCF QUANTITY='TEMPERATURE', PBX=3.5/
&S_LCF QUANTITY='TEMPERATURE', PBY=3.5/

&SURF ID='FIRE1',
SPEC_ID(1)='POLYURETHANE',
MASS_FLUX(1)=0.001544556,
RAMP_MF(1)='poly',
SPEC_ID(2)='WOOD',
MASS_FLUX(2)=0.0016065,
RAMP_MF(2)='wood'/
97 &RAMP ID='poly', T = 0, F = 0.0 /
98 &RAMP ID='poly', T = 60 , F = 0.3 /
99 &RAMP ID='poly', T = 100, F = 0.7 /
100 &RAMP ID='poly', T = 130, F = 1.2 /
101 &RAMP ID='poly', T = 160, F = 1.6 /
102 &RAMP ID='poly', T = 400, F = 1.6 /
103 &RAMP ID='poly', T = 430, F = 1.2 /
104 &RAMP ID='poly', T = 460, F = 0.7 /
105 &RAMP ID='poly', T = 490, F = 0.3 /
106 &RAMP ID='poly', T = 550, F = 0.0 /
107
108 &RAMP ID='wood', T = 0, F = 0.0 /
109 &RAMP ID='wood', T = 60 , F = 0.3 /
110 &RAMP ID='wood', T = 100, F = 0.7 /
111 &RAMP ID='wood', T = 130, F = 1.2 /
112 &RAMP ID='wood', T = 160, F = 1.6 /
113 &RAMP ID='wood', T = 400, F = 1.6 /
114 &RAMP ID='wood', T = 430, F = 1.2 /
115 &RAMP ID='wood', T = 460, F = 0.7 /
116 &RAMP ID='wood', T = 490, F = 0.3 /
117 &RAMP ID='wood', T = 550, F = 0.0 /
118
119 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
120
121 REAC ID='Reaction1',
122 FYI='C_6.3 H_7.1 N O_2.1, NFPA Handbook, Babrauskas',
123 FUEL='REAC_FUEL',
124 C=6.3,
125 H=7.1,
126 O=2.1,
127 N=1.0,
128 CO_YIELD=0.01,
129 SOOT_YIELD=0.04/
REAC SOOT_YIELD=0.01,FUEL='PROPANE'/
MATL ID = 'CARPET'
SPECIFIC_HEAT = 1.0
CONDUCTIVITY = 0.1
DENSITY = 100.0
N_REACTIONS = 1
NU_SPEC = 1.
SPEC_ID = 'PROPANE'
REFERENCE_TEMPERATURE = 320.
HEAT_OF_REACTION = 2000.
HEAT_OF_COMBUSTION = 15000. /

MATL ID = 'PLYWOOD'
SPECIFIC_HEAT = 1.0
CONDUCTIVITY = 0.13
DENSITY = 150.0
N_REACTIONS = 1
NU_SPEC = 1.
SPEC_ID = 'PROPANE'
REFERENCE_TEMPERATURE = 200.
HEAT_OF_REACTION = 1800.
HEAT_OF_COMBUSTION = 50000. /

SURF ID = 'STAGE'
FYI = 'Properties completely fabricated'
COLOR = 'BROWN'
BURN_AWAY = .TRUE.
MATL_ID(1:2,1) = 'CARPET','PLYWOOD'
THICKNESS(1:2) = 0.005,0.1 / 

&OBST XB= 12.5,15.5,12.0,15.0,0.5,1.00, SURF_ID6='INERT', 'INERT', 'INERT', 'INERT', 'INERT', 'INERT', 'FIRE1'/

&PART ID='ignitor particle', SURF_ID='ignitor', STATIC=.TRUE. /

&SURF ID='ignitor', TMP_FRONT=1500., GEOMETRY='CYLINDRICAL', LENGTH=0.15, RADIUS=0.03 /

&INIT XYZ=13,12.5,1.05, DX=0.1, PART_ID='ignitor particle', N_PARTICLES=6 /

&SLCF QUANTITY='TEMPERATURE', PBX=13.0/

&SLCF QUANTITY='TEMPERATURE', PBY=12.5/

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&PROP ID='Cleary Photoelectric P1',

QUANTITY='CHAMBER OBSCURATION',

SMOKEVIEW_ID='smoke detector',

ALPHA_E=2.5,

BETA_E=-0.7,

ALPHA_C=0.8,

BETA_C=-0.9,

ACTIVATION_OBSCURATION=3.24 /

****************************

****************************
&VENT XB= 54.2, 54.2, 3.5, 4.262, 4.5, 5.262, ID='Smoke Vent 1', SURF_ID='FAN', CTRL_ID='SD' / 'Smoke Vent 1

&OBST XB= 54.2, 60.7, 3.5, 4.5, 4.5, 5.3, SURF_ID='WALL' / HVAC Duct

&VENT XB= 54.5, 54.5, 6.5, 7.2, 4.5, 5.262, ID='Smoke Vent 2', SURF_ID='FAN', CTRL_ID='SD' / 'Smoke Vent 2

&OBST XB= 54.5, 60.7, 6.5, 7.262, 4.5, 5.3, SURF_ID='WALL' / HVAC Duct

&VENT XB= 55.0, 55.0, 10.5, 11.262, 4.5, 5.262, ID='Smoke Vent 3', SURF_ID='FAN', CTRL_ID='SD' / 'Smoke Vent 3

&OBST XB= 55.0, 60.762, 10.5, 11.262, 4.5, 5.3, SURF_ID='WALL' / HVAC Duct

&SURF ID='FAN', VOLUME_FLOW=15000, COLOR='BLUE' / 10 CFM = 30.68 m3/s

&SURF ID='FAN2', VOLUME_FLOW=15000, COLOR='ORANGE' / 10 CFM = 30.68 m3/s - for troubleshooting to identify vent

&SURF ID='FAN3', VOLUME_FLOW=15000, COLOR='BLACK' / 10 CFM = 30.68 m3/s - for troubleshooting to identify vent

&DEV C ID='Cleary Photoelectric P1(1)', PROP_ID='Cleary Photoelectric P1', XYZ= 10, 13.0, 9.8, LATCH=.FALSE./3fl

&DEV C ID='Cleary Photoelectric P1(2)', PROP_ID='Cleary Photoelectric P1', XYZ= 25, 13.0, 9.8, LATCH=.FALSE./3fl

&DEV C ID='Cleary Photoelectric P1(3)', PROP_ID='Cleary Photoelectric P1', XYZ= 40, 13.0, 9.8, LATCH=.FALSE./3fl

PROP ID='Smoke Detector', QUANTITY='CHAMBER OBSCURATION', LENGTH=1.8, ACTIVATION_OBSCURATION=3.24 /

CTRL ID='SD', FUNCTION_TYPE='ANY', INPUT_ID='Cleary Photoelectric P1(1)', 'Cleary
Photoelectric P1(2)', 'Cleary Photoelectric P1(3)', INITIAL_STATE=.FALSE. /

212

213

214 &HOLE XB= 2.15, 1.61, 9.86, 10.78, 0, 0.5/ Makeup Air Closest to wall 5 @ floor
215 &HOLE XB= 1.61, 1.07, 9.95, 10.86, 0, 0.5/ Makeup Air Closest to wall 5 @ floor
216 &HOLE XB= 1.07, 0.54, 10.03, 10.95, 0, 0.5/ Makeup Air Closest to wall 5 @ floor
217

218

219 &HOLE XB= 25.75, 25.21, 6.11, 7.02, 0, 0.5/ Makeup Air Mid Wall4 @ floor
220 &HOLE XB= 25.21, 24.68, 6.19, 7.11, 0, 0.5/ Makeup Air Mid Wall4 @ floor
221 &HOLE XB= 24.68, 24.14, 6.28, 7.19, 0, 0.5/ Makeup Air Mid Wall4 @ floor
222

223 &HOLE XB= 25.75, 25.21, 6.11, 7.02, 9.5, 10.0/ Makeup Air Mid Wall4 @ ceiling
224 &HOLE XB= 25.21, 24.68, 6.19, 7.11, 9.5, 10.0/ Makeup Air Mid Wall4 @ ceiling
225 &HOLE XB= 24.68, 24.14, 6.28, 7.19, 9.5, 10.0/ Makeup Air Mid Wall4 @ ceiling
226

227 &HOLE XB= 49.35, 48.82, 2.35, 3.27, 0, 0.5/ Makeup Air Closest to wall 3 @ floor
228 &HOLE XB= 48.82, 48.28, 2.44, 3.35, 0, 0.5/ Makeup Air Closest to wall 3 @ floor
229 &HOLE XB= 48.28, 47.74, 2.52, 3.44, 0, 0.5/ Makeup Air Closest to wall 3 @ floor
230

231

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235 &SPEC ID='WATER VAPOR' /
236 &PART ID='WATER DROPLETS', SPEC_ID='WATER VAPOR', DIAMETER = 1000. /
237

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238

239

240 &MATL ID='CONCRETE',
241 Conductivity = 1.60E-03,
242 SPECIFIC_HEAT=0.75,
243 DENSITY=2400/
&MATL ID = 'GWB',
FYI = 'GA-235-10.pdf',
CONDUCTIVITY = 0.16,
SPECIFIC_HEAT = 1.09,
DENSITY = 750. /

SURF ID = 'FIRE',
COLOR = 'RED',
HRRPUA = 4500
Ramp_Q = 'tsquared'/

SURF ID = 'WALL',
DEFAULT = .TRUE.,
COLOR = 'TAN',
MATL_ID = 'GWB',
THICKNESS = 0.0125 /

SURF ID = 'CEILING',
COLOR = 'INVISIBLE',
MATL_ID = 'CONCRETE',
THICKNESS = 0.1 /

SURF ID = 'GLASS',
DEFAULT = .TRUE.,
COLOR = 'POWDER BLUE',
MATL_ID = 'GWB',
THICKNESS = 0.0125 /

SURF ID='Exhaust',
FYI='Side Smoke Exhaust Vent',
RGB=26.0,128.0,26.0,
VOLUME_FLOW=9.9/

**************************************************

&SURF ID = 'FLOOR',
COLOR = 'SILVER',
MATL_ID = 'CONCRETE',
THICKNESS = 0.1 /

**************************************************

RAMP ID='tsquared', T= 0.0, F=0.00 /
RAMP ID='tsquared', T= 10.0, F=0.00 /
RAMP ID='tsquared', T= 20.0, F=0.02 /
RAMP ID='tsquared', T= 30.0, F=0.04 /
RAMP ID='tsquared', T= 40.0, F=0.06 /
RAMP ID='tsquared', T= 50.0, F=0.10 /
RAMP ID='tsquared', T= 60.0, F=0.14 /
RAMP ID='tsquared', T= 70.0, F=0.19 /
RAMP ID='tsquared', T= 80.0, F=0.25 /
RAMP ID='tsquared', T= 90.0, F=0.32 /
RAMP ID='tsquared', T= 100.0, F=0.39 /
RAMP ID='tsquared', T= 110.0, F=0.47 /
RAMP ID='tsquared', T= 120.0, F=0.56 /
RAMP ID='tsquared', T= 130.0, F=0.66 /
RAMP ID='tsquared', T= 140.0, F=0.77 /
RAMP ID='tsquared', T= 150.0, F=0.88 /
RAMP ID='tsquared', T= 160.0, F=1.00 /

************

&HOLE ID='Right Make Up Air', XB=28.5,29.5,13.0,16.0,0.0,1.1/

************

OBST XB= 14.5,15.5,14.0,15.0,0.0,0.55, SURF_IDS='FIRE','INERT','INERT'/

************

&OBST XB= 46.02, 46.02, 15.3, 16.21, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 46.02, 46.43, 15.23, 16.14, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 46.43, 46.83, 15.15, 16.07, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 46.83, 47.23, 15.08, 15.99, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 47.23, 47.63, 15.01, 15.92, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 47.63, 48.04, 14.93, 15.85, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 48.04, 48.44, 14.86, 15.78, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 48.44, 48.84, 14.79, 15.7, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 48.84, 49.24, 14.71, 15.63, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 49.24, 49.65, 14.64, 15.56, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 49.65, 50.05, 14.57, 15.48, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 50.05, 50.45, 14.5, 15.41, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 50.45, 50.85, 14.42, 15.34, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 50.85, 51.26, 14.35, 15.26, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 51.26, 51.66, 14.28, 15.19, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 51.66, 52.06, 14.2, 15.12, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 52.06, 52.46, 14.13, 15.04, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 52.46, 52.86, 14.06, 14.97, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 52.86, 53.27, 13.98, 14.9, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 53.27, 53.67, 13.91, 14.82, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 53.67, 54.07, 13.84, 14.75, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 54.07, 54.47, 13.76, 14.68, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 54.47, 54.88, 13.69, 14.61, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 54.88, 55.28, 13.62, 14.53, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 55.28, 55.68, 13.54, 14.46, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 55.68, 56.08, 13.47, 14.39, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 56.08, 56.49, 13.4, 14.31, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 56.49, 56.89, 13.32, 14.24, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 56.89, 57.29, 13.25, 14.17, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 57.29, 57.69, 13.18, 14.09, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 57.69, 58.09, 13.11, 14.02, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 58.09, 58.5, 13.03, 13.95, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 58.5, 58.9, 12.96, 13.87, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 58.9, 59.3, 12.89, 13.8, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 59.3, 59.7, 12.81, 13.73, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 59.7, 60.11, 12.74, 13.65, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 60.11, 60.51, 12.67, 13.58, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 60.51, 60.91, 12.59, 13.51, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 60.91, 61.31, 12.52, 13.43, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 61.31, 61.72, 12.45, 13.36, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 61.72, 62.12, 12.37, 13.29, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 62.12, 62.52, 12.3, 13.22, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 62.52, 62.92, 12.23, 13.14, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 62.92, 63.33, 12.15, 13.07, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 63.33, 63.73, 12.08, 13, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 63.73, 64.13, 12.01, 12.92, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 64.13, 64.53, 11.94, 12.85, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 64.53, 64.93, 11.86, 12.78, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 64.93, 65.34, 11.79, 12.7, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 65.34, 65.74, 11.72, 12.63, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 65.74, 66.13, 11.64, 12.56, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 66.13, 66.54, 11.57, 12.48, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 66.54, 66.95, 11.5, 12.41, 0, 10, SURF_ID='WALL'/ Wall 2
&OBST XB= 66.95, 67.35, 11.42, 12.34, 0, 10, SURF_ID='WALL'/ Wall 2
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998 &HOLE XB= 49.29, 70, -23.62, -24.09, 3, 4.2/ Hole Exterior 3
999 &HOLE XB= 49.19, 70, -24.09, -24.57, 3, 4.2/ Hole Exterior 3
1000 &HOLE XB= 49.1, 70, -24.57, -25.04, 3, 4.2/ Hole Exterior 3
1001 &HOLE XB= 49, 70, -25.04, -25.52, 3, 4.2/ Hole Exterior 3
1002 &HOLE XB= 48.9, 70, -25.52, -25.99, 3, 4.2/ Hole Exterior 3
1003 &HOLE XB= 48.8, 70, -25.99, -26.47, 3, 4.2/ Hole Exterior 3
1004 &HOLE XB= 48.71, 70, -26.47, -26.95, 3, 4.2/ Hole Exterior 3
1005 &HOLE XB= 48.61, 70, -26.95, -27.42, 3, 4.2/ Hole Exterior 3
1006 &HOLE XB= 48.51, 70, -27.42, -27.9, 3, 4.2/ Hole Exterior 3
1007 &HOLE XB= 48.41, 70, -27.9, -28.37, 3, 4.2/ Hole Exterior 3
1008 &HOLE XB= 48.32, 70, -28.37, -28.85, 3, 4.2/ Hole Exterior 3
1009 &HOLE XB= 48.22, 70, -28.85, -29.32, 3, 4.2/ Hole Exterior 3
1010 &HOLE XB= 48.12, 70, -29.32, -29.8, 3, 4.2/ Hole Exterior 3
1011 &HOLE XB= 48.02, 70, -29.8, -30.27, 3, 4.2/ Hole Exterior 3
1012 &HOLE XB= 47.93, 70, -30.27, -30.75, 3, 4.2/ Hole Exterior 3
1013 &HOLE XB= 47.83, 70, -30.75, -31.22, 3, 4.2/ Hole Exterior 3
1014 &HOLE XB= 47.73, 70, -31.22, -31.7, 3, 4.2/ Hole Exterior 3
1015 &HOLE XB= 47.63, 70, -31.7, -32.18, 3, 4.2/ Hole Exterior 3
1016 &HOLE XB= 47.54, 70, -32.18, -32.65, 3, 4.2/ Hole Exterior 3
1017 &HOLE XB= 47.44, 70, -32.65, -33.13, 3, 4.2/ Hole Exterior 3
1018 &HOLE XB= 47.34, 70, -33.13, -33.6, 3, 4.2/ Hole Exterior 3
&HOLE XB= 47.24, 70, -33.6, -34.08, 3, 4.2/ Hole Exterior 3


&OBST XB= 4.29, 3.76, 13.3, 13.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.


&OBST XB= 3.22, 2.68, 13.3, 13.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 2.68, 2.15, 13.3, 13.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 2.15, 1.61, 13.3, 13.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 1.61, 1.07, 13.3, 13.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 1.07, 0.54, 13.3, 13.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 0.54, 0.91, 13.3, 13.3, 3, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 45.6, 45.06, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 45.06, 44.53, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 44.53, 43.99, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 43.99, 43.45, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 43.45, 42.92, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 42.92, 42.38, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 42.38, 41.84, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 41.84, 41.31, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 41.31, 40.77, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 40.77, 40.23, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 40.23, 39.7, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 39.7, 39.16, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 39.16, 38.62, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 38.62, 38.09, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 38.09, 37.55, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 37.55, 37.01, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 37.01, 36.48, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 36.48, 35.94, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 35.94, 35.41, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 35.41, 34.87, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.

&OBST XB= 34.87, 34.33, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE.
&OBST XB= 34.33, 33.8, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 33.8, 33.26, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 32.26, 32.72, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 32.72, 32.19, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 32.19, 31.65, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 31.65, 31.11, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 31.11, 30.58, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 30.58, 30.04, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 30.04, 29.5, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 16.63, 16.09, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 16.09, 15.56, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 15.56, 15.02, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 15.02, 14.48, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 14.48, 13.95, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 13.95, 13.41, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 12.87, 12.34, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 12.34, 11.8, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 11.8, 11.27, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 11.27, 10.73, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 10.73, 10.19, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 10.19, 9.66, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 9.66, 9.12, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 9.12, 8.58, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 8.58, 8.05, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 8.05, 7.51, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 7.51, 6.97, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 6.97, 6.44, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 6.44, 5.9, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 5.9, 5.36, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 5.36, 4.83, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 4.83, 4.29, 12.8, 12.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 4.29, 3.76, 10.44, 10.44, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 3.76, 3.22, 10.52, 10.52, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 3.22, 2.68, 10.61, 10.61, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
&OBST XB= 2.68, 2.15, 10.69, 10.69, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./
Flr Glass Wall
1114 &OBST XB= 2.15, 1.61, 10.78, 10.78, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1115 &OBST XB= 1.61, 1.07, 10.86, 10.86, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1116 &OBST XB= 1.07, 0.54, 10.95, 10.95, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1117 &OBST XB= 0.54, 0.91, 11.03, 11.03, 3, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1118
1119 &OBST XB= 45.6, 45.06, 5.86, 5.86, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1120 &OBST XB= 45.06, 44.53, 5.95, 5.95, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1121 &OBST XB= 44.53, 43.99, 6.03, 6.03, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1122 &OBST XB= 43.99, 43.45, 6.12, 6.12, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1123 &OBST XB= 43.45, 42.92, 6.21, 6.21, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1124 &OBST XB= 42.92, 42.38, 6.29, 6.29, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1125 &OBST XB= 42.38, 41.84, 6.38, 6.38, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1126 &OBST XB= 41.84, 41.31, 6.46, 6.46, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1127 &OBST XB= 41.31, 40.77, 6.55, 6.55, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1128 &OBST XB= 40.77, 40.23, 6.63, 6.63, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd
Flr Glass Wall
1129 &OBST XB= 40.23, 39.7, 6.72, 6.72, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1130 &OBST XB= 39.7, 39.16, 6.8, 6.8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

1131 &OBST XB= 39.16, 38.62, 6.89, 6.89, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1132 &OBST XB= 38.62, 38.09, 6.97, 6.97, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1133 &OBST XB= 38.09, 37.55, 7.06, 7.06, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1134 &OBST XB= 37.55, 37.01, 7.14, 7.14, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1135 &OBST XB= 37.01, 36.48, 7.23, 7.23, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1136 &OBST XB= 36.48, 35.94, 7.31, 7.31, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1137 &OBST XB= 35.94, 35.41, 7.4, 7.4, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1138 &OBST XB= 35.41, 34.87, 7.49, 7.49, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1139 &OBST XB= 34.87, 34.33, 7.57, 7.57, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1140 &OBST XB= 34.33, 33.8, 7.66, 7.66, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1141 &OBST XB= 33.8, 33.26, 7.74, 7.74, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1142 &OBST XB= 33.26, 32.72, 7.83, 7.83, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1143 &OBST XB= 32.72, 32.19, 7.91, 7.91, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1144 &OBST XB= 32.19, 31.65, 8, 8, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1145 &OBST XB= 31.65, 31.11, 8.08, 8.08, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall

1146 &OBST XB= 31.11, 30.58, 8.17, 8.17, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 30.58, 30.04, 8.25, 8.25, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 30.04, 29.5, 8.34, 8.34, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 29.5, 28.97, 8.42, 8.42, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 28.97, 28.43, 8.51, 8.51, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 27.9, 27.36, 8.68, 8.68, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 27.36, 26.82, 8.77, 8.77, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 26.82, 26.29, 8.85, 8.85, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 26.29, 25.75, 8.94, 8.94, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 25.75, 25.21, 9.02, 9.02, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 25.21, 24.68, 9.11, 9.11, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 24.14, 23.6, 9.28, 9.28, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 23.6, 23.07, 9.36, 9.36, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 23.07, 22.53, 9.45, 9.45, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
Flr Glass Wall
1167 &OBST XB= 19.85, 19.31, 9.96, 9.96, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1168 &OBST XB= 19.31, 18.78, 10.05, 10.05, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1169 &OBST XB= 18.78, 18.24, 10.13, 10.13, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1170 &OBST XB= 18.24, 17.7, 10.22, 10.22, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1171 &OBST XB= 17.7, 17.17, 10.3, 10.3, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1172 &OBST XB= 17.17, 16.63, 10.39, 10.39, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1173 &OBST XB= 16.63, 16.09, 10.47, 10.47, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1174 &OBST XB= 16.09, 15.56, 10.56, 10.56, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1175 &OBST XB= 15.56, 15.02, 10.64, 10.64, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1176 &OBST XB= 15.02, 14.48, 10.73, 10.73, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1177 &OBST XB= 14.48, 13.95, 10.81, 10.81, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1178 &OBST XB= 13.95, 13.41, 10.9, 10.9, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
1179 &OBST XB= 13.41, 12.87, 10.98, 10.98, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 12.87, 12.34, 11.07, 11.07, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 12.34, 11.8, 11.16, 11.16, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 11.8, 11.27, 11.24, 11.24, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 11.27, 10.73, 11.33, 11.33, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 10.73, 10.19, 11.41, 11.41, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 10.19, 9.66, 11.5, 11.5, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 9.66, 9.12, 11.58, 11.58, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 9.12, 8.58, 11.67, 11.67, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 8.58, 8.05, 11.75, 11.75, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 8.05, 7.51, 11.84, 11.84, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 7.51, 6.97, 11.92, 11.92, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 6.97, 6.44, 12.01, 12.01, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 6.44, 5.9, 12.09, 12.09, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 5.9, 5.36, 12.18, 12.18, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 5.36, 4.83, 12.26, 12.26, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 4.83, 4.29, 12.35, 12.35, 3.5, 4.7, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr Glass Wall
&OBST XB= 0, 56.64, 15.24, 1.83, 7.0, 7.3, SURF_ID='FLOOR'/ 3rd Floor

&OBST XB= 53.64, 0, 15.24, 11, 7.0, 7.3, SURF_ID='FLOOR'/ 3rd Floor

&HOLE XB= 4.83, 4.83, 10.35, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 4.29, 3.76, 10.44, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 3.76, 3.22, 10.52, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 3.22, 2.68, 10.61, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 2.68, 2.15, 10.69, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 2.15, 1.61, 10.78, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 1.61, 1.07, 10.86, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 1.07, 0.54, 10.95, 13.3, 6.5, 7.7/ Hole 1

&HOLE XB= 0.54, 0.91, 11.03, 13.3, 6.5, 7.7/ Hole 1

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1610 &OBST XB= 45.6, 45.06, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1611 &OBST XB= 45.06, 44.53, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
&OBST XB= 44.53, 43.99, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 43.99, 43.45, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 43.45, 42.92, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 42.92, 42.38, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 42.38, 41.84, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 41.84, 41.31, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 41.31, 40.77, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 40.77, 40.23, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 40.23, 39.7, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 39.7, 39.16, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 39.16, 38.62, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 38.62, 38.09, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 38.09, 37.55, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 37.55, 37.01, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 37.01, 36.48, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 36.48, 35.94, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 35.94, 35.41, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1629 &OBST XB= 35.41, 34.87, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1630 &OBST XB= 34.87, 34.33, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1631 &OBST XB= 34.33, 33.8, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1632 &OBST XB= 33.8, 33.26, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1633 &OBST XB= 33.26, 32.72, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1634 &OBST XB= 32.72, 32.19, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1635 &OBST XB= 32.19, 31.65, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1636 &OBST XB= 31.65, 31.11, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1637 &OBST XB= 31.11, 30.58, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1638 &OBST XB= 30.58, 30.04, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1639 &OBST XB= 30.04, 29.5, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1640 &OBST XB= 29.5, 28.97, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1641 &OBST XB= 28.97, 28.43, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1642 &OBST XB= 28.43, 27.9, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1643 &OBST XB= 27.9, 27.36, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1644 &OBST XB= 27.36, 26.82, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
Glass Wall

1645 &OBST XB= 26.82, 26.29, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1646 &OBST XB= 26.29, 25.75, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1647 &OBST XB= 25.75, 25.21, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1648 &OBST XB= 25.21, 24.68, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1649 &OBST XB= 24.68, 24.14, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1650 &OBST XB= 24.14, 23.6, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1651 &OBST XB= 23.6, 23.07, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1652 &OBST XB= 23.07, 22.53, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1653 &OBST XB= 22.53, 21.99, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1654 &OBST XB= 21.99, 21.46, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1655 &OBST XB= 21.46, 20.92, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1656 &OBST XB= 20.92, 20.39, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1657 &OBST XB= 20.39, 19.85, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1658 &OBST XB= 19.85, 19.31, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1659 &OBST XB= 19.31, 18.78, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1660 &OBST XB= 18.78, 18.24, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr

Glass Wall

1661 &OBST XB= 18.24, 17.7, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1662 &OBST XB= 17.7, 17.17, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1663 &OBST XB= 17.17, 16.63, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1664 &OBST XB= 16.63, 16.09, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1665 &OBST XB= 16.09, 15.56, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1666 &OBST XB= 15.56, 15.02, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1667 &OBST XB= 15.02, 14.48, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1668 &OBST XB= 14.48, 13.95, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1669 &OBST XB= 13.95, 13.41, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1670 &OBST XB= 13.41, 12.87, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1671 &OBST XB= 12.87, 12.34, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1672 &OBST XB= 12.34, 11.8, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1673 &OBST XB= 11.8, 11.27, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1674 &OBST XB= 11.27, 10.73, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1675 &OBST XB= 10.73, 10.19, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1676 &OBST XB= 10.19, 9.66, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
1677 &OBST XB= 9.66, 9.12, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall
&OBST XB= 9.12, 8.58, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 8.58, 8.05, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 8.05, 7.51, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 7.51, 6.97, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 6.97, 6.44, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 6.44, 5.9, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 5.9, 5.36, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 5.36, 4.83, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

&OBST XB= 4.83, 4.29, 12.8, 12.8, 7, 8.2, SURF_ID='GLASS', Outline = .TRUE./ 2nd Flr
Glass Wall

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**NOTE:** To set your boundaries open to atmosphere, you must use "&VENT MB", not
"&VENT ID"

**NOTE:** You also need to make sure that vents are applied to surfaces of objects. OPEN
vents are assigned to objects or locations that correspond with the edge of a mesh
boundary.
&VENT MB='XMAX', SURF_ID='OPEN'/Vent 2

&VENT MB='XMIN', SURF_ID='OPEN'/Vent 4

&OBST XB=0,0.1,0,100,0,120, SURF_ID='WALL', Outline = .TRUE./

&VENT MB='YMIN', SURF_ID='OPEN'/Vent 6

&VENT MB='YMAX', SURF_ID='WALL'/Vent 8

&VENT MB='ZMIN', SURF_ID='FLOOR'/Vent 10

&OBST XB = 0,100,1,100,9,9,11, SURF_ID = 'CEILING'/CEILING

&SLCF PBY= 13.5, QUANTITY='VOLUME FRACTION', SPEC_ID= 'CARBON MONOXIDE' /

&SLCF PBY= 7.0, QUANTITY='VOLUME FRACTION', SPEC_ID= 'CARBON MONOXIDE' /

&SLCF PBY= 13.5, QUANTITY='VOLUME FRACTION', SPEC_ID= 'HYDROGEN CYANIDE' /

&SLCF PBY= 7.0, QUANTITY='VOLUME FRACTION', SPEC_ID= 'HYDROGEN CYANIDE' /

&SLCF PBY= 13.5, QUANTITY='VOLUME FRACTION', SPEC_ID= 'CARBON DIOXIDE' /

&SLCF PBY= 7.0, QUANTITY='VOLUME FRACTION', SPEC_ID= 'CARBON DIOXIDE' /

&SLCF PBY= 13.5, QUANTITY='VOLUME FRACTION', SPEC_ID= 'OXYGEN' /

&SLCF QUANTITY='VISIBILITY', PBX=10/

&SLCF QUANTITY='VISIBILITY', PBX=25/

&SLCF QUANTITY='VISIBILITY', PBX=40/

&SLCF QUANTITY='VISIBILITY', PBY=14/
&SLCF QUANTITY='VISIBILITY', PBY=10/
&SLCF QUANTITY='VISIBILITY', PBY=8/

&DEVC XB=10,10,7,7,0,10, QUANTITY='LAYER HEIGHT', ID=LayerHeight /1st FL
&DEVC XB=25,25,7,7,0,10, QUANTITY='LAYER HEIGHT', ID=LayerHeight /2nd FL
&DEVC XB=40,40,7,7,0,10, QUANTITY='LAYER HEIGHT', ID=LayerHeight /3rd FL

&SLCF PBY= 7.0, QUANTITY='VOLUME FRACTION', SPEC_ID= 'OXYGEN' /

&SLCF QUANTITY='TEMPERATURE', PBX=10/
&SLCF QUANTITY='TEMPERATURE', PBX=25/
&SLCF QUANTITY='TEMPERATURE', PBX=40/

&SLCF QUANTITY='TEMPERATURE', PBY=10/
&SLCF QUANTITY='TEMPERATURE', PBY=13/
&SLCF QUANTITY='TEMPERATURE', PBY=8/

&SLCF QUANTITY='TEMPERATURE', PBZ=6/
&SLCF QUANTITY='TEMPERATURE', PBZ=3/
&SLCF QUANTITY='TEMPERATURE', PBZ=2/

&TAIL /

-
Appendix F. Hand Calculations for Event (Atrium) Assembly Egress
Find T. Corridor

AREA 2007 ft² New Fixed Seating

Highest occupant load -> 157FL Area+B w/portable stage

Area

\[ D = \frac{757 \text{ People}}{2007 \text{ ft}^2} = 0.375 \text{ ft}^2 \]

Use \( K_c = 2.75 \text{ ft/min} \quad a = 2.86 \text{ ft}^2 \)

\[ S = K_c - a \cdot D \]

\[ S = (2.75 \text{ ft/min}) - (2.86 \text{ ft}^2) \cdot (2.75 \text{ ft/min}) \cdot (0.375 \text{ ft}^2) \]

\[ S = 162.5 \text{ ft/min} \rightarrow \text{Corridor} \quad \text{Corridor} = \frac{2.95 \text{ ft}}{162.5 \text{ ft/min}} \]

\[ S = 0.5 \text{ ft/min} \rightarrow T_{\text{corridor}} = 34.4 \text{ ft} = 35 \text{ seconds} \]

\[ F_s = \left(1 - a \cdot D \cdot K_c \right) \]

\[ F_s = (1 - 2.86 \text{ ft}^2) \cdot (0.375 \text{ ft}^2) \cdot (2.75 \text{ ft/min}) \cdot (0.375 \text{ ft}^2) \]

\[ F_s = 23 \text{ person/ft/min effective width} \]

\[ w = 8 \text{ ft} \cdot (2 \times 0.6 \text{ in}) = 7 \text{ ft} \]

\[ F_c = \left(1 - a \cdot D \cdot K_D \right) \]

\[ F_c = 1 - (2.86 \text{ ft}^2) \cdot (0.375 \text{ ft}^2) \cdot (2.75 \text{ ft/min}) \cdot (0.375 \text{ ft}^2) \]

\[ F_c = 162 \text{ ft/min} = 162 \text{ ft/min} \times 0.7 = 112 \text{ ft/min} \]

\[ F_s = \frac{2.9 \text{ inches} - 3 \text{ inches boundary}}{66 \text{ inches}} \]

\[ F_{\text{door}} = \frac{162 \text{ ft/min}}{66 \text{ inches}} = 2.45 \text{ ft/min} = 147 \text{ ft/second} \]

\[ TP_{\text{door}} = 162 \text{ ft/min} = 972 \text{ ft/second} \]
**Event Egress Calculations 1st Floor Area B**

**Queueing**

\[-4.2 \text{ p/min} - 24 \text{ p/min} = -28.2\]

FS Door = \(64 \times 3\) = 72 \(\frac{\text{p}}{\text{min}}\)

\[T_{sca} = \frac{28.2}{72 \frac{\text{p}}{\text{min}}} = 3.99 \text{ min} \times 60\text{ sec/min} = 239.4\text{ s}\]
2ND FL Area

Find T corridor Area A
Corridor Area = 15.75 ft²

Find T - 2ND FL Mezzanine Area
Area = 1703 ft²

Find T corridor ATRium Area C side
Area = 185.7 ft²

Highest Occupant Load is 2ND FL Area A plus 4TH OC added

\[
D = \frac{577 + 213 \text{ 2ND FL OC} + 314 \text{ 4TH OC}}{185.7 \text{ ft}²} = 2.37x
\]

D = 0.272

D = \frac{185}{1703 \text{ ft}²} = 0.107 ATRium Area C

Use K = 2.75 ft/min

a = 2.86 ft²/min

S = 2.75 x 0.327

S = 0.75 P/s/min

W = 911 ft = 8 ft

S = 1.75 P/s/min

Use Corridor = \frac{L \text{ Corridor}}{\text{SCR} \times \text{SCR}} = \frac{132.4 ft}{7.5 \times 7.5 ft} = 3.3 ft/min

S = 7.4 \text{ min} \times \frac{60 \text{ sec}}{1 \text{ min}} = 444 \text{ ft}²
2ND FL AREA BALCONY (WITH 2ND FLOOR AREA AS 4% PLAN
OCCUPANCY)

\[ F = C = (17.8)(37.7) = 192.4 \text{ P/min} \]

FS floor = 192.4 P/min
Use 24 P/min/ft

FS door = 5.9 row x 6 P/min x 2 doors = 12 P/min

Query:

192.4 P/min - 24 P/min = 118.4 P/min

Stair effect

\[ A = \frac{2 \times \text{effi} + \frac{2}{4} \times 12}{4} \]

FS stair = 13.1 people/min pending merge

Stair Density

13 people/min \( \cdot \) \( \cdot \) \( \cdot \) 0.2 P/ft

\( 1 - 2.86(D)(D) \)

S = 212 - (212)(2.86)(0.2)

S = 90.7 ft/min

Floor-Floor Height \( \cdot \) 12 ft x 1.85 = 22.2 ft TOWER DISTANCE

\( t = \frac{22.2 \text{ ft}}{90.7 \text{ ft/min}} = 0.24 \text{ min} \times \frac{60 \text{ sec}}{1 \text{ min}} = 14.45 \text{ s} \)

People in Stairs

\( P = N \times \text{stairs} \times \text{FS corridor} \)

\( 2 \times \text{occupied floors} \times 4 \text{ doors} \)

\( (24 \times 4) \times (13) \text{ people} = 12.57 \text{ people in stairs} \)

12.57/2 = 6.28 P/Floor

FS stair door = 24 P/min
Track Express Plan

Stage well full -> CALC 3rd FL to evacuate/descend

\[ T_{\text{out}} = \frac{\text{occupied}}{48 \text{ p/min}} + 0.24 \text{ min} \times \frac{60}{60} = 10.8 \text{ s} \]

\[ \frac{2040}{48 \text{ p/min}} = 41.75 + 0.24 \text{ min} + 1 \text{ min} = 5.49 \text{ min} \]

\[ 5.49 \times 60 \times 60 = 3273 \text{ p} \]

2nd FL MEZZANINE/Reception: Ato C

- Assume: No fixed seating
- DLF 15 ft/min

\[ S = K \times A \times D \]

\[ D = 0.733 \times 125 \text{ people} \]

\[ S = K \times A \times D \]

\[ S = 275 - (2.75)(275)(0.733) = 301.5 \text{ p/ft/min} \]

\[ W_e = 4 \text{ ft} / 1 = 3.4 \]

\[ S = 301.5 \text{ p/ft/min} \Rightarrow T_{\text{corridor}} = L_{\text{corridor}} \]

\[ S = \frac{684}{301.5 \text{ p/ft/min}} = 2.25 \text{ min} \times \frac{60}{60} = 13.5 \text{ s} \]

\[ F_c = (301.5 \times 3.4) = 904.5 \text{ p/min} \Rightarrow 24 \text{ p/min/fT} \]

\[ F_{\text{door}} = 904.5 \text{ p/min} \]

\[ 24 \text{ p/min} = 32.68 \text{ person/min} \]

During

\[ 301.5 \text{ p/min} - 24 \text{ p/min} = 277.5 \text{ p/min} \]

Stair Effect

\[ F_s \left[ \frac{2 \text{ p/ft}^2}{49} \right] = \]

\[ F_s \text{ stairs 13.1 p/min per 2 rung} \]
2nd FL Mezzanine - Area C (Continued)

Stair Density

\[ D = \frac{0.2 \text{ P/ft}^2 \times 13.1 \text{ people/ft} \times 1 - 2 \times 6(1) \times 0.2}{212 - (212 \times (2.86)) \times 0.2} \]

\[ S = 90.7 \text{ ft/min} \]

Floor to Floor \[ H = \frac{12 \text{ ft} \times 1.85}{22.2 \text{ ft/min}} = 1 \text{ min} \times \frac{60 \sec}{\text{ min}} = 9.45 \text{ sec} \]

People in Stairs

\[ P = N \times E_{	ext{descent}} \times E_{	ext{corridor}} \]

\[ E_{	ext{floor occupied}} \times E_{	ext{doors} (4 \times 4)} \]

\[ \left( \frac{24 \text{ min} \times 4}{3.1 \text{ people/ft} \times \text{min}} \right) \times 12.57 \text{ people in stairs} \]

- 12.57 people / 212000 = 0.06 per floor

- \( E_{	ext{Stair doors}} = 2 \times 4 \times 2 = 48 \text{ people} \)

Track Express Flow

\[ T \text{ and } E_{	ext{occupied}} \times 0.2 = 4.45 \text{ min} \]

\[ \frac{264 P}{48 \text{ P/ff} \times \text{min}} = 4.25 \text{ min} + 0.24 \text{ min} \text{ corridor} + 1 \text{ min} \text{ to} \]

\[ \text{Total time} = 5.49 \text{ minutes} \times \frac{60 \text{ sec}}{1 \text{ min}} = 329 \text{ sec} \]
**Event Cycles Hand Calculations - Area C 2NDPC Con.**

- \( D = 1.107 \)
- \( K = 275 \text{ ft}/\text{min} \)
- \( A = 2.84 \text{ ft}^2/\text{pp} \)
- \( S = K - AD \) - Balcony minimum area C side
  \[ S = 2.75 \text{ ft}/\text{min} - (2.84 \text{ ft}^2/\text{pp} \times 2.75 \text{ ft}/\text{min}(10.7)) \]
- \( S = 190 \text{ p/ft/min} \)
- \( Wc = 15' - 1' = 14' \)
- \( S = 190 \text{ p/ft/min} \)
- \( T \) - Corridor
  \[ T = \frac{190 \text{ p/ft/min}}{42 \text{ ft}} = T = 4.6 \text{ min} = 258 \text{ sec} \]

- \( F = (190 \text{ p/ft/min} 	imes 4 \text{ ft}) = 760 \text{ p/min} \)
- \( \frac{760 \text{ p/min}}{24 \text{ p/min/ft}} = 31.6 \text{ p/min} \)

- **Stair Effect**
  \( 44 \left( \frac{2 \text{ ft/h}}{44 \text{ ft}} \right) = 13.1 \text{ people/ft} \)

- **Stair Density**
  \( P = 13.1 \text{ p/min} \)

- \( D = 0.27 \text{ ft/ft}^2 \)
- \( S = 212 - (212 \times (2.84)) \times 0.2 \)
- \( S = 90.7 \text{ ft/min} \)

**Floor to Floor Height**

- \( 12' \times 1.85' = 22.2 \text{ ft} \)

- \( \frac{22.2}{90.7} = 0.24 \text{ min} 	imes \frac{60 \text{ sec}}{1 \text{ min}} = 14.4 \text{ sec} \)
People in Stairs

N floors x (descent x Fs corridor)
Occupied floors x 4 exits

\( \frac{1}{2} \times 9 \times 13.1 \text{ people} = 12.57 \text{ people} \)

12.57/2 floors = 6.28 people/level

Esc stair door: 2.4 x 2 = 4.8 P/min

Track Egress Flow 2nd FL Card Center

Ts out \( \frac{1990}{487 \text{ min}} = 4.14 \text{ min} + 124 \text{ min} + 1 \text{ min} \)

= 5.38 minutes or 323 seconds

248 + 14 + 60 = 322 seconds
FIND

\(A_{\text{corridor}} \approx 207 \text{ ft}^2\)

\(\text{OK} \rightarrow 3\text{rd floor} \rightarrow A = 207 \text{ ft}^2 \rightarrow 204 \text{ occupants} \rightarrow 2 \text{ exits}\)

\(D = \frac{204 \text{ occupants}}{207 \text{ ft}^2}\)

\(D = 0.98 \frac{2}{\text{ft}^2}\)

\(\text{Use} = 275 \text{ ft/min} \quad \alpha = 2.86 \frac{\text{ft}^2}{\text{min}}\)

\(S = K \cdot C \cdot D\)

\(S = 275 \frac{\text{ft}}{\text{min}} - (2.86 \frac{\text{ft}^2}{\text{min}})(275 \frac{\text{ft}}{\text{min}})(0.098)\)

\(S = 197.6 \quad \Rightarrow \text{corridor} \quad \frac{\text{ft}}{\text{min}}\)

\(S = 1.30 \text{ minutes} \rightarrow 90 \text{ seconds}\)

\(F_s = (1 - 0.05)(275)(0.098)\)

\(F_s = (1 - 0.05)(275)(0.098)\)

\(F_s = 19.4 \text{ People/ft}^2 \cdot \text{min}\)

\(W_c = W - \text{ Boundary Layer}\)

\(W_c = 8' - 1' = 7'\)

\(W = 7'\)

**Impact of Door on Exit Flow**

\(F_c = 19.4 \text{ People/ft}^2 \cdot \text{min}\) (??)

\(F_c = 135 \text{ People/min}\)

\(F_c = 135 \text{ People/min}\)

\(24/12 = 2 \text{ ft}^2\)

\(F_c = 67.5 \text{ People/min}\)

**Use \(F_s, F_c, \text{ for max}**

\(U_{60} \text{ ft} = 24 \text{ People/min} \cdot \text{ft}^2\)
Queuing Area

135 people/min - 24 people/min = 11.5 people/min

Stair Effect

\[ F_s = 24 \left[ \frac{2\text{ ft} - 4\text{ ft}}{33\text{ in}} \right] = 24 \left[ \frac{2.375}{33} \right] \]

\[ = 24 \left[ 0.072 \right] = 1.745 \text{ min} \]

\[ F_s = 17.5 \text{ (flow until floors merge)} \]

Stair Density

\[ \frac{17.5 \text{ people}}{\text{min}} = (1 - 2\% D) \frac{21.2 \text{ D}}{} \]

\[ D = 0.2 \]

\[ S = 212 - 212(2.06)(0.2) \]

\[ S = 90.7 \frac{\text{people}}{\text{min}} \]

Floor to Floor Height = 12' x 1.55 = 22.2 ft of travel

\[ t = \frac{22.2 \text{ ft}}{90.7} = 0.24 \text{ min} = 14.4 \text{ seconds} \]

People in Stairway

\[ P = N_{\text{floor}} \times C_{\text{descent}} \times F_{\text{corridor}} \]

\[ P = 2 \times 24 \text{ min} \times 1.30 \text{ min} = 9.3 \text{ people in stair} \]

\[ 9.3 / 2 = 4.65 \text{ people in stair per floor} \]

When Stair is Full: \( F_{\text{door}} = 24 \times 2 = 48 \frac{\text{people}}{\text{min}} \)

Track Express Flow

\[ t_{\text{floor}} = 2.04 \left( \frac{60 \text{ s}}{1 \text{ min}} \right) = 4.25 + 0.24 = 4.49 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 269.5 \]

\[ T_{\text{total}} = T_{\text{floor}} + T_{\text{corridor}} + T_{\text{triumphant}} = \]

\[ T_{\text{total}} = 4.49 + 1.30 \text{ min} + 1 \text{ min} = \frac{6.79 \text{ min}}{1 \text{ min}} \]

\[ 269.5 + 90 + 60 = 419.5 \]
Appendix G. Egress Paths for First through 5 Floors.

Egress Paths for First Floor.
Egress Paths for Second Floor.
Egress Paths for Third Floor.

Egress Paths for Fourth Floor.
Egress Path for Fifth Floor.
Appendix H. Life Safety Drawings

First Floor
Second Floor
Fourth Floor
Fifth Floor
Appendix I: NIST NCSTAR 2: Cone Calorimeter Data for Carpet Flooring at 35 kW/m².
Table D-19. Cone Calorimeter Data for Carpet Flooring at 35 kW/m² (CF).

<table>
<thead>
<tr>
<th>Carpet Flooring</th>
<th>CF-01</th>
<th>CF-02</th>
<th>CF-03</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Heat Flux 35 kW/m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Results:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to Sustained Ignition (s):</td>
<td>38</td>
<td>68</td>
<td>40</td>
<td>48.7</td>
</tr>
<tr>
<td>Peak Heat Release Rate (kW/m²):</td>
<td>474</td>
<td>718</td>
<td>536</td>
<td>576</td>
</tr>
<tr>
<td>Time to Peak Heat Release Rate (s):</td>
<td>221</td>
<td>178</td>
<td>206</td>
<td>202</td>
</tr>
<tr>
<td>Total Heat Release (MJ/m²):</td>
<td>67.6</td>
<td>71.4</td>
<td>71.8</td>
<td>70.3</td>
</tr>
<tr>
<td>60 s Average Heat Release Rate (kW/m²):</td>
<td>139</td>
<td>246</td>
<td>111</td>
<td>166</td>
</tr>
<tr>
<td>Total Mass Loss (g):</td>
<td>12.2</td>
<td>16.6</td>
<td>18.0</td>
<td>15.6</td>
</tr>
<tr>
<td>Average Mass Loss Rate (g/s):</td>
<td>0.052</td>
<td>0.102</td>
<td>0.068</td>
<td>0.074</td>
</tr>
<tr>
<td>Average Effective Heat of Combustion (MJ/kg):</td>
<td>55.3</td>
<td>43.1</td>
<td>40.0</td>
<td>46.1</td>
</tr>
<tr>
<td>Average Smoke Extinction Area (m²/kg):</td>
<td>1118</td>
<td>792</td>
<td>816</td>
<td>908</td>
</tr>
<tr>
<td>Average CO₂ yield (g/g):</td>
<td>3.87</td>
<td>3.07</td>
<td>2.86</td>
<td>3.27</td>
</tr>
<tr>
<td>Average CO yield (g/g):</td>
<td>0.0584</td>
<td>0.0437</td>
<td>0.0424</td>
<td>0.0482</td>
</tr>
</tbody>
</table>

Specimen:

<table>
<thead>
<tr>
<th></th>
<th>CF-01</th>
<th>CF-02</th>
<th>CF-03</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial mass (g):</td>
<td>28.7</td>
<td>29.2</td>
<td>30.2</td>
<td>29.4</td>
</tr>
<tr>
<td>Thickness (mm):</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11.0</td>
</tr>
<tr>
<td>Surface area (cm²):</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Test start time (s):</td>
<td>111</td>
<td>79</td>
<td>84</td>
<td>91.3</td>
</tr>
<tr>
<td>Time to ignition (s):</td>
<td>38</td>
<td>68</td>
<td>40</td>
<td>48.7</td>
</tr>
<tr>
<td>Time to flameout (s):</td>
<td>272</td>
<td>229</td>
<td>302</td>
<td>267</td>
</tr>
</tbody>
</table>